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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

In the Matter of

Exelon Generation Company, LLC

(Early Site Permit for Clinton ESP Site)

Docket No. 52-007-ESP

ASLBP No. 04-821-01-ESP

SUPPLEMENTAL REQUEST FOR HEARING AND PETITION TO INTERVENE BY ENVIRONMENTAL LAW AND POLICY CENTER, BLUE RIDGE ENVIRONMENTAL DEFENSE LEAGUE, NUCLEAR INFORMATION AND RESOURCE SERVICE, NUCLEAR ENERGY INFORMATION SERVICE, AND PUBLIC CITIZEN

In accordance with the Nuclear Regulatory Commission's ("NRC") Rules of Practice for Domestic Licensing Proceedings in 10 C.F.R. Part 2, and the Atomic Safety and Licensing Board's Initial Prehearing Order, Petitioners Environmental Law and Policy Center, Blue Ridge Environmental Defense League, Nuclear Energy Information Service, Nuclear Information and Resource Service, and Public Citizen hereby submit contentions challenging the adequacy of Exelon Generating Company's September 25, 2003 application for an Early Site Permit ("ESP") for the Clinton 2 nuclear plant. As demonstrated below, each of the contentions satisfy the NRC's admissibility requirements that are set forth in 10 C.F.R. § 2.309(f).

I. ENVIRONMENTAL CONTENTIONS

CONTENTION 3.1: THE CLEAN ENERGY ALTERNATIVES CONTENTION - The Environmental Review Fails To Rigorously Explore And Objectively Evaluate All Reasonable Alternatives.

In Section 9.2 of the Environmental Report ("ER"), Exelon claims to satisfy 10 C.F.R. 51.45(b)(3), which requires a discussion of alternatives that is "sufficiently complete to aid the

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Commission in developing and exploring" "appropriate alternatives . . . concerning alternative uses of available resources," pursuant to the National Environmental Policy Act ("NEPA"). However, Exelon's analysis is premised on several material legal and factual flaws that lead it to improperly reject better, lower-cost, safer, and environmentally preferable energy efficiency, renewable energy resource, distributed generation, and "clean coal" resource alternatives. Therefore, Exelon's ER does not provide the basis for the rigorous exploration and objective evaluation of all reasonable alternatives to the ESP that is required by NEPA.

Basis: There are several serious shortcomings in the ER's evaluation of reasonable alternatives for the Clinton ESP application. First, the evaluation of alternatives is improperly constrained because the NRC regulations provide, in clear violation of NEPA, that the application need not analyze the need for power. Second, the ER treats each alternative energy source as a discrete alternative, contrary to the mandate of NEPA to combine alternatives. Third, the ER improperly rejects the reasonable alternative of meeting energy needs through increased energy efficiency efforts on the ground that such efforts would not be profitable for Exelon. Finally, the ER relies on flawed and outdated information to support its conclusion that energy efficiency, renewable energy resources, distributed generation and "clean coal" technologies are not reasonable alternatives to new nuclear power generation. Each of these points demonstrate that there is "a germane dispute" with Exelon "on a material issue of law or fact," thereby making this an admissible contention. 10 C.F.R. 2.309(f)(1)(vi).

A. The NRC Is Required To Consider All Reasonable Alternatives, Including Energy Efficiency And Renewable Energy Resources, To The Siting Of A New Nuclear Power Plant at Clinton.

At the outset, it is important to note that, despite its public statements to the contrary, the NRC is legally required to consider energy efficiency and renewable energy resource alternatives to the siting of a new Clinton nuclear plant. At the NRC's public scoping meeting held in Clinton, Illinois on December 18, 2003, NRC Senior Project Manager Thomas J. Kenyon stated that "the Commission has determined that we do not need to look at alternative energy sources at this time."[1] A power point slide and handout from the NRC also identified "alternative energy sources" as an issue that need not be considered during the ESP process.[2]

These assertions are incorrect. Energy efficiency and renewable energy resources are reasonable alternatives that must be considered. Under NEPA, the NRC must "rigorously explore and objectively evaluate all reasonable alternatives" to the granting of an ESP. 40 C.F.R. 1502.14(a). Furthermore, NRC regulations require that the environmental analysis of the ESP "focus on the environmental effects of construction and operation of a reactor." 10 C.F.R. 52.17. As part of this analysis, the NRC must "develop and explore . . . appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." 10 C.F.R. 51.45(b)(3). Energy efficiency and renewable energy resources clearly qualify as "reasonable" and "appropriate" alternatives to the siting of a new Clinton nuclear plant and to the "environmental effects of construction and operation of a reactor" at the site. Therefore, the NRC must consider these alternatives as part of its environmental analysis under NEPA and 10 C.F.R. 51.45(b)(3).

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[1] U.S. Nuclear Regulatory Commission, Public Scoping Meeting Transcript (Dec. 18, 2003), at p. 14, Lines 14-15 (Exhibit 1).

B. **The ER's Analysis Is Improperly Constrained**
<u>By The Lack Of Consideration Of The Need For Power.</u>

The alternatives analysis in Exelon's ER is improperly constrained by NRC regulations that violate NEPA. In particular, 10 C.F.R. 52.17 and 52.18 provide that the NRC need not consider "the need for power" in determining whether or not to grant an ESP to Exelon. The need for power, however, is at the heart of the purpose and need statement which, in turn, serves as the baseline by which the reasonableness of various alternatives are measured. Without an analysis of whether, how much, and what type of energy is needed, there is no way to accurately weigh alternatives against one another or to conclude whether it is appropriate to site a new nuclear power plant. It is impossible, therefore, to engage in the rigorous and objective evaluation of alternatives required by NEPA without first analyzing the need for power.

In the context of this case, the NRC must determine how to apply its regulations in a manner that complies with NEPA. Or, the NRC must revisit its regulations or take other necessary administrative actions so that the ER process is conducted in a manner that fully complies with NEPA, which is the governing federal law.

While the NRC's regulations purport to foreclose an analysis of the need for power, Exelon identifies a need for power, which it then uses to reject alternatives. In particular, Exelon states that any feasible alternative must be able to generate base-load power (ER, p. 9.2-6), but provides no justification for that statement. In fact, Exelon's later admission that Illinois is a net energy exporter (ER, p. 9.2-5) suggests that additional base-load capacity is not needed here. Exelon justifies rejecting renewable energy resources, such as wind and solar power, on the ground that those resources are purportedly not suitable for large base-load capacity. (ER, pp. 9.2-7, 9.2-8). An examination of the actual need for power could lead to significantly different

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[2] See Exhibit 2, p. 5.

conclusions regarding such alternatives. For example, if Illinois actually needs additional peak-load capacity, then alternative resources such as solar power would fare much better.

C. The ER Must Consider Energy Efficiency And Renewable Energy Resources Both Individually And In Combination.

The alternatives analysis in Exelon's ER is also flawed because it fails to consider energy efficiency and various alternative energy resources in combination. Exelon concedes that Section 9.2 evaluates only discrete electrical generation sources individually and does not evaluate a robust mix of energy resources. (ER, p. 9.2-6). A rigorous and objective analysis of alternatives, however, requires a consideration of alternatives not only individually, but also in combination. *See, e.g., Davis v. Mineta*, 302 F.3d 1104, 1121-22 (10th Cir. 2002) (identifying the failure to consider various alternatives to a highway project in combination as "one of the most egregious shortfalls" in the agency's environmental analysis). Just as today's energy supply comes from a mix of resources, a viable alternative to a new nuclear power plant can also involve a combination of energy efficiency and new clean energy resources. In particular, a combination of wind power, solar power, energy efficiency, distributed generation, and "clean coal" technology would be a better, lower-cost, safer, and environmentally preferable alternative to a new nuclear power plant. Exelon and the NRC are legally required to consider such combinations.

D. The ER's Rejection Of Energy Efficiency Alternatives Is Both Legally And Factually Flawed.

The ER improperly rejects energy efficiency as an unreasonable alternative to the siting of a new nuclear power plant in Illinois. Exelon attempts to justify its rejection of energy efficiency on two grounds. First, Exelon contends that utility deregulation has removed the incentive for Exelon to invest in energy efficiency. (ER, pp. 9.2-2 to 9.2-3). Second, Exelon asserts that the decline in generating costs and the amount of energy efficiency requirements already in place have significantly reduced the cost-effectiveness of energy efficiency efforts. (ER, p. 9.2-4). Exelon's first justification for rejecting energy efficiency is legally flawed, and its second purported justification is factually flawed.

Exelon's first excuse for rejecting energy efficiency ignores the NRC's legal duty under NEPA to evaluate all reasonable alternatives. The NRC is not bound by the wishes of the project applicant, *Simmons v. U.S. Army Corps of Engineers*, 120 F.3d 664, 669 (7th Cir. 1997), but instead must consider all reasonable alternatives to meeting the goal of a proposal, whether or not the applicant wants to or is able to carry it them out. *Cf.* 42 C.F.R. 1502.14(c) (agency cannot reject an alternative simply because it is outside the agency's jurisdiction); *Muckleshoot Indian Tribe v. U.S. Forest Serv.*, 177 F.3d 800, 814 (9th Cir. 1999) (same). As explained below, energy efficiency is a better, cheaper, safer, and less environmentally risky alternative to a new nuclear power plant. Therefore, whether or not Exelon and its subsidiaries prefer to invest in energy efficiency, that reasonable alternative must be rigorously explored and objectively evaluated. 40 C.F.R. 1502.14(a). The fact that energy efficiency efforts may materialize as a result of state or federal government initiatives, other public investments, and market-based policies and rate structures does not provide a basis for rejecting the economically, technologically, and environmentally feasible alternative of energy efficiency. Therefore, the ER should have considered a thorough analysis of this alternative – energy efficiency both alone and in combination with other energy resources.

Perhaps realizing the weakness of its legal position, Exelon also asserts in the ER that deregulation and declines in generation costs make energy efficiency an ineffective alternative to a new nuclear power plant. The ER, however, provides no support for this claim that energy efficiency is not cost-effective. In reality, energy efficiency is a better, cheaper, safer, and less environmentally risky alternative.

In contrast to the unsupported conclusions provided in the ER, recent studies demonstrate that energy efficiency is a more viable and cost-effective alternative to new nuclear power generation. For example, the 2001 *Repowering the Midwest* study,[3] which is a comprehensive clean energy development analyses conducted on the Midwest's energy sector, demonstrates that energy efficiency efforts can significantly reduce the demand for power at a cost of 2.5 cents per kilowatt-hour or less – lower than the cost of generation, transmission, and distribution of electricity from central power plants. Implementing modern new cost-effective energy efficiency technologies for commercial and residential lighting, heating, ventilation and cooling, industrial motors, refrigerators, and other appliances can flatten electricity demand over the next two decades. *Repowering the Midwest* relied on the methodology of the United States Department of Energy's 1997 "Five National Labs" Study, which is an analysis by a working group with members from five national energy laboratories,[4] in concluding that:

- Energy efficiency efforts can reduce electricity demand by 16% in 2010 and 28% in 2020 versus a projected base case scenario.

- Energy efficiency efforts can save 50,761 GWh of electricity annually by 2020 in Illinois alone.

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[3] Environmental Law and Policy Center, et al., *Repowering the Midwest: The Clean Energy Development Plan for the Heartland* (2001) (Exhibit 3).

[4] U.S. Department of Energy, *U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond* (1997) (The Executive Summary of this document is attached as Exhibit 4).

- Energy efficiency efforts are highly cost-effective, requiring an average investment equivalent to only 2.5 cents per kilowatt-hour.
- Energy efficiency efforts can reduce net electricity costs in Illinois by $1 billion by 2020.
- These energy efficiency initiatives use technologies and equipment that are widely available today.

Other analyses have reached similar conclusions on the availability and cost-effectiveness of energy efficiency. For example, an Interlaboratory Working Group following up on the Five National Labs study concluded adopting a number of policies directed at promoting energy-efficient technologies could reduce projected energy needs in 2020 by 20%.[5] The Interlaboratory Working Group determined that these energy efficiency efforts could save an amount of energy equal to 25% of the nation's current energy use.[6] The American Council for an Energy Efficient Economy ("ACEEE") found even greater potential for energy efficiency, concluding in a 2001 study that nine specific energy efficiency policies could reduce energy consumption by 11% by 2010 and 26% by 2020.[7] The net economic savings as a result of these efficiency efforts would be $170 billion through 2010 and more than $600 billion through 2020.[8] The ACEEE also determined that efficiency standards for 13 appliances and equipment alone could save 1.8 quads of energy, or 5% of projected residential and commercial sector energy use.[9] The benefit-to-cost ratio of such standards would be 5 to 1.[10] Finally, the Union of Concerned Scientists and the Tellus Institute determined in their Clean Energy Blueprint that energy efficiency efforts

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[5] Interlaboratory Working Group, *Scenarios for a Clean Energy Future* (Nov. 2000), p. ES.6 (Exhibit 5).
[6] *Id.*
[7] Steven Nadel and Howard Geller, *Smart Energy Policies: Saving Money and Reducing Pollutant Emissions Through Greater Energy Efficiency* (Sept. 2001), p. vii (Exhibit 6).
[8] *Id.* at i.
[9] Toru Kubo, *Opportunities for New Appliance and Equipment Efficiency Standards: Energy and Economic Savings Beyond Current Standards Programs* (Sept. 2001), p. ii (Exhibit 7).

throughout the United States could save 915 billion kilowatt-hours of electricity by 2010 and 2,512 billion kilowatt-hours by 2020.[11]

Energy efficiency efforts are feasible, and they also provide significant economic benefits. The follow-up *Job Jolt* analysis of the economic impacts of implementing the clean energy development recommendations in *Repowering the Midwest* concluded that investments in energy efficiency in Illinois would create 43,400 new jobs and $4.6 billion in additional economic output by 2020.[12] A 1998 ACEEE study of energy efficiency potential in Illinois reached similar results, concluding that investments in energy efficiency would create 59,400 jobs by 2015 and save consumers and business $76 billion in energy costs between 1999 and 2015.[13]

As the above studies show, energy efficiency is a technologically and economically feasible alternative – alone and in combination with other energy resources – to the siting of a new nuclear power plant at Clinton. Energy efficiency is a better, faster, cheaper, safer, and environmentally preferable alternative to a new nuclear power plant. Therefore, Exelon and the NRC are required to fully evaluate it as a reasonable alternative under NEPA.

E. The ER's Rejection Of Renewable Energy Resources Is Factually Flawed And Relies On Outdated Information.

The ER considers, but improperly rejects, a number of viable renewable energy resources. These resources, in combination with energy efficiency, represent a reasonable

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[10] *Id.*

[11] Steve Clemmer, et al., *Clean Energy Blueprint: A Smarter National Energy Policy for Today and the Future* (Oct. 2001), at 11 (Exhibit 8).

[12] Environmental Law and Policy Center, et al., *Job Jolt: The Economic Impacts of Repowering the Midwest* (2002), p. 7 (Exhibit 9).

[13] Marshall Goldberg, et al., *Energy Efficiency and Economic Development in Illinois* (Dec. 1998) (Exhibit 10).

alternative to siting a new nuclear plant at Clinton. Exelon, however, uses outdated and flawed information to reject these alternatives. For example, Exelon relies "heavily" upon the NRC's 1996 Generic Environmental Impact Statement for License Renewal of Nuclear Plants ("GEIS") for much of its data regarding alternative energy sources. (ER, p. 9.2-6). The data in the GEIS, which the NRC is in the process of revising, is mostly from the early 1990s and, it presents a very outdated view of the viability and environmental impacts of renewable energy resources including wind power, solar power, and distributed generation. Technological improvements and market developments since the early 1990s have greatly increased the efficiency and capacity of many renewable energy resources, while at the same time reducing their costs and environmental impacts. Exelon must provide, and the NRC must consider, the current information in analyzing renewable energy alternatives. *Cf. Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council*, 435 U.S. 519, 552-53 (1978) (recognizing that the concept of alternatives is an "evolving one" that an agency must judge "by the information then available to it.")

In addition, the ER's analysis of wind power, solar power, and distributed generation alternatives is flawed in several other ways as well.

1. The ER Ignores The Fact That Wind Power <u>Is A Viable And Growing Source Of Clean Renewable Energy.</u>

Exelon fails to acknowledge that wind power is a viable and growing source of energy that, both alone and in combination with energy efficiency and other energy resources, can be a reasonable alternative to the siting of a new nuclear power plant at Clinton.

First, wind resources in Illinois are sufficient to replace the power that would be generated by a new Clinton nuclear plant. According to the United States Department of

Energy's Wind Powering America study on wind resources in the state, Illinois has a potential capacity of at least 3,000 MW of Class 4 wind sites and 6,000 MW of Class 3+ wind sites.[14]

Second, technological advancements, as described below, and economic advantages have led to a substantial increase in the amount of wind power installed. From 2001 through 2003, a total of 3,795 megawatts of wind power was installed nationwide, raising the total wind power in the United States to 6,374 megawatts.[15] Within Illinois, the first utility-scale wind project has recently begun operations and approximately 1,700 MW of additional wind power projects are in various stages of development. Across the border in Iowa, there are 420 MW of wind power installed with an additional 345 MW in development.

Third, the ER treats wind power as if it would have to replace the power created by a new Clinton plant on its own. Instead, wind power should be considered in combination with energy efficiency and other clean energy resources as part of the NEPA-required rigorous exploration and objective evaluation of all reasonable alternatives. 40 C.F.R. 1502.14(a)

Fourth, technological advancements are increasing the amount of power created by wind turbines. Although the largest commercially available wind turbines in recent years were between 1 MW and 1.5 MW, now GE Wind Energy is producing 2.3 – 2.7 MW land-based turbines, and 3.6 MW turbines designed for offshore use.[16] 5 MW wind turbines may be

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[14] U.S. Department of Energy – Wind Powering America, *Illinois Wind Resource Maps*, http://www.eere.energy.gov/windpoweringamerica/where_is_wind_illinois.html (Exhibit 11).

[15] American Wind Energy Association, *Wind Power Outlook 2003* (2003); American Wind Energy Association, *Wind Energy Fast Facts* (Jan. 2004) (Exhibit 12).

[16] GE Wind Energy, *Our Products*, http://www.gepower.com/businesses/ge_wind_energy/en/products.htm (Exhibit 13)

available in the near future.[17] In addition, wind turbines have an availability factor of 98%, higher than most other power resources.[18]

Fifth, the cost of wind power has fallen dramatically since the 1980s, with an average generation cost of three to six cents per kilowatt-hour,[19] so that it is now competitive with most other energy resources. In addition, wind power generation has "zero fuel cost" and thus avoids risks of fluctuating fuel prices.

Sixth, the ER improperly limits its analysis to wind resources in Illinois. (ER, p. 9.2-7) Six of the 10 states with the highest wind power potential in the United States are in the Midwest.[20] Wind farms in neighboring states such as Iowa could be a viable source of energy for Illinois.

In light of these facts, the ER vastly exaggerates the impact that an expansion of wind power would have. Although the ER claims that it would take 330,000 acres of land to produce from wind the amount of power that would be created by a new Clinton nuclear plant (ER, p. 9.2-7), the ER neglects to note that at least 95% of the land for a wind power site remains available for agriculture and other uses. In addition, wind generation uses no coolant water, has no emissions and does not degrade land. Finally, contrary to the assertion in the ER (p. 9.2-8), recent studies show very few avian collisions with modern wind turbines.[21]

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[17] Ari Reeves, *Wind Energy For Electric Power: A REPP Issue Brief* (Nov. 2003), at 22 (Exhibit 14).
[18] American Wind Energy Association, *The Most Frequently Asked Questions About Wind Energy* (2002), p. 5 (Exhibit 15).
[19] American Wind Energy Association, *Comparative Costs of Wind and Other Energy Sources*, (2002) (Exhibit 16).
[20] American Wind Energy Association, *Wind Energy: An Untapped Resource* (2003) (Exhibit 17).
[21] National Wind Coordinating Committee, *Avian/Wind Turbine Interaction: A Short Summary of Research Results and Remaining Questions* (Dec. 2002).

2. The ER Misstates The Impacts Of Solar Power

The conclusion in the ER that Illinois would need 77,000 acre area of photovoltaic ("PV") cells or 30,800 acres of solar thermal systems to replace the power that would be produced by a new nuclear plant at Clinton (ER, p. 9.2-9) provides a distorted view of the impacts of solar power. In particular, the ER's suggestion that solar power would have a substantial impact on natural resources and land use ignores the fact that solar power is distributed power. Many solar power units are located on rooftops of buildings, meaning that solar power would not cause land disturbances.

In addition, the ER treats solar power as if would have to replace the power from a new Clinton plant on its own. Instead, as explained above, Exelon and the NRC should consider solar power in combination with energy efficiency and other clean energy resources as part of the NEPA-required rigorous exploration and objective evaluation of all reasonable alternatives. 40 C.F.R. 1502.14(a).

3. Distributed Generation Is A Relatively Clean Alternative For Providing Base-Load Power

The ER does not adequately address the opportunities for meeting base-load power needs through efficient on-site natural gas-fired generation, such as combined heat and power, district energy systems, and fuel cells. Natural gas distributed generation emits substantially less air pollution than coal-fired power plants, and does not pose the high-level waste and safety hazards inherent to nuclear power. It can serve as a relatively cleaner and safer base-load supplement to, and in combination with, energy efficiency and renewable energy resources as an alternative to the new Clinton nuclear power plant. *Repowering the Midwest* estimates that Illinois alone has the potential for 2,162 MW of efficient distributed gas-fired generation by 2010, and 5,000 MW by 2020.[22]

Again, the ER treats this distributed generation as if it would have to replace the power from a new Clinton nuclear plant on its own. (ER, p. 92.12) Instead, distributed generation should be considered in combination with energy efficiency and other clean energy resources as part of the NEPA-required rigorous exploration and objective evaluation of all reasonable alternatives. 40 C.F.R. 1502.14(a).

CONTENTION 3.2: THE WASTE CONFIDENCE RULE CONTENTION -

The Waste Confidence Rule Does Not Apply to This Proceeding And Thus The Environmental Review Must Evaluate Whether And In What Time Frame Spent Fuel Generated By the Proposed New Clinton 2 Plant Can Be Safely Disposed Of.

The ER for the Clinton ESP application is deficient because it fails to discuss the environmental implications of the lack of options for permanent disposal of the irradiated (*i.e,* "spent") fuel that will be generated by the proposed new Clinton nuclear plant if it is built and operated. Nor has the NRC made an assessment on which Exelon can rely regarding the degree of assurance now available that radioactive waste generated by the proposed reactors "can be safely disposed of [and] when such disposal or off-site storage will be available." Final Waste Confidence Decision, 49 Fed. Reg. 34,658 (August 31, 1984), citing *State of Minnesota v. NRC,* 602 F.2d 412 (D.C. Cir. 1979). Accordingly, the ER fails to provide a sufficient discussion of the environmental impacts of the proposed new nuclear reactors.

Basis: The ER for the proposed new Clinton nuclear plant does not contain any discussion of the environmental implications of the lack of options for permanent disposal of the irradiated

[22] *Repowering the Midwest*, at p. 83.

fuel to be generated by a new reactor on the Clinton site. Therefore, it is fatally flawed. *State of Minnesota v. NRC,* 602 F.2d at 416-17.

While Exelon may have intended to rely on the NRC's Waste Confidence decision, issued in 1984 and most recently amended in 1999, that decision is inapplicable because it concerns plants that are currently operating, not new plants. The second finding of the Waste Confidence Decision, as amended in 1999, is that the NRC has:

> reasonable assurance that at least one mined geologic repository will be available within the first quarter of the twenty-first century, and that sufficient repository capacity will be available within 30 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of any reactor to dispose of the commercial high-level radioactive waste and spent fuel originating in such reactor and generated up until that time. (This finding revised the finding in the original decision that a mined geologic repository would be available by the years 2007 to 2009).

Waste Confidence Decision Review: Status, 64 Fed. Reg. 68,005, 68,006 (December 6, 1999). Clearly, the NRC's finding applies to any existing reactor, including reactors whose licenses are revised or renewed. The NRC gives no indication that it has confidence that repository space can be found for spent fuel and other high-level radioactive waste from new reactors licensed after December of 1999.

Moreover, the revised second finding in the 1999 Waste Confidence review statement fails to assert confidence in the likelihood that more than one repository will be licensed. In fact, the NRC has backtracked on its original 1984 "Nuclear Waste Confidence Decision," in which the NRC expressed confidence that "one or more" repositories would open between 2007 and 2009. Waste Confidence Decision, 49 Fed. Reg. at 34,673. The 1999 Status Report states merely that "at least one" repository will open by 2025. 64 Fed. Reg. at 68,006.

It is also clear that the inventory of spent fuel and other high-level radioactive waste being generated by the *current* generation of nuclear reactors is far greater than what can be accommodated in the single repository – Yucca Mountain, Nevada – in which the NRC appears to place its confidence. The proposed Yucca Mountain repository can only accept 63,000 metric tons of commercial high-level radioactive waste and irradiated nuclear fuel, at least until a second national repository became operational.[23] Even assuming only 40 years of operations with no operating license renewals and no new nuclear reactors, the United States Department of Energy ("USDOE") has known since at least the mid-1990's – that is, since before the most recent NRC review in 1999 of its "Nuclear Waste Confidence Decision" – that by the year 2030 or so, well over 80,000 metric tons of irradiated nuclear fuel generated at commercial nuclear reactors will exist in the U.S.[24] This is significantly in excess of the "disposal" capacity at Yucca Mountain.

The NRC's recent approvals of 20-year license extensions to old commercial nuclear reactors will increase the quantity of high-level radioactive waste that exceeds the capacity limits at the proposed Yucca Mountain, Nevada repository. In its "Final Environmental Impact Statement for a Repository for Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca

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[23] Under the Nuclear Waste Policy Act ("NWPA"), 63,000 metric tons is the legal limit for commercial waste storage that can be "disposed of" at Yucca Mountain, Nevada, at least until a second repository is operational elsewhere in the U.S. As the NWPA states at Section 114(d):

> The [NRC] decision approving the first such application [for a license to open and operate a repository] shall prohibit the emplacement in the first repository of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel until such time as a second repository is in operation..."

42 U.S.C. § 10134(d). By long-established USDOE policy, the first 70,000 metric tons of irradiated nuclear fuel and solidified high-level radioactive waste "disposed of" at Yucca Mountain, Nevada would include 90% commercial nuclear reactor waste, and 10% USDOE waste from the nuclear weapons production complex and nuclear energy research activities. 90% of 70,000 metric tons means that only 63,000 metric tons of commercial irradiated nuclear fuel could be "disposed of" at Yucca Mountain, Nevada, at least until a second national repository is operational in the United States. *See* Yucca Mountain EIS at A-1 (Exhibit 18).

Mountain, Nye County, Nevada," (February 2002) (hereinafter "Yucca Mountain EIS"), USDOE predicted the generation of over 105,000 metric tons of commercial irradiated nuclear fuel by the year 2046.[25] Although the NRC's standard license extension term is 20 years, the USDOE prediction assumed that the term of license extensions would be only 10 years. The USDOE also assumed no new commercial nuclear reactors would operate in the United States. Thus, the high-level waste and spent fuel generated by the *current* generation of reactors will far exceed the capacity of the single repository that the NRC has identified as feasible and likely.[26]

Accordingly, the spent fuel and other high-level radioactive wastes generated at the proposed new Clinton 2 nuclear plant could not be "disposed of" at Yucca Mountain unless and until a second national repository is operating. But the NRC has not expressed confidence that a second repository will open. Any spent fuel or other high-level radioactive waste generated after the year 2011 or so (after 63,000 metric tons of commercial irradiated nuclear fuel has been generated) would have nowhere to go, would lack "disposal" space at a repository, unless and until a second repository is opened and operating in the United States in addition to the Yucca Mountain, Nevada – a process that could take many decades, based on the experience of trying to open the first repository at Yucca Mountain, Nevada.

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[24] United States Nuclear Waste Technical Review Board ("NWTRB") "Disposal and Storage of Spent Nuclear Fuel: Finding the Right Balance," Figure 2 at page 11 (March 1996), (Exhibit 19).
[25] Yucca Mtn. EIS at Table A-8, page A-16 (Exhibit 20).
[26] Experience also shows that the NRC has been overly optimistic about the opening of the first repository. It took from 1982 (the year the Nuclear Waste Policy Act was passed) until 2002 – 20 full years – just for the USDOE to recommend Yucca Mountain as "suitable" for repository development (a recommendation, by the way, that is being challenged in federal court by the State of Nevada). Although DOE still predicts the Yucca Mountain repository will open by the year 2010, the General Accounting Office has reported that a repository at Yucca Mountain, Nevada probably could not open to receive waste shipments till 2015. GAO-02-191, "Nuclear Waste: Technical, Schedule, and Cost Uncertainties of the Yucca Mountain Repository Project" (December, 2001) (Exhibit 21). Even this date is doubtful, given the serious technical criticism of the USDOE's current repository design. *See, e.g.*, United States NWTRB, "Technical Report

Moreover, Congress has not given the NRC any basis for assuming that a second repository will be opened. Section 161(b) of the Nuclear Waste Policy Act provides that: "[t]he Secretary [of Energy] shall report to the President and to Congress on or after January 1, 2007, but not later than January 1, 2010, on the need for a second repository." 42 U.S.C. § 10172a(b). Section 161(a) also states that: "The Secretary [of Energy] may not conduct site-specific activities with respect to a second repository unless Congress has specifically authorized and appropriated funds for such activities." 42 U.S.C. § 10172a(a). The Secretary of Energy has not made a finding that a second repository is needed, nor has Congress specifically authorized or appropriated funds for site-specific activities.

The NRC's failure to express confidence that a second repository will be opened soon also implicates the third and fourth findings of the Waste Confidence Decision, *i.e.* that spent fuel and other high-level radioactive waste can be safely stored at reactor sites for up to 30 years. 64 Fed. Reg. at 68,006. If the NRC cannot express confidence that a second repository will open at some reasonable future time, it must be assumed that spent fuel may sit at the reactor site for an indefinite period of time. The environmental impacts of such indefinite storage must be evaluated before an ESP can be granted for the proposed new Clinton 2 nuclear plant.

II. <u>MISCELLANEOUS CONTENTION</u>

CONTENTION 5.1: ILLINOIS STATE MORATORIUM STATUTE CONTENTION - The Illinois State Law Imposing A Moratorium On New Nuclear Plants Forecloses The Issuance Of An Early Site Permit For Clinton 2.

Exelon's ESP permit application fails to address the Illinois statute, 220 ILCS 5/8-406(c), which prohibits any new nuclear power plant within the state until such time as the Director of

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on Localized Corrosion" (November 25, 2003) (Exhibit 22). In addition, several legal challenges have been filed against the Yucca Mountain repository and the proposed standards for operation.

the Illinois Environmental Protection Agency ("IEPA") finds that the United States government has identified and approved a demonstrable technology or means for the disposal of high-level nuclear waste. The Director of the IEPA has, properly, not made the requisite finding, meaning that no new nuclear plant may now be built in Illinois and the issuance of an ESP is legally foreclosed.

The NRC must deny the ESP application because to grant it would violate Illinois' legal determination that there is no appropriate site for a new nuclear power plant in Illinois until the problems of disposing of high-level nuclear wastes are solved. In particular, Illinois law, 220 ILCS 5/8-406(c), provides that:

> After the effective date of this amendatory Act of 1987, no construction shall commence on any new nuclear power plant to be located within this State, and no certificate of public convenience and necessity or other authorization shall be issued therefor by the Commission, until the Director of the Illinois Environmental Protection Agency finds that the United States Government, through its authorized agency, has identified and approved a demonstrable technology or means for the disposal of high level nuclear waste, or until such construction has been specifically approved by a statute enacted by the General Assembly

This moratorium law takes the common sense approach of foreclosing the possibility of new nuclear power plants in the state until the federal government "has identified and approved a demonstrable technology or means for the disposal of high level nuclear waste" or construction has been specifically authorized by the Illinois General Assembly (state legislature). In essence, the moratorium answers with a resounding "no" the question presented in this ESP proceeding: Is the Clinton site (or any other site in Illinois) appropriate for a new nuclear power plant? Therefore, the NRC cannot approve the Clinton site and must deny the ESP at this time.

Exelon incorrectly asserts in its answer to Petitioners' original Hearing Request and Petition to Intervene that the Illinois state moratorium law is irrelevant to this proceeding because it prohibits only the construction of a new nuclear plant, not the siting of such a plant. In fact, the moratorium is relevant and controlling in this proceeding because it demonstrates the clear intent of Illinois to prohibit any new nuclear power plants in the state until the waste disposal problem is solved. For example, the moratorium is not limited to prohibiting only the "construction" of a new nuclear power plant - it also forbids the issuance of a certificate of public convenience and necessity or "other authorization" for such a plant by the Illinois Commerce Commission. In addition, at the time that the Illinois General Assembly passed the moratorium in 1987, the ESP process did not even exist. The moratorium references "construction" because in 1987 a company seeking to build a new nuclear plant would have needed to first obtain a construction permit. The NRC's changes to the permitting process since 1987 do not alter the fact that the moratorium clearly forecloses the necessary step towards building a new nuclear power plant in Illinois that the ESP would represent.

It is also important to note that the standard required for lifting the moratorium - that the federal government has "identified and approved a demonstrable technology or means for the disposal of high level nuclear waste" - will not be satisfied anytime in the near future. As explained more fully above, the only identified high-level nuclear waste disposal site, Yucca Mountain, will not open until at least 2010 if at all. In fact, the United States Department of Energy has not yet even submitted its application for the Yucca Mountain repository to the NRC.

Even more fundamentally, the Yucca Mountain site would not solve the waste disposal problem for a new nuclear plant such as Clinton 2. As presently conceived, Yucca Mountain would not have sufficient capacity to hold all of the wastes from existing nuclear plants, especially as the NRC is granting 20-year license extensions to some of those plants. Therefore, the moratorium law would not be satisfied in this regard until there is a second high-level waste repository available.

III. STANDING

Petitioners demonstrated standing in their original Hearing Request and Petition to Intervene by submitting declarations from members of each Petitioner organization authorizing the Petitioners to represent their interests. In their response to that original Petition, the NRC Staff have challenged only the standing of Petitioner Nuclear Energy Information Service ("NEIS") on the ground that its two members, Samuel Galewsky and Sandra Lindberg, have authorized more than one Petitioner organization to represent their interests.

There is no legal reason why an individual cannot designate more than one organization as his or her representative, at least unless and until such time as a conflict from such multi-organization representation is shown to arise. Therefore, Petitioners contend that their original Petition adequately demonstrated the standing of each Petitioner organization, including NEIS. Should the Panel, however, determine that an individual cannot be represented by more than one organization, then Sandra Lindberg wishes to designate NEIS as the sole representative organization for her interests in this proceeding.

IV. CONCLUSION

For the foregoing reasons and for those stated in the Petitioner's original Hearing Request and Petition to Intervene, the named Petitioners have standing in this proceeding and are raising contentions that satisfy the admissibility requirements of 10 C.F.R. 2.309(f). Therefore, the Nuclear Regulatory Commission should grant the Petitioners' request for a hearing and petition to intervene in this proceeding.

Respectfully Submitted,

Diane Curran /s/

Attorney on Behalf of Petitioner
Blue Ridge Environmental Defense League

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

In the Matter of Exelon Generation Company, LLC (Early Site Permit for Clinton ESP Site)	Docket No. 52-007-ESP ASLBP No. 04-821-01-ESP

CERTIFICATE OF SERVICE

I, Shannon Fisk, hereby certify that copies of the Supplemental Request For Hearing and Petition to Intervene by the Environmental Law and Policy Center, Blue Ridge Environmental Defense League, Nuclear Information and Resource Service, Nuclear Energy Information Service, and Public Citizen in the above captioned proceeding have been served on the following via electronic mail and by Federal Express overnight delivery or U.S. mail, first class, on this 3rd day of May, 2004.

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(E-mail: GPB@nrc.gov)

Administrative Judge
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Rockville, MD 20852-2738
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Administrative Judge
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Shannon Fisk
One of the Attorneys for the
Environmental Law and Policy Center

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD PANEL

In the Matter of Exelon Generation Company, LLC (Early Site Permit for Clinton ESP Site)	Docket No. 52-007-ESP ASLBP No. 04-821-01-ESP

APPENDIX FOR

SUPPLEMENTAL REQUEST FOR HEARING AND PETITION TO INTERVENE BY ENVIRONMENTAL LAW AND POLICY CENTER, BLUE RIDGE ENVIRONMENTAL DEFENSE LEAGUE, NUCLEAR INFORMATION AND RESOURCE SERVICE, NUCLEAR ENERGY INFORMATION SERVICE, AND PUBLIC CITIZEN

Howard A. Learner
Shannon Fisk
Environmental Law and Policy Center
35 E. Wacker Dr. Suite 1300
Chicago, IL 60601

May 3, 2004

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

PUBLIC SCOPING MEETING

Thursday, December 18, 2003

The Vespasian Warner Public Library

310 North Quincy Street

Revere Ware Room

Clinton, Illinois 61727

The above-entitled meeting was held at 7:00 p.m.

ATTACHMENT 1

This slides gives you an idea of the kind of things that we look at during our review. We'll be looking at ecological issues, public health issues, socioeconomic issues. We'll also be looking at water use and water quality issues, which we already know are of a concern to the people here in the area.

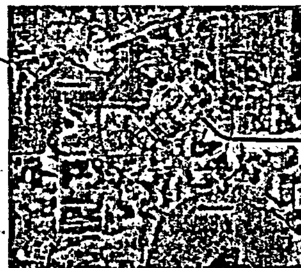
Now to prepare for the review, we've assembled a team of NRC staff with backgrounds in the scientific and technical disciplines that are required to do this review. In addition, we've engaged the assistance of the Pacific Northwest National Laboratory to make sure that we have a well rounded knowledge base on which to do this review. In all we've assembled a team of about 20 people, many of whom are here today to hear what you have to say. And all of them will be coming out to the site in March to gather the information necessary to do the review.

Now, the regulations identify some issues that do not need to be considered in an environmental review of an early site permit. That includes the need for power and the cost of power. And in addition, the Commission has determined we do not need to look at alternative energy sources at this time. Now that is not to say that these issues will not be reviewed before a plant is built and operated. What it means is it does not have to be reviewed for the early site permit stage. However, should Exelon decide to apply for a combined license to build and operate a plant, these issues will have to be addressed at that point.

Now these are the key dates for our review process for the early site permit. We've already mentioned scoping. You can submit your written comments to us having to do with the scope of the review by January 9th. John has mentioned that you can petition to intervene through the January 12th. Now we have copies of both *Federal Register* Notices in the back of the room at the Registration Desk that describe how you can both submit your scoping comments as well as petition to intervene.

2

Public Scoping Meeting on the Early Site Permit Application for the Clinton ESP Site

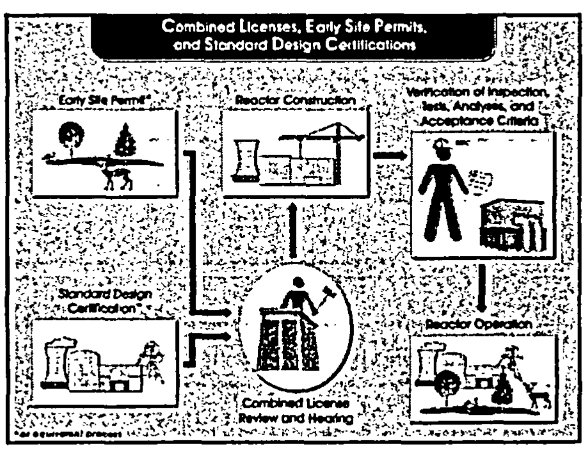


U.S. Nuclear Regulatory Commission
December 18, 2003

Introduction

- Discuss early site permit environmental review process
- Discuss schedule
- Discuss how to participate in process
- Gather comments on the scope of review

2



Key Participants in NRC Licensing Process

Nuclear Regulatory Commission

Regulatory Agency
Licensing Authority
Protect Public Health & Safety

STAKEHOLDERS

Participate Through Public Meetings & Hearings

Exelon Generation Company, LLC.

Applicant

4

What is an Early Site Permit?

- An NRC decision that ensures that the proposed site is suitable for construction and operation of a nuclear power plant or plants
- The permit is not authorization or a decision to actually build and operate a plant

5

How Does an Early Site Permit Fit in the Licensing Process?

- An ESP resolves site suitability issues early
- An ESP can be referenced in an application for a license to construct a nuclear power plant
- An ESP may be combined with an approved design when a license to construct a nuclear power plant is requested

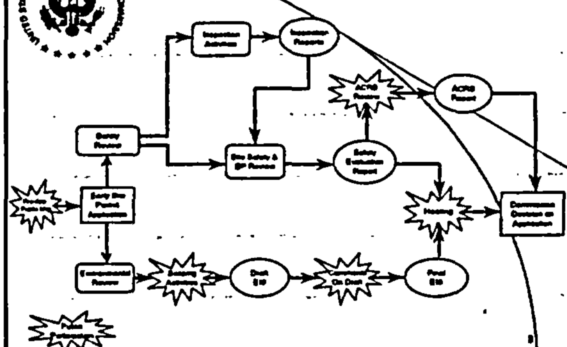
6

Why Does an Applicant Want an Early Site Permit?

- Allows an applicant to "bank" a site for up to 20 years
- Reduces licensing uncertainty
- Resolves siting issues before construction

7

Early Site Permit Review Process



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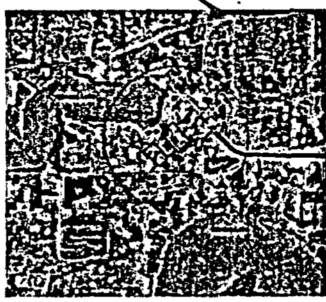
Site Safety Review Process

- Site suitability in relation to
  - Reactor safety – site characteristics pose no undue risk for a reactor sited here
  - Emergency Planning – no significant impediments, reasonable assurance plan can and will be implemented

9

Environmental Review Process For the Early Site Permit at the Clinton ESP Site



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National Environmental Policy Act

- NEPA requires Federal agencies to use a systematic approach to consider environmental impacts
- An environmental impact statement (EIS) is required for major Federal actions significantly affecting the quality of the human environment
- Issuing early site permit is considered a major Federal action

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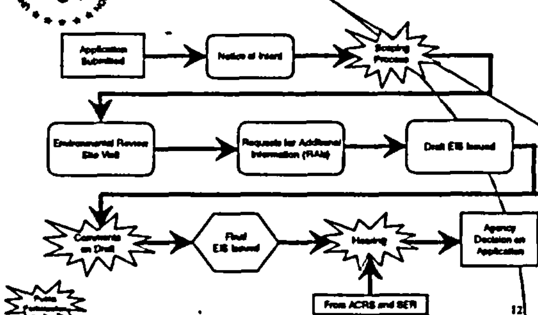
Environmental Review Process



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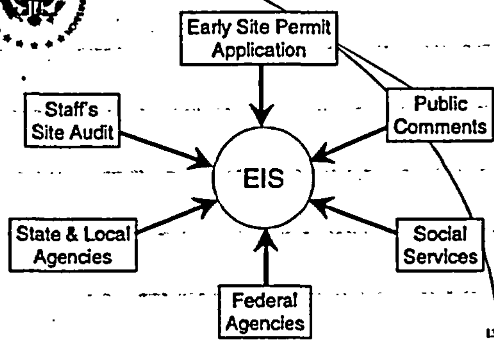
Information Gathering



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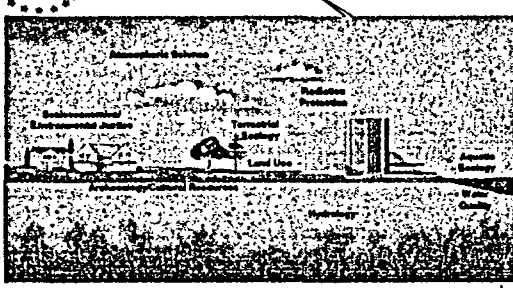
Team Expertise



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Issues That Need Not Be Considered in an ESP Environmental Review

- Need for power
- Cost of power
- Alternative Energy Sources

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Review Schedule

- Scoping through January 9, 2004
- Can petition to intervene through January 12, 2004
- Issue draft EIS - December 2004
- Public Meeting on draft EIS - February 2005
- Issue final EIS - August 2005

Commission decision expected 35 months after application (includes time for hearing process)

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Public Involvement

- Public interaction during environmental review
  - Comment periods
  - Public meetings
- Atomic Safety & Licensing Board Hearing
  - Opportunity to participate provided; deadline to file petition to intervene is January 12, 2004
  - Hearing covers both safety and environmental issues

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Environmental Scoping

- Staff is considering what issues should be included in the environmental review
- Comments and concerns can be provided through January 9, 2004

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NRC Addresses

Provide comments:

- By mail at: Chief, Rules and Directives Branch
  Division of Administrative Services
  Mailstop T-6D59
  U.S. Nuclear Regulatory Commission
  Washington, DC 20555-0001
- E-mail at: ClintonEIS@nrc.gov
- In person at: 11545 Rockville Pike
  Rockville, Maryland

19

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Nanette Gilles, Site Safety Project Manager
1 (800) 368-5642, extension 1180

Documents can be viewed in the "electronic reading room" on NRC's website (www.nrc.gov), at www.nrc.gov/reactors/new-reactor-licensing.html, or at the Vespasian Warner Public Library in Clinton, Illinois

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3

REPOWERING THE MIDWEST

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

ENVIRONMENTAL LAW & POLICY CENTER
CITIZENS ACTION COALITION OF INDIANA
DAKOTA RESOURCE COUNCIL
IOWA-RENEW
IZAAK WALTON LEAGUE OF AMERICA
MINNESOTANS FOR AN ENERGY-EFFICIENT ECONOMY
RENEW WISCONSIN
UNION OF CONCERNED SCIENTISTS

Acknowledgments

Repowering the Midwest was guided and reviewed with the cooperation of:

Steering Committee

Bill Grant, Midwest Office, Izaak Walton League of America
Howard Learner, Environmental Law & Policy Center
Una McGeough, Environmental Law & Policy Center
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Prepared by

Synapse Energy Economics

In collaboration with:

Brower and Company
Environmental Law & Policy Center
Renewable Energy Policy Project
Tellus Institute

Authors

Synapse Energy Economics was the prime contractor for this report. Three subcontractors were responsible for important portions of the analysis: Brower and Company, the Renewable Energy Policy Project, and Tellus Institute.

Tim Woolf of Synapse was the lead consultant for this report. Bruce Biewald was the project manager and responsible for the PROSYM modeling effort, with assistance from David White and Molly Olver. Synapse was responsible for modeling both the business-as-usual scenario and the Clean Energy Development Plan, with assistance from the other consultants. Synapse also developed the estimates of the potential for energy efficiency in the residential and commercial sectors. Lucy Johnston of Synapse also provided review and comments for portions of the report. For more information on Synapse, see www.synapse-energy.com

Michael Brower provided the resource, technical and economic assessment of the wind, biomass, photovoltaic and fuel cell technologies. He assisted with the methods and assumptions used to model these renewable resources in PROSYM. He was the principal author of Chapter 5 and parts of Chapters 3 and 6. Brower was assisted by Richard Perez of NREL and Bruce Bailey of AWS Scientific. For more information on Brower and Company, see www.browerco.com.

Tellus Institute provided the analyses of: industrial sector energy efficiency; cogeneration in the paper and pulp and other manufacturing industries; district energy systems for commercial buildings; biomass power plants; biomass co-firing in coal plants; and fuel cells for electric power supply. Tellus also contributed on other technical issues, model inputs and the modeling approach. The Tellus team included Steve Bernow, Jana Dunbar, Sivan Kartha, Michael Lazarus and Tom Page. For more information on Tellus Institute, see www.tellus.org.

Dr. Adam Serchuk and Virinder Singh of the Renewable Energy Policy Project provided analysis for Chapter 9 on strategies to promote key renewable technologies. REPP was supported with additional research on: wind from John Dunlop; biomass co-firing from Jeff Fehrs; fuel cells from Joel Gordes; and district heating from Tim Maker. The REPP team also contributed to Chapters 5 and 6. For more information on REPP, see www.repp.org.

* * * *

Howard A. Learner, Executive Director of the Environmental Law & Policy Center (ELPC), was the principal author of the Executive Summary and Chapter 1, which provide an overview of the Clean Energy Development Plan for the Heartland. Learner and the Steering Committee for *Repowering the Midwest* were responsible for the policy discussion presented in the Executive Summary and in Chapters 7, 8, and 9. Una McGeough, an environmental consultant with ELPC, coordinated and assisted with the review, editing and production of *Repowering the Midwest.* Dan Rosenblum and Hans Detweiler of ELPC and Steve Clemmer of the Union of Concerned Scientists, also provided review and comments for portions of the report. For more information on the Environmental Law & Policy Center, see www.elpc.org.

TABLE OF CONTENTS

LIST OF FIGURES

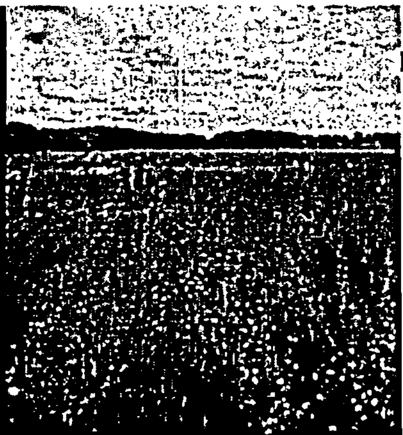
Acronyms and Abbreviations

AEO	Annual Energy Outlook, prepared by the DOE
AFC	alkaline fuel cell
ASTM	American Society for Testing and Materials
BIPV	building-integrated photovoltaics
CHP	combined heat and power
CO_2	carbon dioxide
DES	district energy systems
DESP	District Energy St. Paul
DOE	Department of Energy
DSM	demand-side management
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPAct	1992 Energy Policy Act
GIS	geographical information system
GW	gigawatt
IEEE	Institute of Electrical and Electronic Engineers
ISO	Independent System Operator
LIEF	Long-Term Industrial Energy Forecast model
MCFC	molten carbonate fuel cell
MDF	Market Development Fund
MW	megawatt
NAECA	National Appliance Energy Conservation Act
NERC	National Electric Reliability Council
NREL	National Renewable Energy Laboratory
NGCC	natural gas combined-cycle
NO_x	nitrogen oxides
NSR	New Source Review
O&M	operation and maintenance
P2	Pollution Prevention
PAFC	phosphoric acid fuel cell
PBC	public benefits charge
PBR	performance-based ratemaking
PEMFC	proton exchange membrane fuel cell
PTC	production tax credit
PV	photovoltaics
REC	Rural Electric Cooperative
REPI	Renewable Energy Production Incentive
RPS	Renewables Portfolio Standard
RTO	Regional Transmission Organization
SIC	standard industrial classification
SIP	state implementation plan
SCR	selective catalytic reduction
SO_2	sulfur dioxide
SOFC	solid oxide fuel cell
TWh	one billion kWh

EXECUTIVE SUMMARY

REPOWERING THE MIDWEST

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND



As the 21st century begins, the Midwest can lead the way to a clean energy future, through strategic development of untapped energy efficiency opportunities and abundant renewable resources.

CHALLENGES AND OPPORTUNITIES

The Midwest needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy makes both good environmental <u>and</u> economic sense for our region. Clean energy development will reduce pollution, improve reliability by diversifying our power supply and create new "green" manufacturing and installation jobs, as well as provide new renewable energy "cash crops" for farmers. *Repowering the Midwest* is a plan to seize these opportunities.

Modern life runs on electricity to power our homes and businesses. From refrigerators to computers to dairies, we depend on reliable electricity. However, at the dawn of the 21st century when rapid technological progress is transforming society, the Midwest is still saddled with polluting and inefficient 1950s equipment generating the energy to drive the "new economy." This overdependence on aging coal and nuclear plants and many utilities' underinvestments in modernizing their deteriorating transmission and distribution systems are causing both pollution and power reliability problems.

Many economists tell us that technological advances are shaping a new economy in which economic growth provides new jobs and creates greater wealth. The rapid technological progress should also result in modern processes that produce less waste and less pollution. While that is true enough in many industrial sectors, the electric industry lags behind. It is time for electric utilities and power generators to implement modern technologies that give the public what we want: clean, reliable and efficient energy at a fair price. Can we keep the lights on without polluting the air and water and leaving radioactive nuclear wastes for future generations to clean up? The answer is yes and, perhaps surprising to some, the Midwestern heartland can lead the way if we put the right policies and practices in place.

Developing clean energy efficiency and renewable energy resources is the smart and sustainable solution to the Midwest's pollution problems, to power constraints at summer peak demand times and to challenges in meeting the region's overall electricity needs. Clean energy resources are the modern technologies for our 21st century energy future.

The cost of renewable energy is plummeting as wind, biomass and solar power technologies have improved dramatically. There are also abundant opportunities to install cost-effective modern energy efficiency technologies ranging from improved residential and commercial lighting to new industrial motors. The Midwest is poised to capitalize on these clean energy development opportunities.

When it comes to wind power, the flat lands of the Midwest are valuable assets. Wind power is the world's fastest growing energy source, expanding about 35 percent in 1998. Tremendous design improvements in wind turbines have led to a huge drop in the per-kilowatt price of installed capacity. The cost is now less than one-third of the 1981 price and close to competitive with conventional power sources.

Six of the 10 states with the highest wind power potential are in the Midwest, according to the American Wind Energy Association. Iowa and Minnesota are leading the way with more than 500 megawatts (MW) of wind power (equivalent to the size of a typical coal plant) coming online since 1998. That includes the world's largest wind farm, which provides enough energy to power 64,000 typical homes in northwestern Iowa.

More clean energy means more green jobs. Not coincidentally, two leading wind power businesses have recently located in the Midwest, providing well-paid manufacturing jobs and capitalizing on current and future market opportunities. That's sustainable development in action for factory workers and farmers. Still, the enormous potential of this growing industry remains largely untapped.

Everyone already knows that Midwestern farmlands are ideal for growing the foods that energize our bodies. If we put the right policies in place, we can also count on Midwestern farmers to grow high-yield "energy crops" to help power our economy. Expanding this biomass power will create new rural jobs and provide new markets for crops while reducing air and water pollution and deterring soil erosion.

Other advanced technologies such as fuel cells and industrial and commercial co-generation systems, which generate electricity and heat simultaneously, can also diversify our energy supply in the near term. And, yes, even in the often-gray skies of the Great Lakes, solar photovoltaic panels that convert sunlight to electricity can play a growing role, especially on sunny summer days when peak electricity demand is highest and in hard-to-reach remote areas where solar power provides a way around costly transmission and distribution line extensions. Natural gas plants are not entirely clean, but are generally less polluting than coal and nuclear power. When properly sited, they can also be an important part of a strategy to improve the overall environmental performance of the Midwest's power sector.

As for the demand side of the equation, many clean energy efficiency improvements are smart, economical and waiting to be tapped. Inefficient energy use continues to waste money and cause unnecessary pollution. That can be changed by deploying new, more energy-efficient heating and cooling systems, lighting, appliances and building designs and materials. Seizing these opportunities will save money, relieve electricity demand pressures and improve our quality of life. That is especially true in the Midwest where most utilities have underinvested in efficiency programs that save customers energy and money. Here, too, clean energy means more green jobs because Midwestern companies manufacture many of the new energy-efficient products.

Unfortunately, the electric utilities have failed to keep pace with these improvements and opportunities. Even though new technologies can generate power cleanly and efficiently, a staggering 95 percent of the Midwest's electricity is produced by coal and nuclear plants – the two fuel sources with the worst environmental and public health impacts. These old power plants produce pollution that causes smog, acid rain and global warming, and they generate radioactive nuclear wastes and other toxic pollutants. Depending so heavily on business-as-usual coal and nuclear power locks in a high-pollution future and misses the opportunity to improve reliability by diversifying our power resources. Bypassing more energy-efficient processes and technological advances not only increases businesses' costs, but misses the job creation opportunities in the growing clean energy sector.

Repowering the Midwest is a blueprint for sustainable energy development that will produce economically robust and environmentally sound electricity throughout the heartland.

The Midwest's clean energy resources are here and ready to be developed. Our region is blessed with abundant wind resources, untapped biomass production potential and relatively high levels of solar power availability. Likewise, new energy-efficient lighting and appliances operate at low costs while avoiding pollution, but have yet to capture a firm foothold within the industry or the marketplace.

Repowering the Midwest is a blueprint for producing economically robust and environmentally sound electricity in the 21st century by comparing two possible energy futures for the Midwest – one in which we continue to rely on conventional, or "business-as-usual" technologies, and a second in which the Midwest unleashes its homegrown clean energy development potential. This Clean Energy Development Plan quantifies the region's untapped energy efficiency and renewable resources and lays out strategies, policies and practices to advance a cleaner electricity future from the industrial Midwest across to the Great Plains. These clean power options are technologically and commercially available today, and they can be obtained with only a modest increase in total electricity cost – 1.5 percent in 2010 and roughly three percent in 2020 – that is far offset by the environmental and public health improvements and the economic and employment gains for our region.

As engineering improvements continue to be made, many of the modern clean technologies await sensible policy shifts to reverse the incentives that prop up the polluting technologies of the past. It is no longer a question of engineering know-how, but, instead, a challenge of political will. It is time to leave the 1950s behind and realize the promises of homegrown clean energy in the Midwest to provide us with a healthier environment and a truly new economy. Now is the time to repower the Midwest for a clean energy development future.

The Clean Energy Development Plan harnesses the Midwest's abundant renewable resources and implements underutilized energy efficiency measures, thus producing environmental, reliability and economic development benefits.

Summary of the Midwest Clean Energy Development Plan

The Midwest Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only very modest increases in cost. Moreover, investing in clean modern energy efficiency and renewable energy technologies will diversify the region's electricity portfolio and thereby improve reliability. The Midwest Clean Energy Development Plan will:

1. Aggressively implement modern cost-effective energy efficiency technologies, including the newest as well as the tried-and-true approaches.
2. Develop and implement new clean renewable energy technologies, including wind power, biomass and solar photovoltaics (PV).
3. Develop and implement efficient natural gas uses in appropriate locations, especially combined heat and power, district energy systems and fuel cells.
4. Retire selected older, less efficient and highly polluting coal plants.
5. Apply sustainable development strategies to aggressively link these environmental improvement policies to economic development. Clean energy development means more green energy jobs for the Midwest.

Summary of Benefits for the Midwest

Taking these actions to implement the Clean Energy Development Plan will produce:

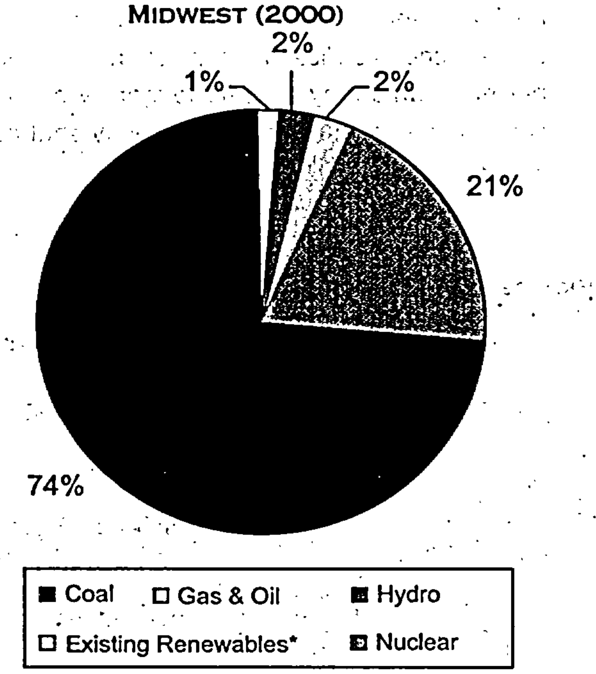
1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual policies and practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 56 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 71 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 51 percent.
2. Energy efficiency improvements for Midwestern consumers that save 17 percent of electricity use by 2010 and 28 percent by 2020. The average investment of 2.4¢ per kilowatt-hour (kWh) to achieve these energy savings is much less than the cost of generating, transmitting and distributing electricity from a coal plant or most other sources.
3. Renewable energy development that provides eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
4. Improved electricity reliability as a result of a more robust and diversified mix of Midwestern power resources compared to the region's historic almost-total reliance on coal and nuclear plants.
5. Economic development and job growth through new wind power and biomass energy "cash crops" for farmers, increased business for manufacturers of energy efficiency and renewable energy equipment and new skilled jobs for the installation and maintenance of this equipment throughout the Midwest.

These benefits can be achieved with only slightly increased electricity costs across the Midwest: 1.5 percent in 2010 and 3.4 percent in 2020.

The Midwestern Electricity Portfolio Under the Business-As-Usual Scenario

The Midwest relies almost exclusively upon coal and nuclear power for electricity supply, as shown in Figure 1. Coal plants produce 74 percent of the Midwest's electricity, and nuclear plants generate 21 percent, while natural gas and oil plants provide two percent. Renewable energy resources supply only three percent, mostly from hydropower dams,

FIGURE 1. CURRENT SOURCES OF ELECTRICITY GENERATION IN THE MIDWEST (2000)



* Includes Wind, Solar and Biomass

The Midwest's reliance on coal plants to generate electricity results in air pollution that causes serious health and environmental problems, including acid rain, smog, and global warming.

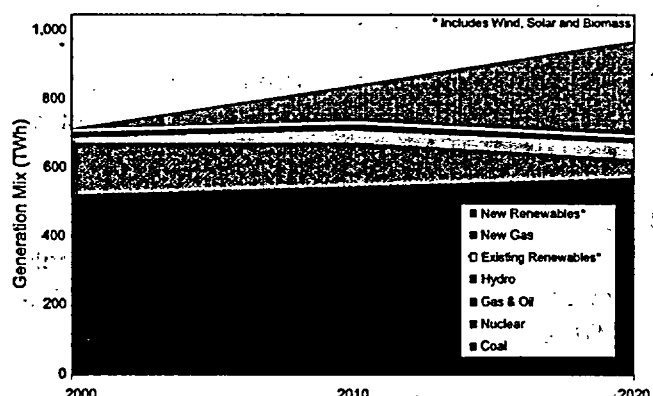
with relatively small contributions, thus far, from wind, biomass and solar photovoltaic power. Modern energy efficiency technologies and "tried and true" efficiency measures are significantly underutilized.

Most Midwestern coal plants were built between 1940 and 1970 and many have not been fully upgraded with modern pollution control technologies. Compared to other regions, the Midwest relies more heavily on these older, inefficient coal plants and thus produces a disproportionate amount of air pollution causing health and environmental problems. The Midwest generates 21 percent of the nation's electricity, but produces 31 percent of the SO_2 pollution, 32 percent of the NO_x pollution, and 26 percent of the CO_2 pollution from the nation's electric industry sector.

Substantial changes in public policies and business planning are necessary to achieve the benefits of implementing the largely untapped energy efficiency and renewable energy technology opportunities. Otherwise, the current portfolio of old, highly polluting coal and nuclear plants will remain overwhelmingly dominant in the Midwest for decades. Figure 2 projects the likely sources of generation for the next 20 years if business-as-usual policies and practices continue. Although nuclear generation is expected to decline as some plants reach the end of their operating licenses, coal plant generation would steadily increase. New natural gas plants would meet most of the growing demand for electricity, but might not replace much generation from old coal plants.

This combination of business-as-usual factors casts a pollution cloud over the Midwest. The harmful health impacts from air pollution impose social and economic costs on the public. The social costs are increased asthma and respiratory ailments (and deaths) especially for children, senior citizens and other "at risk" groups. In addition, there are high economic costs for the region and the nation from increased health care and insurance expenses and lower productivity due to missed work. Business-as-usual practices also lead to a risk of significant costs for compliance with future environmental regulations.

FIGURE 2. PORTFOLIO OF ELECTRICITY GENERATION SOURCES: BUSINESS-AS-USUAL PRACTICES



The harmful environmental impacts of the Midwest's coal plants extend nationally and globally as air pollution drifts downwind to the Northeast and Canada. They cause smog, acid rain and global warming and impose associated public health, environmental quality and economic burdens. Running these coal plants on a business-as-usual basis will lead to a 30 percent increase in CO_2 pollution between 2000 and 2020.

The Clean Energy Development Plan will result in renewable resources — such as wind power — providing eight percent of the Midwest's electricity generation by 2010 and 22 percent by 2020.

The Midwest Clean Energy Development Plan: Principal Findings

There are better courses for the Midwestern electricity sector than to continue along this shortsighted and damaging path. The Clean Energy Development Plan proposes developing underutilized energy efficiency measures and largely untapped homegrown renewable energy resources to form a cleaner, more reliable and more diverse electricity portfolio for the Midwest that can spur job creation in this emerging economic sector.

Figure 3 describes this preferable Midwestern electricity portfolio by 2020 under the Clean Energy Development Plan:

1. Energy efficiency measures reduce electricity generation from power plants because demand remains essentially constant over time, instead of growing steadily each year.

2. Renewable energy resources – wind, biomass and solar – supply roughly eight percent of generation by 2010 and 22 percent by 2020.

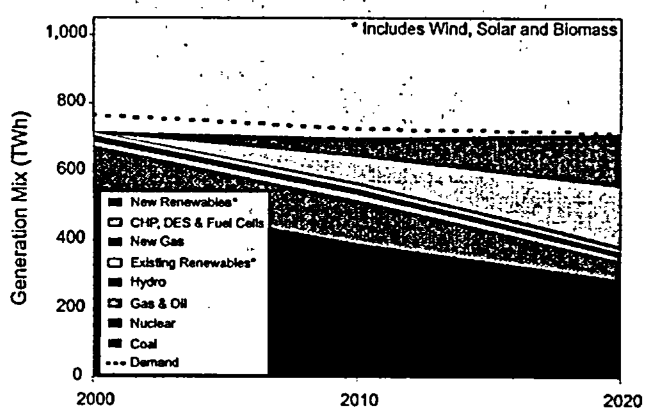
3. Coal generation declines significantly as renewable energy resources with increasingly lower operating costs generate more power in the Midwest.

4. New efficient natural gas generation provides 10 percent of generation in 2010 and 25 percent of generation in 2020.

5. Fewer new conventional natural gas plants are needed than under the business-as-usual scenario because less capacity is needed to meet demand due to energy efficiency.

6. Nuclear generation declines to the same extent as under the business-as-usual scenario, as the nuclear plants in the Midwest retire, on average, at their scheduled license termination dates. Some nuclear plants may operate longer by obtaining license extensions, while others may shut down earlier.

FIGURE 3. PORTFOLIO OF ELECTRICITY GENERATION SOURCES: CLEAN ENERGY DEVELOPMENT PLAN



Findings: Environmental Improvements

The Clean Energy Development Plan reduces acid rain and smog by decreasing SO_2 and NO_x pollution. By 2020, SO_2 emissions are projected to be 56 percent lower and NO_x emissions 71 percent lower than under business-as-usual policies and practices, and 51 percent lower and 83 percent lower than in 2000, respectively. This will reduce acid rain falling in the Great Lakes and inland lakes and forests of the Upper Midwest and Canada, and it will reduce smog that harms public health. Because SO_2 emissions are subject to a "cap-and-trade" system under the Clean Air Act, and NO_x emissions may also be governed by a trading regime under the U.S. EPA's rules, the precise pollution percentage reductions in the Midwest may vary. However, it is clear that citizens in the Midwestern states will benefit from improved environmental quality and public health due to lower SO_2 and NO_x emissions under the Clean Energy Development Plan.

The Clean Energy Development Plan helps mitigate global warming by reducing CO_2 pollution. By 2020, CO_2 emissions are 51 percent lower than under business-as-usual policies and practices, and 36 percent lower than in 2000. In 1997, the United States and other developed nations agreed to the Kyoto Protocol, which requires the United States to reduce CO_2 emissions to seven percent below 1990 levels over the period of 2008-2012. As indicated in Figure 4, the Clean Energy Development Plan puts the Midwest on target to meet the Kyoto Protocol goals by 2010, and it would continue to significantly reduce CO_2 emissions over the following years.

Developing wind power in the Midwest will provide a "cash crop" for farmers and spur job growth in businesses that manufacture, install and maintain renewable energy equipment.

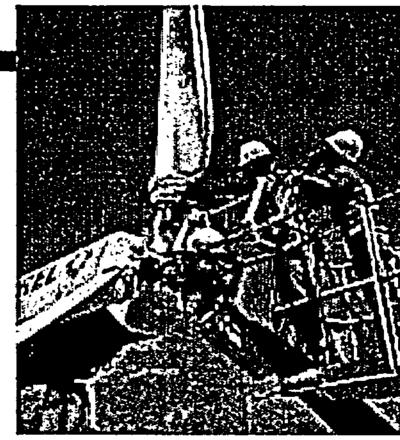
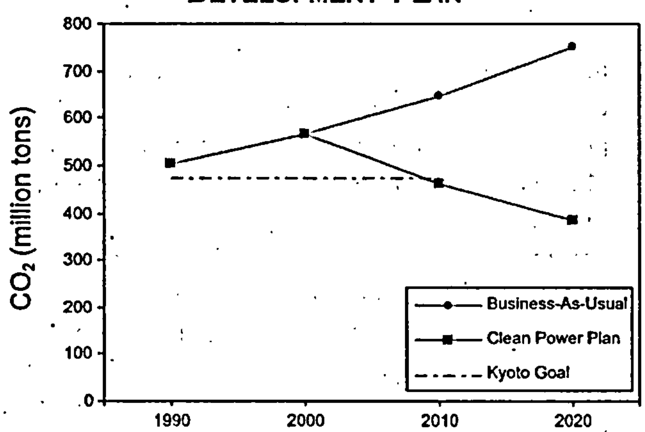


FIGURE 4. CO_2 POLLUTION REDUCTIONS FROM THE CLEAN ENERGY DEVELOPMENT PLAN



FINDINGS: REGIONAL ECONOMIC DEVELOPMENT BENEFITS

The Clean Energy Development Plan will promote job growth and economic development in the Midwest. Wind and biomass power are "cash crops" for farmers in the heartland, supplementing their income from agricultural land. At the same time, manufacturing, assembling, installing and maintaining wind power and solar equipment are creating new jobs as well. For example, NEG Micon's wind turbine assembly plant in Champaign, Ill., is the second largest in the country, and LM Glasfiber has created 400 new jobs manufacturing wind turbine blades in Grand Forks, N.D. Likewise, Spire Solar is creating 55 new jobs manufacturing solar photovoltaic panels on a former "brownfield" site on Chicago's West Side.

The Midwest is also home to a large share of the nation's energy efficiency manufacturing industry. Osram Sylvania in Lake Zurich, Ill., and GE Lighting in Cleveland, Ohio, manufacture energy-efficient lighting. Honeywell Home and Building Control makes thermostatic controls in Golden Valley, Minn., and Johnson Controls in Milwaukee, Wis., makes energy-efficient motors. Andersen Corporation in Bayport, Minn., and Pella Corporation in Pella, Iowa, both make energy-efficient windows. Maytag manufactures energy-efficient refrigerators in Galesburg, Ill., and Trane Company manufactures high-efficiency air conditioning systems in La Crosse, Wis.

Implementing these modern energy efficiency technologies saves money for businesses to reinvest in their Midwestern operations. It saves money for residential consumers, which can then be spent for goods and services on the main streets of Midwestern towns. The Midwest regional economy benefits in all of these respects.

FINDINGS: COST IMPACTS

The environmental and economic development benefits of a cleaner energy future can be achieved for the Midwest with only a modest increase in overall electricity costs. Many energy efficiency measures, such as commercial lighting improvements, are highly cost-effective and are significantly less expensive than conventional power sources. The energy efficiency savings thus offset much of the cost of renewable energy resources, which are generally more expensive than running "cheap and dirty" coal plants.

The Clean Energy Development Plan is expected to increase total electricity costs across the Midwest by 1.5 percent in 2010 ($765 million) and 3.4 percent in 2020 ($1,780 million). On the other hand, the public will receive benefits in the form of lower health care costs and fewer health-related productivity losses.

Energy-efficient appliances, such as this clothes washer, save consumers money, while reducing energy use, pollution, and the resulting health and environmental damages.

Findings: Enhanced Reliability

The Clean Energy Development Plan will improve electricity reliability by diversifying the Midwest's energy portfolio. Today, the Midwest relies almost entirely on older coal and nuclear plants to supply electric power needs. The Clean Energy Development Plan deploys a more robust mix of energy efficiency, renewable energy and natural gas resources, along with the coal and nuclear plants. Energy efficiency reduces demand for power and improves reliability by saving generation and alleviating strained transmission and distribution systems. Adding substantial wind, biomass and solar resources, along with natural gas plants, to the Midwest's energy portfolio enhances diversity and makes the region less vulnerable to swings in coal prices and to nuclear plant risks.

Reaping Energy Efficiency Opportunities

An array of modern energy efficiency technologies – ranging from smart thermostats to new lighting ballasts to new motors – and "tried and true" measures, such as high R-value insulation and "Energy Star" appliances, are highly cost-effective, but greatly underutilized in the Midwest. Many energy efficiency opportunities can be deployed by business, residential and public agency consumers at less than the cost of electricity, thus saving them money and avoiding wasteful energy use. Businesses will free up dollars for investment and become more profitable. Residential consumers will have more disposable income to spend or save. Public agencies can use budget savings to meet other responsibilities and hold down taxes. The public gains environmental and health benefits because implementing energy efficiency reduces pollution from coal and nuclear plants.

The most significant energy efficiency opportunities in the Midwest, by sector, are:

1. In the residential sector, the greatest potential is more efficient lighting (20 percent of potential residential savings) and water heating (nine percent). For example, compact fluorescent lamps (CFL) produce the same amount of light as conventional incandescent light bulbs, but use only one-quarter as much electricity and last 12 times longer. Replacing one incandescent bulb in a high-use area with a CFL will save a Chicago-area residential consumer about $50 in electricity costs over the life of the CFL.

2. In the commercial sector, the greatest potential is efficient lighting technologies (50 percent of potential commercial savings) and space cooling (15 percent). For example, installing modern energy-efficient lighting ballasts in new commercial buildings, or through retrofits of existing buildings, produces rapid paybacks and operating cost savings in almost all settings.

3. In the industrial sector, the greatest opportunities for efficiency are found in the metals fabrication (28 percent of potential industrial electricity savings), rubber and plastics (13 percent), primary metals (12 percent), and agricultural (11 percent) industry sectors by deploying more efficient industrial motors and drives; more advanced heating, ventilating and cooling techniques; and better lighting technologies.

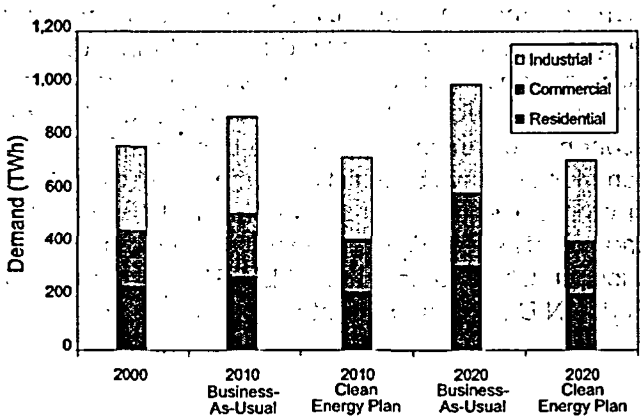
The major population centers and industrialized areas of the Midwest are the largest electricity load centers and provide the greatest opportunities to reap energy efficiency savings. Of the total efficiency savings in the Clean Energy Development Plan, about 24 percent are available in Ohio, 20 percent in Illinois, 16 percent in Michigan, and 14 percent in Indiana.

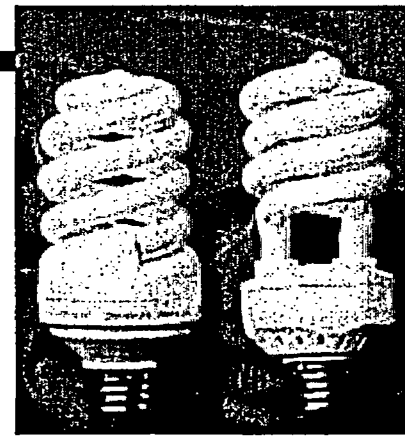
Findings: Energy Efficiency

The Clean Energy Development Plan enables Midwestern consumers to save up to 17 percent of electricity use through energy efficiency improvements by 2010, and 28 percent by 2020, as shown in Figure 5. Electricity demand will decline slightly each year, rather than increase by more than one percent per year under the business-as-usual scenario. By 2020, these energy efficiency savings will avoid the need for 290 billion kWh (TWh) of generation – roughly equivalent to the output of 100 coal plants at 500 megawatts (MW) each.

Implementing these energy efficiency measures is highly cost-effective. On average, reaping the energy efficiency opportunities in the Clean Energy Development Plan requires a 2.4¢ per kWh investment. That is significantly less than the cost of generating, transmitting and distributing electricity to consumers. By 2020, the proposed energy efficiency measures will save $12.1 billion in power plant and distribution system costs in return for a $6.6 billion investment. The result is $5.5 billion in net benefits or, put another way, savings of $1.80 for every $1.00 invested in energy efficiency. That, of course, does not include the economic and social value of the environmental and public health benefits.

Figure 5. Midwestern Electricity Demand Reductions Due to Efficiency Gains





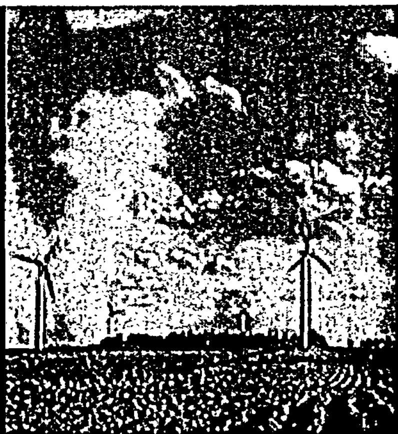
Replacing conventional incandescent light bulbs with compact fluorescent lights, which use one-quarter as much electricity to produce the same amount of light, reduces pollution and energy costs.

Developing Renewable Energy Resources

The Midwest possesses abundant renewable energy resources. The Great Plains states have the best large-scale wind power potential in the nation, and there are also significant distributed wind power opportunities throughout the Midwest. Biomass potential is large in the agricultural belt of the heartland, and there are focused, though smaller, solar power development opportunities, especially to meet costly summer peak power demand, throughout the region. Dramatic technological improvements in wind turbines and solar photovoltaic panels have enhanced generating efficiencies and lowered power production costs over the past 20 years. Developing these clean renewable energy technologies avoids pollution from coal and nuclear plants and increases generation reliability by diversifying the region's energy portfolio and using local resources. Because renewable energy resources can also be deployed on a distributed basis – as relatively small generators located near customer demand – power delivery reliability is enhanced and new transmission and distribution upgrades and extensions can sometimes be avoided. Capital costs vary widely among types of renewable energy resources; however, even when their capital costs are high, the fuel and operating costs are typically very low.

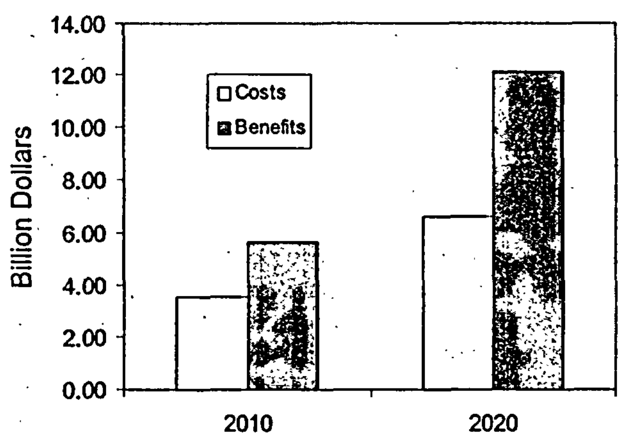
Wind Power

Large-scale wind energy generation has improved tremendously, both in cost and reliability, since the first wind energy boom in the early 1980s. Wind power is now the fastest growing energy resource in the world in large part due to substantial technological improvements. Modern wind turbines generate



The wide open farmlands of the Great Plains states have been called the "Saudi Arabia of wind energy." Here farmers can reap "cash crops" for wind power development while their other farming operations continue uninterrupted.

FIGURE 6. NET BENEFITS FROM ENERGY EFFICIENCY INVESTMENTS IN THE CLEAN ENERGY DEVELOPMENT PLAN



electricity at an average cost that is close to competitive with new coal and combined-cycle natural gas plants. The Midwest has been the nation's leader in wind power growth as Iowa, Minnesota and Wisconsin have installed a total of 500 MW of new wind capacity over the past few years, and are on their way to 1,000 MW of capacity. For example, about 400 MW of wind power is being developed in the Buffalo Ridge area of southwestern Minnesota (as part of utility commitments for 825 MW), a 112.5 MW wind power "farm" is operating in Alta, Iowa, and a new 30 MW wind power project is planned in Iowa County, Wis.

The Midwest is blessed with such an abundance of windy terrain, especially in the Great Plains states of North and South Dakota, Iowa, Minnesota and Nebraska, that it is sometimes referred to as the "Saudi Arabia of wind energy." There are also other windy areas scattered through Illinois, Indiana, Michigan, Ohio and Wisconsin that offer strong opportunities for distributed wind power development.

Large wind energy machines have the most potential to replace coal plants, but small wind turbines designed for local residential and commercial uses are a growing market niche in the Midwest. Although their costs per kWh are usually higher than the larger wind turbines, they can still displace some higher-cost energy sources and also function well in lower winds.

Wind power costs have declined significantly over the past 20 years and continue to do so. In 2000, wind power was produced at a range of 3 - 6¢ per kWh (depending on wind speeds), but by 2020, wind power generating costs are projected to fall to 3 - 4¢ per kWh.

Wind power provides substantial environmental and public health benefits because it creates no air pollution, greenhouse gases or radioactive nuclear and other dangerous wastes. By applying responsible siting practices, wind projects can have minimal impacts on wildlife and natural resources. Wind is an intermittent power resource, fluctuating with daily and hourly wind patterns and velocities. Its energy supply can be made more consistent and balanced, if desired, by managing wind resources and gas plants together as is now being done with Northern Alternative Energy's major new 350 MW project in Minnesota, which combines 50 MW of wind power with 300 MW of natural gas generation.

Wind power development also provides a new cash crop – mostly for farmers – in the communities where it is located. In agricultural areas, farmers can often increase their incomes by 50 percent or more by leasing a portion of their land for wind turbines and access roads; farming operations on the rest of their land are unaffected. The opportunity to promote rural economic development and the support of farming communities have been critical to the recent expansion of wind power in Iowa and Minnesota. Likewise, the creation of new wind power manufacturing jobs by NEG Micon in Champaign, Ill., and LM Glasfiber in Grand Forks, N.D., has spurred interest and support.

BIOMASS ENERGY

The Midwest has enormous untapped biomass energy potential from both crop residues (left over from farming) and energy crops (grown expressly for energy). The Midwest also has many coal plants that could be converted to use biomass for part of the fuel supply.

The Clean Energy Development Plan focuses on two leading near-term options to increase biomass energy production: (1) Co-firing with biomass in existing coal plants; and (2) Installing efficient combined heat and power (CHP) systems at large industrial facilities, especially pulp and paper mills. Co-firing with biomass directly reduces some of the coal use and the associated SO_2, NO_x, CO_2 and other pollution. CHP is much more efficient than separately generating electricity and heat. Virtually all sizable pulp and paper mills in the Midwest already use their mill residues for energy, but many use inefficient steam- or heat-only boilers. Modern CHP equipment can convert biomass to steam, heat and electric power with close to 90 percent efficiency. In the future, biomass gasification may also become increasingly practical.

Increasing biomass energy will produce substantial economic and environmental benefits in the Midwest. Employment impact studies demonstrate that biomass is likely to create many more jobs than it would displace in other sectors because money flowing into agriculture creates a large number of jobs. Because biomass fuels are rarely shipped long distances, the money spent on this energy development tends to remain in rural communities.

Sustainably produced biomass provides significant environmental advantages because it generates no net CO_2. The Clean Energy Development Plan relies only on biomass fuel sources that minimize environmental damages and assumes that biomass energy plants meet the same strict pollution limits as newer coal plants. It does not call for any increased logging for biomass feedstocks, but rather seizes the opportunities for use of energy crops such as switchgrass and crop residues. Biomass co-firing and CHP are the most cost-effective forms of renewable energy generation at roughly 2 - 3¢ per kWh.

SOLAR POWER (PHOTOVOLTAICS)

Solar photovoltaic panels convert sunlight directly into electricity using semiconductor materials. They can be built in various sizes and placed in arrays ranging from watts to megawatts. Their simplicity and flexibility makes them suitable for a wide variety of applications, including central-station power plants, substation power plants for distribution support, grid-connected systems for home and business uses and off-grid systems for remote power uses.

Sustainably produced biomass crops, such as switchgrass, produce no net carbon dioxide (which causes global warming) and can be co-fired to reduce some coal use and the resulting pollution.

The amount of sunlight available to generate electricity varies by season, time of day and location. The wide-open spaces of Nebraska and the Dakotas have solar power resources comparable to parts of northern California and east Texas. Shading from buildings and trees, natural obstacles, and other variables affect local energy-producing potential. Although the Midwest is not usually considered an especially sunny region, solar power can provide economically valuable electricity because of the strong coincidence between its greatest availability on sunny summer days and the timing of peak power demands for air conditioning.

The cost of solar photovoltaics is now significantly higher than most other electricity generation, but rapid technological improvements and increased production leading to lower per unit costs are likely to make solar more cost-competitive in the future. At present, there are three markets in which solar photovoltaics are becoming economically viable. First, as mentioned above, the recent history of soaring summer peak energy price spikes makes solar a potentially attractive energy source during high energy use times on sunny days. Second, solar photovoltaics are cost-effective generation for particular off-grid uses, such as remote residences in rural areas that are far from power lines and hard-to-reach cellular relay towers. Third, solar photovoltaics may be useful and cost-effective distributed resources in specific locations that need grid support or would otherwise require costly upgrades to the existing transmission and distribution system. Moreover, solar photovoltaics may be a desired energy source for those businesses and residences preferring to buy "green power."

Solar power development provides substantial environmental and public health benefits because it creates no air pollution, greenhouse gases or radioactive nuclear and other dangerous wastes. In addition, there are significant economic development opportunities for Midwestern solar companies that

These solar panels, made by Spire Solar, provide clean electricity for Reilly Public School in Chicago. The manufacturing facility has created 55 new jobs on Chicago's West Side.

manufacture both for domestic use and export to developing countries. Chicago, in particular, is seizing these solar development opportunities by supporting Spire Solar's new solar panel manufacturing plant on a former "brownfield" site, installing solar panels on the rooftops of nine major museums, and planning to build the largest single photovoltaic assembly (2.5 MW) in the country to provide cleaner and greener power for public use.

Deploying Efficient Generation Technologies

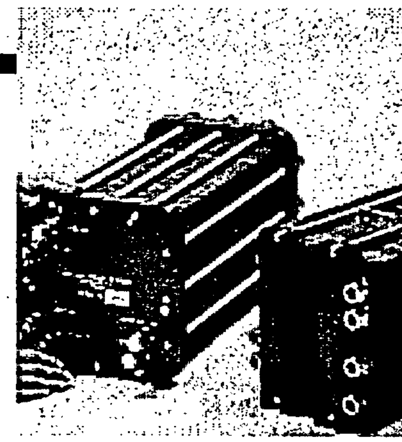
Natural gas is a cleaner fuel than coal and will likely gain an increasing share of the electricity generating market. However, the market share will depend on the long-term price of natural gas, which has tended to fluctuate significantly, and fuel availability. Although natural gas plants produce less SO_2, NO_x, particulates and mercury pollution than do coal plants, the gas plants do produce considerable CO_2 emissions that exacerbate climate change. Moreover, it is important that community environmental values be respected in determining where to site these large power plants. Natural gas should be viewed as a transitional fuel from our current energy path to a more sustainable energy future, rather than as a long-term solution. The Clean Energy Development Plan includes three highly efficient technologies to use natural gas: fuel cells, combined heat and power and district energy systems.

1. *Fuel cells* combine hydrogen (from the fuel source) and oxygen (from the air) in the presence of a catalyst to generate electricity, heat and water. They have great promise as an efficient, modular, combustion-free power technology. Over the next two decades, fuel cells can be used for central power plants or as on-site generators providing reliable distributed generation. Fuel cells are an especially strong option for "high-quality" power users – such as hospitals, financial institutions, data processing and other computer centers, museums, police and fire stations, and research labs – that have little tolerance for utility outages and interruptions. The superb reliability of fuel cells compensates for the added expense because outages can cause severe economic costs for those consumers and, in some cases, catastrophes. For this reason, the First National Bank in Omaha, Neb., recently installed four 200-kilowatt fuel cells to run its computer system, which processes $6 million each hour in transactions. This high-reliability system is down less than four seconds per year. In the longer term, fuel cells are an essential component in a transition to a renewable energy economy.

2. *Combined heat and power* (CHP) brings together a conventional heat-producing industrial boiler or furnace with a turbine to co-generate electricity. This dual-production process harnesses waste heat and can generate electricity at efficiencies as high as 80 percent. Ongoing technological advances give CHP great potential for energy savings and economic benefits in industrial and community energy systems. For example, the McCormick Place Convention Center in Chicago uses a CHP system operated by Trigen Energy to achieve an 81 percent fuel efficiency rate, while reducing pollution from NO_x, CO_2 and SO_2. It has received a U.S. EPA Energy Star award for environmental performance.

3. *District energy systems* provide thermal energy through steam or hot water pipes to multiple customers within a specific geographic area for space heating, water heating, cooling and industrial processes. They often co-generate electric power along with thermal energy, and thereby create a highly efficient source of electricity generation. District energy systems also provide an excellent opportunity for biomass-fired CHP. For example, District Energy St. Paul supplies the downtown business district with electricity, heating and cooling. It recently announced plans to upgrade its

system by replacing the coal and natural gas boilers with a 98 MW wood chip-fired CHP plant that combines thermal and electricity production.



The remarkable reliability of fuel cells makes them ideal for users such as hospitals and financial institutions, where an uninterrupted power supply is critical and utility outages can be catastrophic.

Findings: Renewable Energy and Modern Efficient Generation Technologies

Both renewable energy resources and modern efficient generation technologies can provide substantial clean power for the Midwest. Figure 7 presents the generation resources that are included in the Clean Energy Development Plan. Wind turbines account for the greatest new renewable capacity. Combined heat and power, using natural gas or biomass, provides the second largest source of new clean power potential. Solar photovoltaics, biomass gasification and fuel cells play a smaller role because of their relatively high costs, but, as these technologies rapidly improve, they are expected to be more cost-effective toward 2020.

Renewable energy technologies will generally be deployed in those areas with the best combination of resource potential, public policy support and business opportunities. As shown in Figure 8, the wind power potential is largest in the Great Plains states, and Illinois, Indiana, Michigan and Ohio will use more CHP because of their greater concentration of industrial facilities. Biomass potential is largest in Illinois, Indiana and Ohio because of the opportunities for co-firing in their large number of existing coal plants and their agricultural lands.

Policy Recommendations: Implementing the Clean Energy Development Plan

These clean energy resources are now technologically achievable and economically realistic. They will not,

Figure 7. New Clean Generation Capacity Included in Clean Energy Development Plan

	2010			2020		
Generator Type	Installed Capacity (MW)	Generation (GWh)	Generation (percent of total)	Installed Capacity (MW)	Generation (GWh)	Generation (percent of total)
Wind Turbines	6,698	21,283	3.0	24,510	80,795	11.3
CHP - Biomass	2,949	23,881	3.4	6,003	48,527	6.8
Biomass - Co-Firing	1,850	9,778	1.4	4,807	22,113	3.1
Photovoltaics	161	196	0.0	482	571	0.1
Biomass Gasification	75	536	0.1	575	4,049	0.6
Subtotal Renewables	11,733	55,674	8.0	36,377	156,055	21.9
CHP – Natural Gas	5,650	45,422	6.5	12,230	98,286	13.8
District Energy Systems	3,223	25,309	3.6	6,446	50,470	7.1
Fuel Cells	282	2,267	0.3	3,257	25,925	3.6
Subtotal Efficient Natural Gas	9,155	72,998	10.4	21,933	174,681	24.5
Total	**20,888**	**128,672**	**18.3**	**58,310**	**330,736**	**46.4**

This includes all renewables added after 2000. The totals may not add up precisely due to rounding.

This light fixture is fitted with an energy-efficient compact fluorescent light bulb. Investing in energy efficiency produces significant environmental and economic benefits, without sacrificing comfort.

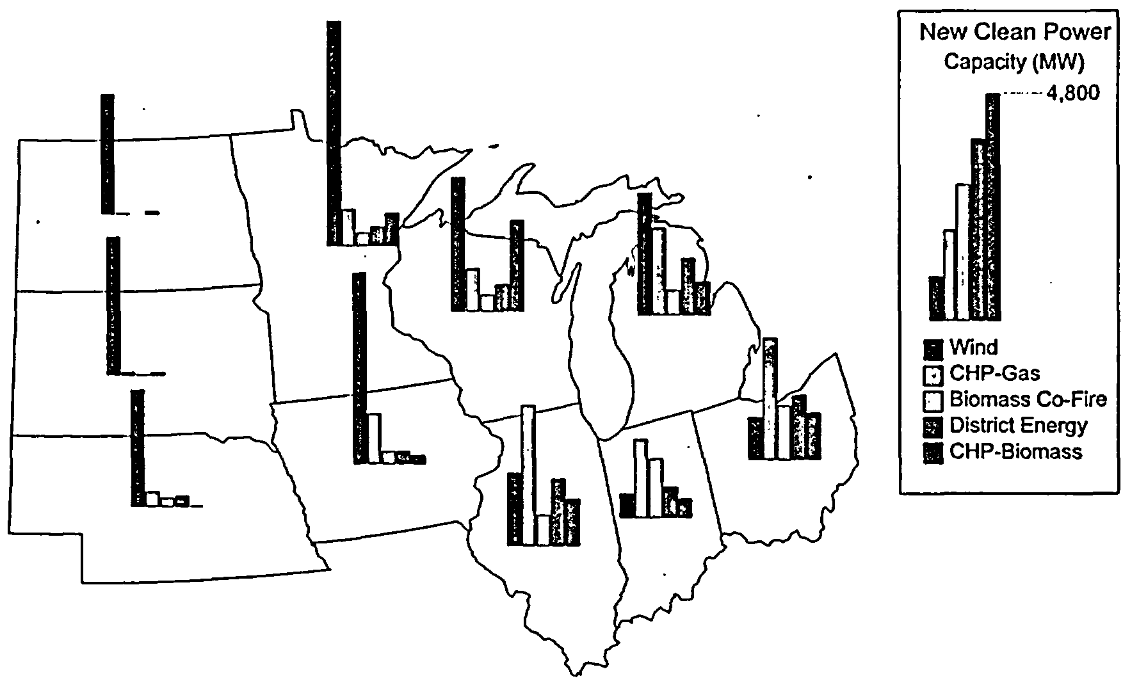
however, reach their full potential without significant public policy support. Coal plants and nuclear energy currently receive enormous financial subsidies and policy benefits. Implementing the Clean Energy Development Plan will require thoughtful and aggressive action beyond business-as-usual practices and regulatory policies. Energy efficiency and renewable energy resources are also hindered by a variety of "market barriers" that prevent them from competing fairly against coal and nuclear plants on a level playing field. Public policies to overcome these market barriers are needed to obtain the benefits of more energy efficiency and wind, biomass and solar power for a more diversified electricity portfolio in the Midwest.

Several Midwestern states have recently taken important steps to promote clean energy, but much more remains to be done. The key policies and action steps necessary to achieve the fundamental energy policy shift and reach the goals of the Clean Energy Development Plan are presented below.

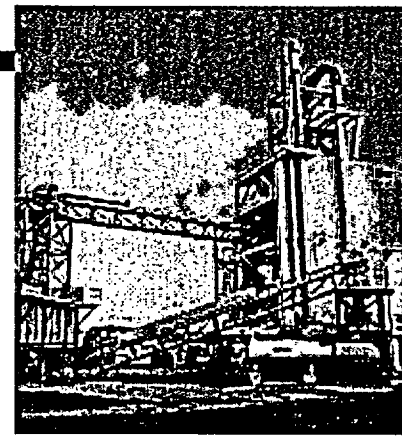
Energy Efficiency

Each Midwestern state should establish an Energy Efficiency Investment Fund, or an equivalent mechanism, supported by a non-bypassable charge of 0.3¢ per kWh (less than one-third of 1¢) to support the robust energy efficiency initiatives of the Clean Energy Development Plan. All electricity customers should invest in the Fund just as various decommissioning charges, franchise fees, utility taxes and other utility charges already apply to all customers on their electric utility distribution bills. All customers will benefit from the cleaner air and improved health resulting from developing energy efficiency opportunities. The Energy Efficiency Investment Fund should be implemented as soon as possible and maintained at this level until at least 2010. At that time, the impacts of energy efficiency investments should be evaluated, and public officials and stakeholders should assess whether to modify the funding levels in order to achieve the Clean Energy Development Plan's energy efficiency target for 2020. Finally, ***Congress should enact legislation to provide substantial matching energy efficiency investment funds that can be used by states to supplement or partially offset their investment funds.***

Figure 8. New Clean Energy Generating Additions by State in 2020



The Energy Efficiency Investment Fund should be managed by an independent and highly capable third-party administrator – a not-for-profit organization or foundation or an appropriate public agency. The Energy Efficiency Administrator should be overseen by a board including environmental and consumer organization representatives, state energy officials and energy efficiency industry representatives. The overall mission of the Administrator should be to transform the markets for energy efficiency products and services, and to maximize the long-term economic and societal benefits from energy efficiency. The new $225 million Illinois Clean Energy Community Foundation with its mission to improve energy efficiency and develop renewable energy resources, among other things, is one model of an Energy Efficiency Administrator.



Biomass gasifiers, which are an emerging renewable energy technology, can generate electricity using agricultural residues or sustainably grown energy crops as fuel.

More stringent energy efficiency standards and building codes should be applied throughout the Midwest. Commercial lighting improvements, more energy-efficient windows, daylighting, and heating and air conditioning efficiency are some of the most cost-effective opportunities for better environmental performance in the Midwest. Each of the Midwestern states should: (a) evaluate its current efficiency standards and building codes; (b) upgrade outdated codes and standards; and (c) establish monitoring and enforcement practices to ensure that revised standards and codes are implemented. States should coordinate their efforts to provide regional consistency.

Renewable Energy Resources

Each Midwestern state should promptly establish a Renewables Portfolio Standard (RPS) that requires all retail electricity suppliers to include a specified percentage of renewable resources in their generation mix. The RPS percentage requirement should increase steadily each year to reach eight percent by 2010, and then reach 20 percent by 2020. The RPS should require new renewable energy generation to meet the specified percentage target, not just a repackaging of already existing resources. In states that have adopted electric industry restructuring legislation, the RPS should apply to all customers, including "standard offer" or "default" customers served by electric distribution companies. The RPS should also include a renewable credit trading system, consistent with assuring improvements to local air quality through renewables development in all states, by which qualifying renewable energy generators in the Midwest would produce credits that could be sold to retail electricity suppliers in the region. Ideally, a national RPS would be enacted, in addition to a regional RPS policy for the Midwest as a whole.

Each Midwestern state should establish a Renewable Energy Investment Fund, or an equivalent mechanism, supported by a non-bypassable charge of 0.1¢ per kWh (one-tenth of 1¢) to support the robust development of wind, biomass and solar power. All electricity customers should invest in the Fund just as with the Energy Efficiency Investment Fund, because all customers will benefit from developing renewable energy resources. The Renewable Energy Investment Fund complements the Renewables Portfolio Standard, which largely supports technologies that are already close to commercial viability. The Investment Fund will also advance technologies that are still in the developmental stages. The Renewable Energy Investment Fund should be implemented as soon as possible and maintained at this level until at least 2010. At that time, the impacts of the renewables investments should be evaluated, and public officials and stakeholders should assess whether to modify the funding levels in order to achieve the Clean Energy Development Plan's renewable energy resources target for 2020. *Finally, Congress should also enact legislation to provide substantial matching renewable energy investment funds that can be used by the states to supplement or partially offset their investment funds.*

The Renewable Energy Investment Fund should be managed by an independent and highly capable third-party administrator – a not-for-profit organization or foundation or an appropriate public agency – that should be overseen by a board including environmental and consumer organization representatives, state energy

Net metering laws allow consumers to sell electricity to the utility when their home or business system generates more power than they need. This promotes distributed resources and their benefits.

officials and renewable energy industry representatives. Competitive bidding processes, such as "reverse auctions," should be emphasized to most effectively deploy these investment funds.

Transmission pricing policies and power pooling practices should treat renewable energy resources fairly. They must account for the intermittent nature of wind and solar power operations, and their generally smaller scale and remote locations. The regional transmission Independent System Operators (ISO) and Regional Transmission Organizations (RTO) should have governance structures that reasonably include representation of both environmental organizations and renewable energy generators. "Pancaked" multiple transmission rates should be eliminated, and single "postage stamp" rates should be encouraged. Real-time balancing markets should allow generators to buy or sell firm transmission capacity that deviates from the amount reserved in advance. Spot-market bidding systems should not penalize renewable energy generators that have intermittent generating patterns. Net metering and fairer interconnection policies should be adopted as explained below.

CLEAN DISTRIBUTED GENERATION

Distributed generation resources are small power plants that can be deployed at many locations throughout an electric distribution area. They can enhance generation reliability by providing power when and where most needed, as well as provide power in remote locations where it is costly and/or difficult to build new transmission lines. They can also enhance distribution reliability by providing grid support to relieve stress on aging electricity delivery systems, especially in urban and older suburban areas such as Chicago, that have recently been plagued by recurring power outages. In some cases, distributed resources may avoid the need for transmission line extensions as sprawl pushes development beyond existing suburban areas. Policies should be designed to support clean distributed generation technologies, including small wind turbines, solar photovoltaic panels and fuel cells.

Net metering should be enacted and implemented in all Midwestern states. Net metering should apply to all of the clean distributed generation technologies listed above. Net metering customers should be paid the retail rate for surplus generation that is provided back to the utility and the grid. Federal legislation to adopt net metering nationally is appropriate as well.

Uniform safety and power quality standards should be developed throughout the Midwest in order to facilitate the process for customers and developers to reasonably, economically and safely interconnect to the electricity distribution system.

Utilities and state utility regulatory commissions across the Midwest should work cooperatively to establish standard business and interconnection terms and conditions that will help to overcome existing institutional barriers to clean distributed generation technologies. Utilities should waive their interconnection charges for small wind power, solar photovoltaic panels and fuel cell installations because of the reliability and environmental benefits provided by these clean technologies. State utility regulatory commissions should require these steps if not undertaken voluntarily by the utilities.

Federal and state environmental officials should apply clean air standards to small distributed generation sources so that clean power technologies are promoted and highly polluting diesel generators are discouraged. Congress should eliminate the exemption from federal Clean Air Act standards for small generation sources. In today's circumstances, this exemption undermines the national air quality improvement goals, and it provides inefficient diesel generators with an unfair competitive advantage. Diesel generators, for example, produce up to 30 times as much NO_x and particulate pollution as new combined-cycle natural gas plants and microturbines, but these old generators are often the first choice of some customers for standby and peak power. In addition to truly clean wind turbines, solar photovoltaic panels and fuel cells, there are also new relatively clean microturbines and other small generator technologies on the market that can achieve the benefits of distributed power resources without sacrificing environmental quality and public health.

CO_2 REDUCTION POLICIES

Legislators, regulators and public stakeholders seeking to reduce CO_2 pollution from coal and natural gas plants should also look beyond these clean energy proposals. Aggressive energy efficiency and renewable energy resources development can, indeed, play an important role in offsetting increased CO_2 pollution. However, coal plants produce the largest share of the Midwest's air pollution and achieving significant CO_2 reductions will require reducing pollution from these plants. State and federal policymakers should consider three basic approaches to achieve CO_2 reductions:

1. Environmental regulations have traditionally treated each pollutant separately. Pollution regulations for SO_2, NO_x, CO_2, particulates and mercury should be integrated in order to allow power plant owners to pursue efficient compliance strategies, including repowering with natural gas or retirement of older coal plants.

2. CO_2 pollution from fossil-fueled power plants should be subject to a cap-and-trade system similar to that currently used for SO_2.

3. Legislatures, regulators and public stakeholders should establish policies to encourage or require the retirement of older, less-efficient coal plants. Retirements can be achieved through voluntary negotiations, explicit requirements and other mechanisms.

* * *

The Midwest cannot do it alone. Air and water pollution cross state and regional lines. There is also an important federal role and responsibility to ensure that all regions contribute to solving pollution problems and obtaining the environmental, public health, reliability and economic benefits from clean energy development. Federal legislation should be enacted soon to provide a national renewables portfolio standard, matching energy efficiency and renewable energy resources investment funds as described above, sensible pollution reduction policies, net metering and targeted tax credits for clean energy technologies. These forward-thinking actions will provide significant added benefits for the Midwest and the nation.

The Clean Energy Development Plan is an achievable vision for a robust electricity system that can improve environmental quality and public health, while promoting sustainable economic growth.

CONCLUSION

The Midwest Clean Energy Development Plan is visionary, and it is practical and achievable. It will require a dedicated and concerted effort by governors, legislators, regulators, the electric power industry, consumers and citizens to replace current, outdated power plants and practices with modern clean technologies and policy innovations. It will require specific steps to adopt and aggressively implement the recommended new strategies, policies, and practices. The Midwestern public is ready to seize the opportunities to robustly develop our clean energy efficiency and renewable energy resources that will lead to better environmental quality and public health, improved electric system reliability and regional economic development gains.

One or two states alone cannot achieve the full benefits of the Midwest Clean Energy Development Plan. The electricity services market is regional, and successful energy strategies and policies for the Midwest require regional solutions and cooperation across state lines. The Clean Energy Development Plan is a smart policy and technical strategy for the Midwest that can also serve as a model for the rest of the nation. As federal legislators consider more aggressive clean energy development policies and practices to secure national environmental benefits, balanced fuel portfolios and economic growth, we can and should lead the way here in the Midwest – the nation's heartland.

1. Overview: Seizing the Opportunities to Invest in Clean Energy Development for the Heartland

The Midwest needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy makes both good environmental and economic sense for our region. Clean energy development will reduce pollution, improve reliability by diversifying our power supply, and create new "green" manufacturing and installation jobs, as well as provide new renewable energy "cash crops" for farmers. *Repowering the Midwest* is a plan to seize these opportunities.

Modern life runs on electricity to power our homes and businesses. From refrigerators to computers to dairies, we depend on reliable electricity. Nevertheless, at the dawn of the 21st century, when rapid technological progress is transforming society, the Midwest is still saddled with polluting and inefficient 1950s equipment generating the energy to drive the "new economy." This overdependence on aging coal and nuclear plants and many utilities' underinvestments in modernizing their deteriorating transmission and distribution systems are causing both power reliability and pollution problems.

Many economists tell us that technological advances are shaping a new economy in which economic growth provides new jobs and creates greater wealth. The rapid technological progress should also result in modern processes that produce less waste and pollution. While this is true enough in many industrial sectors, the electric industry lags behind. It is time for electric utilities and power generators to make the technological advances to give the public what we want: clean, reliable, efficient energy at a fair price. Can we keep the lights on without polluting our air and water and leaving radioactive nuclear waste for future generations to clean up? The answer is yes, and perhaps surprising to some, the Midwest heartland can lead the way if we put the right policies and practices in place.

Developing clean energy efficiency and renewable energy resources are smart and sustainable solutions to the Midwest's pollution problems, to power constraints at summer peak demand times, and to challenges in meeting the region's overall electricity needs. Clean energy resources are the modern technologies for our 21st century energy future.

The cost of renewable energy is plummeting as wind, biomass and solar power technologies have dramatically improved. There also are abundant opportunities to install cost-effective, modern, energy efficient technologies ranging from improved residential and commercial lighting to new industrial motors. The Midwest is poised to capitalize on these clean energy development opportunities.

When it comes to wind power, the flat lands of the Midwest are valuable assets. Wind power is the world's fastest growing energy source, expanding nearly 35 percent in 1998. Tremendous design improvements in wind turbines have led to a huge drop in the per kilowatt price of installed capacity. Currently, this is less than one-third of the 1981 price and close to competitive with conventional power sources.

Six of the 10 states with the highest wind power potential are in the Midwest, according to the American Wind Energy Association. Iowa and Minnesota are leading the way with more than 500 megawatts (MW) of wind power (equivalent to the size of a typical coal plant) coming online since 1998. This includes the world's largest wind farm, which provides enough energy to power 64,000 typical homes in northwestern Iowa.

More clean energy means more green jobs. Not coincidentally, two leading wind power businesses have recently located in the Midwest, providing well-paid manufacturing jobs and capitalizing on current and future market opportunities. For factory workers and farmers, this is sustainable development in action. Yet, the enormous potential of this growing industry remains largely untapped.

Everyone already knows that Midwestern farmlands are ideal for growing the foods that energize our bodies. If we put the right policies in place, we can also count on Midwestern farmers to grow high-yield "energy crops" to help power our economy. Expanding this biomass power will create new rural jobs and provide new markets for crops while reducing air and water pollution and deterring soil erosion.

Other advanced technologies, such as fuel cells and industrial and commercial cogeneration systems, which generate electricity and heat simultaneously, can also diversify our energy supply in the near term. And, yes, even in the often-gray skies of the Great Lakes, solar photovoltaic panels that convert sunlight to electricity can play a growing role, especially on sunny summer days when peak electricity demand is highest, and in hard-to-reach remote areas where solar power provides a way around costly transmission and distribution line extensions. Natural gas plants are not entirely clean, but are generally less polluting than coal and nuclear power. When properly sited, they can also be an important part of a strategy to improve the overall environmental performance of the Midwest's power sector.

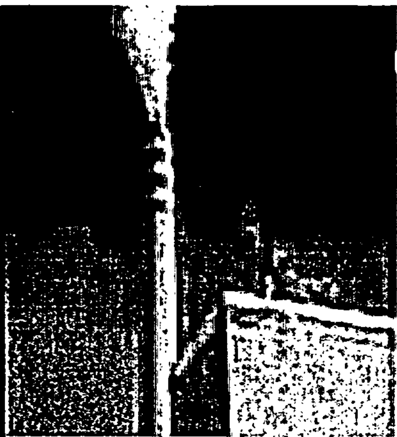
As for the demand side of the equation, many clean energy efficiency improvements are smart, economical and waiting to be tapped. Inefficient energy use continues to waste money and cause unnecessary pollution. This can be changed by deploying new, more energy efficient heating and cooling systems, lighting, appliances, and building designs and materials. Seizing these opportunities will save money, relieve electricity demand pressures and improve our quality of life. This is especially true in the Midwest, where most utilities have underinvested in efficiency programs that save customers energy and money. Here, too, clean energy means more green jobs because Midwestern companies manufacture many of the new energy-efficient products.

Unfortunately, the electric utilities have failed to keep pace with these improvements and opportunities. Even though new technologies can generate power cleanly and efficiently, a staggering 95 percent of the Midwest's electricity is produced by coal and nuclear plants – the two fuel sources with the worst environmental and public health impacts. These old power plants produce pollution that causes smog, acid rain and global warming, and they generate radioactive nuclear waste and other toxic pollutants. Depending so heavily on business-as-usual coal and nuclear power locks in a high-pollution future and misses the opportunity to improve reliability by diversifying our power resources. Bypassing more energy-efficient processes and technological advances not only increases businesses' costs, but misses the job creation opportunities in the growing clean energy sector.

The Midwest's clean energy resources are here and ready to be developed. Our region is blessed with abundant wind resources, untapped biomass production potential and relatively high levels of solar power availability. Likewise, new energy efficient lighting and electric appliances operate at low costs while avoiding pollution, but have yet to capture a firm foothold within the industry or the marketplace.

Repowering the Midwest is a blueprint for producing economically robust and environmentally sound electricity in the 21st century by comparing two possible energy futures for the Midwest – one in which we continue to rely on conventional, or "business-as-usual," technologies, and a second in which the Midwest unleashes its homegrown clean energy development potential. This Clean Energy Development Plan quantifies the region's untapped energy efficiency and renewable resources and lays out strategies, policies and practices to advance a cleaner electricity future from the industrial Midwest to the Great Plains. These clean power options are technologically and commercially available today, and can be obtained with only a modest increase in total electricity costs – 1.5 percent in 2010 and roughly three percent in 2020 – that are far offset by the environmental and public health improvements and the economic and employment growth for our region.

As engineering improvements continue, many of the modern, clean technologies await sensible policy shifts to reverse the incentives that prop up the polluting technologies of the past. It is no longer a question of engineering know-how, but, instead, a challenge of political will. It is time to leave the 1950s behind and realize the promises of homegrown, clean energy in the Midwest to provide us with a healthier environment and a truly new economy. Now is the time to repower the Midwest for a clean energy development future.

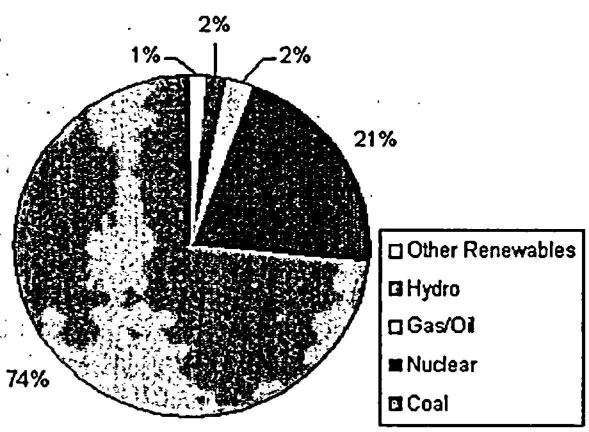


2. Electric Power in the Midwest: Challenges and Opportunities

2.1 The Midwestern Electricity Portfolio Under the Business-As-Usual Scenario

The Midwest relies almost exclusively upon coal and nuclear power for its electric power. As shown in Figure 2.1, coal plants generate roughly 74 percent of the region's electricity, while nuclear plants account for 21 percent. The nuclear units run as baseload whenever they are available, resulting in a capacity factor of 84 percent. The coal units have a capacity factor of 63 percent on average, indicating that some of them could operate at higher levels as electricity demand increases.

FIGURE 2.1 CURRENT SOURCES OF ELECTRICITY GENERATION IN THE MIDWEST (2000)



Oil and gas power plants provide two percent of the Midwest's electricity. Most of these plants are used for cycling and peaking purposes, and maintain a low capacity factor of seven percent on average. Renewable resources supply just three percent of the region's electricity. This is mostly (63 percent) from hydro-electric plants, with relatively small contributions from wind, biomass and solar photovoltaic power. Furthermore, modem energy efficiency technologies and tried-and-true efficiency measures are significantly underutiltized.

FIGURE 2.2 GENERATION FUEL MIX BY STATE (2000)

Figure 2.2 summarizes each Midwestern state's generation resources. Most electricity is generated in the five easternmost states. All Midwestern states depend on coal and most also rely on nuclear power.

Most Midwestern coal plants were built between 1940 and 1970, and many have not been upgraded with modern pollution control technologies. Approximately 37 percent of the coal plants predate 1960. These older coal plants operate at 28 to 32 percent average efficiency. Newer, combined-cycle power plants achieve far greater efficiency levels, sometimes reaching 50 percent.

Compared to other regions, the Midwest relies more heavily on these older, inefficient coal plants and thus produces a disproportionate amount of air pollution, causing health and environmental problems. The Midwest generates 21 percent of the nation's electricity, but produces 31 percent of the SO_2 pollution, 32 percent of the NO_x pollution, and 26 percent of the CO_2 pollution from the nation's electric industry sector.

The Midwest's easternmost power plants are among the nation's worst polluters. For SO_2 emissions, power plants in Ohio, Indiana and Illinois rank first, third and fifth, respectively, in their contribution to 1999 U.S. power plant emissions. For NO_x emissions, Ohio, Indiana and Illinois rank first, third and seventh. For CO_2 emissions, Indiana, Ohio, and Illinois rank second, third and eighth, with Michigan not far behind at 11th (USPIRG 2000).

2.2 The Electricity Future Under Business-As-Usual Practices

Most industry forecasts assume that natural gas power plants will be the primary source of new generation to meet future load growth. Combined-cycle natural gas power plants are much more efficient, cost less to build, and produce fewer air emissions than conventional coal power plants. The Department of Energy's Annual Energy Outlook (AEO) forecast estimates that nearly all of the new generation capacity in Midwestern states between 2000 and 2020 will be from natural gas power plants (DOE 1999).

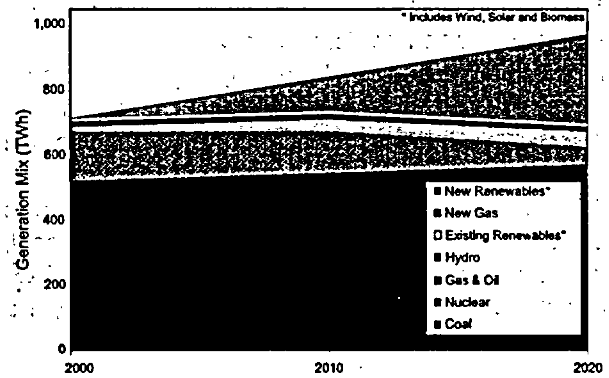
The AEO forecasts that Midwestern electricity demand will grow at an average annual rate of roughly 1.3 percent from 2000 to 2010, and about 1.0 percent from 2010 to 2020. While this is lower than the nearly two percent annual average growth rate during the 1990s, it still means much higher electricity demands. By 2020, Midwestern electricity demand will be nearly 26 percent higher than in 2000.

A reference case forecast indicates the Midwestern electric industry's likely future under business-as-usual practices. This is based primarily on the AEO forecasts, as described in Appendix 3.

The primary results of our business-as-usual forecast are shown in Figure 2.3. There is a modest decline in coal capacity expected by 2020, as some older coal plants are retired. The operating coal plants' capacity factors, however, should increase to as much as 71 percent, as existing coal plants operate more to meet new load growth. The net impact is a steady increase in coal generation over the next 20 years. There is a more significant decline in nuclear capacity by 2020, as some older units reach the end of their operating licenses.

The most significant shift between 2000 and 2020 is to new natural gas facilities. Over the coming 20 years, as much as 67.5 GW of new gas could be installed to meet new load growth and replace some retiring coal and nuclear capacity. By 2020 new gas facilities will be the second largest source of generation in the Midwest, providing up to 27 percent of all electricity. The price of natural gas and competing fuels will drive natural gas' relative contribution to future electricity generation.

Figure 2.3 Portfolio of Electricity Generation Sources: Business-As-Usual Practices



The combination of new load growth, retiring nuclear units and new natural gas generation will result in much higher CO_2 emissions. Under business-as-usual practices, CO_2 emissions in the Midwest are likely to increase from 557 million tons in 2000 to 726 million tons in 2020, a 30 percent hike. This model assumes a decline in NO_x emissions as power plant owners comply with the U.S. EPA's rules implementing the Clean Air Act. SO_2 emissions are expected to rise moderately as power plant owners comply with Phase II of the Acid Rain Program under the Clean Air Act.[1]

2.3 The Price of Business-As-Usual

The Midwest's dependence on coal and nuclear power plants exacts a heavy toll on local public health, environmental quality and the economy. Some costs specifically affect power plant owners – which could lead to higher electric rates – if not absorbed by shareholders because of rate caps. Other costs are imposed on society as a whole. In addition, as pollutants migrate from the Midwest to New England and the Mid-Atlantic, they carry a cloud of public health, economic and liability concerns along with them.

Environmental and Public Health Consequences

Greenhouse Gases

The greenhouse effect occurs when trace gases in the atmosphere trap solar energy at the earth's surface

[1] SO_2 emissions are currently covered by a national cap-and-trade system under the Clean Air Act. This moderate increase in SO_2 emissions implies that some Midwestern power plant owners will purchase SO_2 allowances from elsewhere in order to maintain the national cap.

and warm the atmosphere. CO_2 is the most important greenhouse gas. Fossil-fired power plants produce roughly 40 percent of the total U.S. CO_2 emissions. Global warming will cause dire global consequences, including higher sea levels, coastal wetland floods, fish and bird habitat loss, prolonged droughts, lost crop production, increased hurricanes, increased heat-related deaths, and animal and plant extinction, as well as a spread in the geographical range of dangerous pests and diseases. In 1997, the United States and other developed nations agreed to the Kyoto Protocol, which requires the United States to reduce CO_2 emissions to seven percent below 1990 levels by the period 2008 to 2012.

Ozone

Ground-level ozone, or "smog," is created when nitrogen oxide and volatile organic compounds react in the presence of sunlight. Ozone causes upper respiratory illness, increased asthma attacks and reduced pulmonary function, especially in "at-risk" groups such as children and the elderly. It compromises resistance to infectious disease and has systemic effects on other organ systems (e.g., liver and immune system). Ground-level ozone causes several billion dollars in annual crop yield loss, as well as damage to forests and other ecosystems. In 1997, electricity generation contributed to roughly 26 percent of all NO_X emissions in the United States. Illinois, Indiana, Michigan, Ohio and Wisconsin all have counties that do not comply with the National Ambient Air Quality Standards for ozone. One recent study found that residents in the Ohio River Valley experienced 83,000 asthma attacks, 1,909 emergency room visits and 636 hospitalizations because of smog levels in 1997 (OEC, OVEC and RCOVER 2000).

Acid Rain and Visibility Impacts

Acid rain is caused by SO_2, and NO_X, which react with other chemicals naturally occurring in the atmosphere. Acid rain has a serious impact on the Midwest, falling on the Great Lakes and the inland lakes and forests of the upper Midwest. It can damage human health, public and private property, and acidify lakes. SO_2 and NO_X emissions also create sulfates and nitrates, which, along with particulate matter, impair visibility and create regional haze. In 1997, electricity generation was responsible for roughly 64 percent of total U.S. SO_2 emissions.

Particulates

Particulate matter includes dust, soot and other solid materials, including secondary nitrates and sulfates, that enter the atmosphere during fossil fuel combustion. Particulate matter causes asthma and respiratory illnesses, and even premature deaths. Some studies show that as many as 60,000 U.S. residents may die prematurely as a result of particulates emitted at or below currently allowed levels, and that mortality risks are 15 to 17 percent higher in more polluted cities compared to the least polluted cities (EPA 1995).

Air Toxics

Heavy metals, which occur naturally in coal and oil deposits, are released into the air during combustion of fossil fuels. The main metals emitted include arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel and selenium. Once in the environment, metals persist and can be deposited on soil, in lakes and in streams. Contaminated soil may present a health risk when directly ingested (by children) or indirectly ingested (by humans and animals) through crops that take up metals. Metal deposits in lakes and streams may harm fish, humans and other species that consume contaminated fish. Mercury poses one of the greatest health risks among persistent air toxics. Fossil-fired power plants accounted for roughly 33 percent of U.S. mercury emissions in 1995.

Solid and Liquid Waste from Coal Combustion

Coal plants also create toxic pollution in the form of solid and liquid wastes. In fact, control technologies that capture air emissions can concentrate toxins in solid and liquid wastes. These waste streams can contain high mercury, arsenic, chromium and cadmium levels. No federal environmental laws govern disposal of such wastes, however, and only a few states have adequate waste disposal regulations. More than 100 million tons of solid and liquid wastes are generated at U.S. coal- and oil-fired power plants each year. Most of this waste is disposed of at power plant sites in unlined and unmonitored lagoons, landfills and mines (CCC, HEC and CATF 2000).

Nuclear Fuel Cycle Impacts

Nuclear power plants create a significant risk of exposing the environment, industry workers and the general public to dangerous levels of radiation. Nuclear reactors release low levels of radiation to the air and water during routine operations, as does mining and processing nuclear fuel.

The long-term disposal of both high- and low-level radioactive nuclear wastes poses particularly difficult environmental problems. To date, six low-level nuclear waste sites have operated in the United States, and each has had major radiation leaks. Four of these six sites are now closed. There is no high-level nuclear waste site in the United States. The federal government had hoped to use the Yucca Mountain site in Nevada. Despite years of research, key concerns regarding cost, potential groundwater contamination, local seismic activity and nuclear waste transportation risks are not yet resolved. Nuclear power plants also create the threat of major radiation release through mechanical error and catastrophic accidents (REPP 4/2000; UCS 1999).

For specific estimates of environmental impacts of the Midwest's electric industry, see the Environmental Law and Policy Center's pollution calculator at www.pollutioncalculator.org. This Web site provides information on the impacts of varying levels of electricity generation and use in the Midwest.

Impacts of Restructuring

Some observers contend that restructuring the electric industry will reduce pollution by promoting new, low-emission natural gas plants and forcing the retirement of inefficient coal plants with high air emissions. It is more likely, however, that restructuring will increase pollution until regulators adopt specific restructuring policies to prevent it (CCAP 1997; Tellus and RAP 1995). Highly polluting coal plants will continue operating into the future, perhaps at even higher capacity, as the markets expand under restructuring (Synapse 6/1998). Electric industry restructuring creates the opportunity to reduce pollution, but only if regulators adopt aggressive and focused policies designed to achieve cleaner energy development.

Local, Regional, and National Effects

Despite growing interest in emission cap-and-trade programs to alleviate pollution, these approaches can worsen environmental problems and health harms to people living near the coal plants in the Midwest. The existing SO_2 and proposed NO_x allowance trading programs allow each power plant owner to exceed clean air standards, if their pollution is offset by allowances purchased from other generators, which might be located far away. For example, Illinois Power bought allowances from an Oregon utility; as a result, the costs of high air pollution continued near the central Illinois coal plants, while the benefits of pollution reduction were achieved in the Pacific Northwest. These trading programs could increase Midwestern coal generation because of the region's concentration of older coal plants. While trading programs might help achieve regional or national ozone and acid rain goals, environmental and health costs will rise in the neighborhood of power plants. In December 2000, the Harvard School of Public Health published a study of nine coal plants in northern Illinois which found that health risks (e.g., premature deaths, asthma attacks and respiratory illness) were greatest near the power plants and decreased with distance from the source (Harvard 2000).

In addition to the local public health and environmental harms, the effects of the Midwest's electric plants reverberate beyond the region, as air pollution drifts downwind to the Northeast and Canada (EPA 1998), causing smog, acid rain and global warming. This pollution migration saddles other states with associated health and environmental costs and imposes an economic burden as they struggle to comply with environmental regulations, such as National Ambient Air Quality Standards for ozone (Synapse 7/1998). The health impacts of air pollution impose serious social and economic burdens on families and society. Greater illness, whether from asthma or cancer, affects "at-risk" groups such as children and the elderly disproportionately, and equals higher health care costs, higher health insurance premiums and lower productivity due to missed work (UCS 1999).

Economic Consequences

In addition to the economic costs of the health and environmental impacts discussed above, overdependence on coal and nuclear plants will likely raise the cost of future regulatory compliance. In the past, electric utilities consistently underestimated the costs of future environmental regulations, and their high-polluting resource portfolios reflect this gamble. Thus, generators face regulatory compliance costs that are higher than a clean resource portfolio would incur, and electricity customers must pay for poor planning and short-sightedness.

In coming years, the U.S. EPA will likely: (1) require compliance with the NO_x SIP Rule; (2) apply more stringent National Ambient Air Quality Standards for NO_x; (3) regulate fine particulates for the first time; (4) consider regulations regarding mercury and other air toxics emissions; and (5) implement a visibility rule regarding air emissions affecting national parks. Also likely in the near- to mid-term future is some form of a CO_2 reduction policy, whether voluntary or mandatory.

Likewise, relying so heavily on coal makes the region vulnerable to volatile prices and fuel supply interruptions that can cause reliability problems. The current nationwide interest in developing natural gas power plants could push up the price of natural gas over the long term. Even amateur investors in the stock market understand the need for maintaining a diverse investment portfolio.. Unfortunately, this theory has been lost on many Midwestern electric utilities, which have mostly failed to diversify by developing renewable and energy efficiency resources as a significant part of their electricity portfolios. While a larger share of natural gas generation will diversify the fossil fuel portfolio, a truly prudent portfolio should include more than fossil fuels. Failing to diversify in this manner imposes another economic cost: the lost opportunity to invest in the emerging economic sector of energy efficiency and renewable energy. Developing these industries in the Midwest can spur job creation and promote economic development opportunities in the emerging clean energy sector.

3. THE CLEAN ENERGY DEVELOPMENT PLAN: A BLUEPRINT FOR CLEAN POWER IN THE MIDWEST

There are better courses for the Midwest's electricity sector than to continue along this shortsighted and damaging path. The Clean Energy Development Plan proposes developing underutilized energy efficiency measures and largely untapped homegrown renewable energy resources to form a cleaner, more reliable and more diverse electricity portfolio for the Midwest that can spur job creation in this emerging economic sector.

The Midwest Clean Energy Development Plan will:

1. Aggressively implement modern, cost-effective energy efficiency technologies, including the newest as well as the tried-and-true approaches.

2. Develop and implement new, clean, renewable energy technologies, including wind power, biomass and solar photovoltaics (PV).

3. Develop and implement efficient natural gas uses in appropriate locations, especially combined heat and power, district energy systems and fuel cells.

4. Retire selected older, less efficient and highly polluting coal plants.

5. Apply sustainable development strategies to aggressively link these environmental improvement policies to economic development. Clean energy development means more green energy jobs for the Midwest.

The building blocks of a blueprint for the Midwest's clean energy future are described briefly in the following sections, and discussed in greater detail in Chapters 4, 5 and 6.

3.1 ENERGY EFFICIENCY

Today, there are many energy efficiency opportunities already available, with more developing every year.[2] Residential customers can purchase efficient lighting, refrigerators, air conditioners, water heaters and clothes washers. Residential building shells can be redesigned or retrofitted to lower heating and cooling demand. Likewise, commercial customers can reduce energy consumption via efficient lighting, cooling, heating, refrigeration, ventilation and office equipment. They can use energy management systems to optimize technology and energy use patterns. Industrial customers can piggyback highly efficient motors and redesigned industrial processes on the above measures for added energy savings.

THE MANY BENEFITS OF ENERGY EFFICIENCY

Energy efficiency is highly cost-effective. Installing and operating efficiency measures costs significantly less per kWh saved than generating, transmitting and distributing electricity – sometimes by a factor of two or three. Some customers know the economic advantages of energy efficiency and adopt improvements on their own. Most energy efficiency opportunities remain untapped, however, due to a variety of market barriers. Strategies to remove these barriers are explained in Chapter 8.

Lower utility bills are not the only benefits of energy efficiency. New end-use technologies and designs can improve indoor environments and comfort levels, strengthen building safety, provide health benefits, reduce water and other resource consumption, and lower building operation and maintenance costs. Energy efficiency programs targeted to low-income customers reduce a variety of social ills and costs including public fuel assistance bills, health costs, fire dangers, kerosene fume hazards, utility terminations, homelessness and other low-income social services (NCLC 1999).

Energy efficiency also benefits electric utilities. Energy efficiency reduces demand for power and improves

[2] The term "energy efficiency" here refers to new technologies, designs, and practices that will reduce energy use without reducing the level of electricity service provided.

the reliability of generating plants and strained transmission and distribution systems. By reducing end-use electricity demand, energy efficiency avoids electricity transmission and distribution losses. For vertically integrated electric utilities, energy efficiency saves generation, transmission and distribution costs, and improves reliability. For distribution-only utilities, energy efficiency can help avoid or mitigate the costs of transmission and distribution system upgrades.

Energy efficiency also benefits the environment. Minimizing electricity generation, transmission and distribution limits environmental damages. Hence, the environmental impacts of coal and nuclear plants – CO_2 emissions, NO_x emissions, SO_2 emissions, nuclear and solid waste generation, land and water use – are contained via energy efficiency. Because efficiency is cost-effective, the resulting environmental gains cost society nothing – a clear "win-win" situation.

Energy efficiency also promotes economic development and can spur job creation in the Midwest. First, energy efficiency creates new jobs in trades related to the design, production and installation of efficiency measures. The Midwest is home to a large share of the nation's energy efficiency manufacturing industry. Osram Sylvania in Lake Zurich, Ill., and GE Lighting in Cleveland, Ohio, manufacture energy-efficient lighting. Honeywell Home and Building Control makes thermostatic controls in Golden Valley, Minn., and Johnson Controls in Milwaukee, Wis., makes energy-efficient motors. Andersen Corporation in Bayport, Minn., and Pella Corporation in Pella, Iowa, both make energy-efficient windows. Maytag manufactures energy-efficient refrigerators in Galesburg, Ill., and washing machines in Newton, Iowa. Trane Company manufactures high efficiency air conditioning systems in La Crosse, Wis.

Second, energy efficiency lowers bills, providing residential customers with extra disposable income for other goods and services, resulting in "respending" effects that promote economic development and create jobs. Commercial and industrial customers will be more competitive, and may pass on their cost savings to customers, thus expanding their market shares (Tellus 1995). Public agencies can use budget savings to meet other responsibilities and hold down taxes. One study estimates that aggressive energy efficiency programs implemented in Illinois, Indiana, Michigan and Ohio between 1995 and 2010 could create as many as 205,000 net jobs by 2010 (ACEEE 1995).

A few electric utilities in Minnesota and Wisconsin have historically tapped into energy efficiency resources through demand-side management (DSM) programs. Most Midwestern utilities' demand-side and energy management efforts have, however, lagged far behind those in other states (ACEEE 2000).

Energy Efficiency Opportunities

Residential and Commercial Sectors

The potential for energy efficiency in the residential and commercial sectors is comprehensively developed in *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond,* prepared by a working group of five national laboratories (Five Labs 1997). That study included an investigation of the costs and performance of energy efficiency technologies available throughout the United States to reduce energy consumption and achieve significant reductions in CO_2 emissions.

In order to estimate the efficiency potential for the Midwest Clean Energy Development Plan, *Repowering the Midwest* applies the Five Labs analysis to the residential and commercial end-uses in each Midwestern state. The savings estimates in the Five Labs study are increased to compensate for efficiency savings from measures that were not included. The Five Labs analysis also is adjusted here to reflect state implementation rates and electricity prices. Midwestern states that have already invested money in utility DSM programs are assumed to have slightly lower implementation rates, while those with less DSM experience are assigned slightly higher implementation rates. Similarly, *Repowering the Midwest* assumes that states with electricity prices above the national average achieve slightly more efficiency savings, and those with below average prices achieve less.

Industrial Sector

The industrial sector end-use efficiency savings are based on the Long-Term Industrial Energy Forecast (LIEF) model, developed at Argonne National Laboratory. This model was used to estimate industrial efficiency in the Five Labs study, as well as several previous studies, including *Energy Innovations* (Energy Innovations 1997) and *America's Global Warming Solutions* (WWF and EF 1999).

The analysis considers industrial energy efficiency technologies that cut across process- or product-specific operations in the industrial sector and include improved motor systems, more efficient heating and cooling technologies, better maintenance, greater process control, and increased feedstock recycling.

The LIEF model was applied to each Midwestern state, using that state's electricity prices, the electric intensity for each sector (based on national data per unit of economic activity), each sector's current economic activity (i.e., contribution to the gross state product), and each sector's forecasted growth in that state.

Summary of Efficiency Potential

The most significant energy efficiency opportunities in the Midwest, by sector, are:

1. In the residential sector, the greatest potential is in more efficient lighting (20 percent of potential residential savings) and water heating (nine percent). For example, compact fluorescent lamps (CFL) produce the same amount of light as conventional incandescent light bulbs, but use only one-quarter as much electricity, and last 12 times longer. Replacing one incandescent bulb in a high-use area with a CFL saves a Chicago-area consumer nearly $50 in electricity costs over the life of the CFL.

2. In the commercial sector, the greatest efficiency potential is in lighting technology (50 percent of potential commercial savings) and space cooling (15 percent). For example, installing modern, energy-efficient lighting ballasts in new commercial buildings or through retrofits of existing buildings produces rapid paybacks and operating cost savings in almost all settings.

3. In the industrial sector, the greatest efficiency opportunities are found in the metals fabrication (28 percent of potential industrial electricity savings), rubber and plastics (13 percent), primary metals (12 percent), and agricultural (11 percent) industry sectors by deploying more efficient industrial motors and drives, more advanced heating, ventilating and cooling (HVAC) techniques, and better lighting technologies.

The major population centers and industrialized areas of the Midwest are the largest electricity load centers and provide the greatest opportunities to reap energy efficiency savings. Of the total efficiency savings in the Clean Energy Development Plan, about 24 percent are available in Ohio, 20 percent in Illinois, 16 percent in Michigan, and 14 percent in Indiana.

Figure 3.1 summarizes the potential efficiency savings for the Midwest, by customer sector. Under the Clean Energy Development Plan, Midwestern electricity consumers could save as much as 17 percent of electricity demand through efficiency measures by 2010, and 28 percent by 2020. Average annual electricity demand would decline slightly from 2000 to 2020, instead of increasing by more than one percent per year under the business-as-usual scenario. By 2020, efficiency savings will avoid the need for 290 TWh of generation – roughly equivalent to the output of 100 coal plants at 500 MW each.

Implementing these energy efficiency measures is highly cost-effective. On average, reaping the energy efficiency opportunities in the Clean Energy Development Plan requires a 2.4¢ per kWh investment. That is significantly less than the cost of generating, transmitting and distributing electricity to consumers. By 2020, the proposed energy efficiency measures save $12.1 billion in power plant and distribution system costs in return for a $6.6 billion investment. The result is $5.5 billion in net benefits or a savings of $1.80 for every $1.00 invested in energy efficiency. That, of course, does not even include the economic and social value of the environmental and public health benefits.

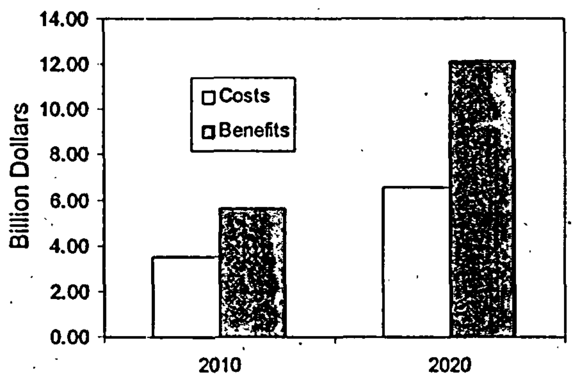
3.2 Renewable Resources

Repowering the Midwest's Clean Energy Development Plan focuses on three particularly valuable renewable energy technologies: wind energy, biomass (plant matter), and solar (photovoltaics). Other renewable

Figure 3.1 Summary of Efficiency Savings in the Clean Energy Development Plan

	2010 Savings (percent)	2010 Savings (TWh)	2020 Savings (percent)	2020 Savings (TWh)
Residential	22.3	61.9	33.8	107.1
Commercial	16.5	39.5	26.4	72.2
Industrial	13.4	48.2	26.8	110.3
Total	**16.6**	**149.6**	**28.1**	**289.7**

FIGURE 3.2 BENEFITS OF EFFICIENCY RESOURCES IN THE CLEAN ENERGY DEVELOPMENT PLAN



resources, including hydropower, geothermal and solar thermal energy, are not included for a variety of reasons.[3]

WIND ENERGY

Wind energy is categorized as either large- or small-scale. Many utilities have favored large-scale wind power plants for bulk power generation. They use wind turbines of several hundred kilowatts capacity each, usually deployed in arrays of a few to several dozen machines tied to the power grid. A small-scale wind installation can consist of a single wind turbine generating up to 10 to 50 kilowatts and is designed to meet the localized needs of a farm or small business. Sales back to the grid are common, especially when net metering rates are available. Our study focuses on large wind plants because they displace the most fossil fuel use at the lowest cost, but small wind installations, as described in Chapter 5, also have a pivotal role in the development of clean energy in the Midwest.

Utility-scale wind generation technology has improved tremendously since the first wind energy boom in the early 1980s. Modern wind plants generate electricity at 3-6 ¢/kWh, depending on plant size, the site's windiness, the availability of incentives such as the federal production tax credit, and other factors. The lower end of this range is comparable to competing fossil-fuel plants such as new coal and natural gas combined cycle facilities. Over the last decade, this has helped make wind energy the fastest growing energy resource in the world. The Midwest has been the nation's leader in wind power growth as Iowa, Minnesota and Wisconsin have installed a total of 500 MW of new wind capacity over the past few years, and they are on their way to 1,000 MW of capacity. For example, about 400 MW of wind power is being developed in the Buffalo Ridge area of southwestern Minnesota (as part of utility commitments for 825 MW), a 112.5 MW wind farm is operating in Alta, Iowa, and a new 30 MW wind power project is planned in Iowa County, Wis. Consistent with industry and government estimates, this study projects continued cost decreases and improvements in wind plant performance from 2000 to 2020, resulting in a levelized cost range in 2020 of 2.8 to 3.7¢/kWh (with no tax credit or other subsidy).

The Midwest is blessed with an abundance of windy land, especially in the Great Plains states of North and South Dakota, Nebraska, Minnesota, and Iowa. There are also other windy areas scattered through Illinois, Indiana, Michigan, Ohio and Wisconsin that offer strong opportunities for distributed wind power development. In principle, many states could generate far more than their current electric demand using wind, earning the region the moniker, "Saudi Arabia of wind energy." Of course, not all of this potential is likely to be developed. Three primary constraints and their implications for wind energy are considered in the Clean Energy Development Plan:

1. Wind plant output is variable as wind speeds rise and fall. Some observers have concluded that wind plants cannot displace conventional plant capacity, but only their fuel use. Many studies have proven the opposite: wind plants have a positive "capacity" value in addition to their "energy" value. Nevertheless, the intermittence of wind energy entails an added cost for the power system, which grows in proportion to wind's share of the system. This cost is accounted for in the study by applying appropriate statistical methods in the PROSYM model used to generate the Clean Energy Development Plan.

2. Sites that are distant from the existing power grid are less attractive for wind development because they require new transmission lines. This affects the site choice and wind development costs. A geographical

[3] (1) Hydropower is a well developed technology that is already widely used in the Midwest. The potential to expand hydropower use in the Midwest is limited; however, because of laws and regulations protecting many rivers from further development. (2) The Midwest lacks high-temperature geothermal resources suitable for power production, although low-temperature resources are useful for efficient heating and cooling of buildings using ground-source heat pumps. (3) Most of the Midwest does not have sufficient direct solar radiation on an annual basis to support solar-thermal power plants operating year-round. Solar thermal devices are effective, however, for heating water and buildings and for low-temperature industrial processes.

information system (GIS) is used to estimate such interconnection costs.

3. Deploying large amounts of wind capacity in the Clean Energy Development Plan will increase loads on both local and long-distance transmission facilities in some areas, particularly in the Great Plains and in the bulk power lines linking those states to points east. This has two implications for wind energy. First, there are added costs if transmission lines are upgraded specifically to carry the increased wind power and provide adequate security in case of line outages. Second, as transmission costs rise, there will be an incentive to locate wind projects closer to major load centers, even if that means placing them at less windy sites. Both effects were accounted for in this study, using a GIS to estimate the cost of line upgrades between wind project sites and load centers.

Wind energy provides substantial environmental and public health benefits because it creates no air pollution, greenhouse gases, or radioactive and other dangerous wastes. Nevertheless, environmental and siting issues deserve careful consideration in wind energy development. By applying responsible siting practices, wind projects can have minimal impacts on wildlife and natural resources. Wind projects in the Great Plains have not produced significant reported bird deaths. Siting issues may become more important, however, particularly in states with higher population densities and more limited wind resources. The absence of such problems in the Midwest to date and the relatively small fraction of land area designated for wind projects resulted in no specific siting constraints on wind development other than to avoid national parks and other federally protected areas.

The Clean Energy Development Plan includes 6,698 MW of new wind turbines in 2010, which is roughly four percent of the total generation capacity in the Midwest. By 2020 the amount of wind turbines increases to 24,510 MW, or roughly 13 percent of generation capacity.

Biomass Energy

There are many biomass resources and conversion technologies, and it was not possible to consider them all in detail for this study. On the resource side, this study focuses on feedstocks with the most promise for future expansion: agricultural residues and energy crops. The most important agricultural residues - because they are produced in abundance in the Midwest and do not degrade quickly in the field - are wheat straw and corn stover. Energy crops, which are not yet commercially produced, would be grown expressly to supply biomass power plants. The most likely cultivar for this purpose is switchgrass, a native of the Great Plains.

Logging residues are also evaluated as a fuel source. The study assumes no increase in logging activity but only better collection of residues currently left in the field and more efficient combustion of those resources. Municipal solid wastes are not included because of their environmental disadvantages. All in all, 49 percent of the Clean Energy Development Plan's biomass growth to its level in 2020 would come from switchgrass, an energy crop, 42 percent from agricultural residues, and nine percent from logging residues. The average delivered price is projected to be $1.90 per million BTU (MBTU).

The Clean Energy Development Plan focuses on two leading near-term options to increase biomass energy production: (1) co-firing with biomass in existing coal plants; and (2) installing efficient combined heat and power (CHP) systems at large industrial facilities, especially pulp and paper mills. Co-firing has the benefit of directly reducing coal use and its associated CO_2 and other pollutant emissions. Wood and wood waste co-firing with coal has been practiced at a number of U.S. plants, including several Midwestern facilities such as XCel Energy's (formerly Northern States Power) Allen S. King facility. Co-firing agricultural residue and plant species like switchgrass is now being tested at a plant in Iowa. There is additional experience in Denmark and other countries. No fundamental technical obstacles appear to prevent co-firing at Midwestern coal plants.

This study assumes that only coal plants built since 1970 would be candidates for co-firing. This excludes many of the more polluting and less efficient plants, which also tend to run less often. This study further assumes that appropriate policies, such as a renewable portfolio standard, would lead to co-firing displacing 10 percent of the coal use at these plants. Federal studies indicate that co-firing rates of up to 15 percent at individual plants are technically feasible. The overall cost would be low – lower, in fact, than any other renewable resource option available on this scale except CHP. Based on DOE and private research, the estimated average cost of plant conversion is $200 per kilowatt of biomass capacity, with a modest increase in operating costs. The resulting levelized cost of energy, at $1.9/MBTU, is just 2.5¢/kWh.

Combined heat and power offers similar costs and benefits. Virtually all sizable pulp and paper mills in the Midwest already use their mill residues for energy, but most use relatively inefficient steam- or heat-only boilers. With modern CHP equipment, biomass can be converted to steam, heat and electric power at nearly 90 percent efficiency. The Clean Energy Development Plan assumes that all pulp and paper mills that currently convert their wastes will adopt new equipment by 2020, substantially increasing power generation. Wastes probably won't supply all of the mills' fuel demand; thus fuels will have to be purchased on the market. Nevertheless, the levelized cost of electricity remains a very attractive 2.3¢/kWh.

Eventually, dedicated biomass-fueled power plants will develop. One promising option is biomass gasification combined-cycle generation. Although this technology is relatively expensive, its cost will likely decrease over time through technological improvements and economies of scale. The Clean Energy Development Plan deploys limited amounts of such capacity to encourage gasification's development. These deployments would be supported by targeted subsidies or research and development programs.

The potential adverse environmental impacts of using biomass must be carefully considered. For example, this study restricts projections for logging and agricultural residue removal in order to protect soil quality. No increase in logging activity is envisioned. Energy crops are limited to perennial species that minimize erosion such as switchgrass. In fact, switchgrass is widely used as a cover crop for lands enrolled in the Conservation Reserve Program. The same strict pollutant emissions limits were assumed for co-fired power plants, CHP, and dedicated biomass plants as were applied to conventional power plants. Sustainably produced biomass provides significant environmental advantages because it generates no net CO_2; in some cases, however, the assumptions that assure sustainability may require specific regulations to ensure compliance.

The Clean Energy Development Plan includes 2,949 MW of new biomass-fueled CHP and 1,850 MW of biomass co-firing in 2010. By 2020 these amounts increase to 6,003 MW for biomass-fueled CHP and 4,807 MW for biomass co-firing.

SOLAR PHOTOVOLTAICS

Solar photovoltaic panels convert sunlight directly into electricity using semiconductor materials. They can be built in sizes and placed in arrays ranging from watts to megawatts. Their remarkable simplicity and flexibility makes them suitable for a wide variety of applications, including central-station power plants, substation power plants for distribution support, grid-connected systems for home or business use, and off-grid systems for remote power use.

Repowering the Midwest focuses on grid-connected PV systems because they offer the most long-term potential for displacing fossil-fuel use. Early applications are likely to be of intermediate size (10-100 kW) and designed to enhance the distribution grid. Later, rooftop commercial and residential systems could become common. Off-grid applications are the most important near-term market for PV systems, however, and should be a policy priority to stimulate the PV industry's growth.

The amount of sunlight available to generate electricity varies by season, time of day and location. The wide-open spaces of Nebraska and the Dakotas have solar power resources comparable to parts of northern California and east Texas. Shading from buildings and trees, natural obstacles, and other variables affects local energy-producing potential. Although the Midwest is not usually considered an especially sunny region, solar power can provide economically valuable electricity because of the strong coincidence between its greatest availability on sunny summer days and the timing of peak power demands for air conditioning.

The cost of solar photovoltaics is now significantly higher than most other electricity generation, but rapid technological improvements and increased production leading to lower per unit costs are likely to make solar more cost-competitive in the future. At present, there are three markets in which solar photovoltaics are becoming economically viable. First, as mentioned above, the recent history of soaring summer peak energy price spikes makes solar a potentially attractive energy source during high energy use times on sunny days. Second, solar photovoltaics are cost-effective generation for particular off-grid uses, such as remote residences in rural areas that are far from power lines and hard-to-reach cellular relay towers. Third, solar photovoltaics may be useful and cost-effective distributed resources in specific locations that need grid support or would otherwise require costly upgrades to the existing transmission and distribution system. Moreover, solar photovoltaics may be a desired energy source for those businesses and residences preferring to buy "green power."

This study assumes costs and performance typical of fixed, flat-plate PV systems. The current cost of $5,416/kW (37¢/kWh with a capacity factor of 23 percent) for large installations is projected to decrease to $2,877/kW (20¢/kWh) by 2010 and $2,275/kW (15 ¢/kWh) by 2020.

The projected costs remain too high for wide-scale grid-connected applications of PV; however, the Clean Energy Development Plan envisions targeted policies that would lead to deployment of 482 MW of cost-effective PV in specific locations by 2020.

3.3 Efficient Generation Technologies

Natural gas will play a key role in any future electric industry scenario. But, depending on natural gas carries the risk of rapid fuel price increases and fuel shortages. Plus, natural gas generation produces CO_2 emissions that exacerbate climate change. Natural gas should be viewed as a transitional fuel to a more sustainable energy future, rather than a long-term solution. Therefore, it is essential to use natural gas as efficiently as possible. Moreover, community environmental values must be respected in determining where to site these large power plants. The Clean Energy Development Plan includes three highly-efficient technology types that use natural gas: fuel cells, combined heat and power, and district energy systems.

Fuel Cells

Fuel cells combine hydrogen (from the fuel source) and oxygen (from the air) in the presence of a catalyst to generate electricity, heat and water. As a modular, combustion-free power technology, fuel cells hold great promise for the future. Over the next two decades, they can be used in cars, basements, and central utility generating stations, replacing engines, boilers, and turbines, and producing almost no noise or pollution. Over the longer term, fuel cell technology could be an essential ingredient in a major transition to a hydrogen-based renewable energy economy.

Less than 30 MW of fuel cells are currently installed nationwide, but with recent major breakthroughs, and more pending, research budgets are skyrocketing. Today, the phosphoric acid fuel cell (PAFC) is commercially available at roughly $3,000/kW, but costs continue to drop for all fuel cell technologies. Proton exchange membrane technologies could, if mass-produced, reach levels as low as $200/kW once the technology matures.

The other major challenge with fuel cells is the hydrogen supply. Although solar and wind systems are the ultimate hydrogen sources (achieved by converting intermittent electricity into a dispatchable hydrogen resource through electrolysis of water), fossil fuels may be the only affordable hydrogen sources in the near-term.[4]

Fuel cells are expected to be relatively expensive throughout our study period; however, a small number of fuel cells are likely to be developed in markets where uninterruptible power supply is especially valuable, and as an outgrowth of public policies. The policy drivers could be technology learning, market development, local pollution reduction, and improved reliability.

Combined Heat and Power

Combined heat and power (CHP) combines a conventional heat-producing industrial boiler or furnace with a turbine to co-generate electricity. This dual-production process harnesses waste heat and can generate electricity at incremental efficiencies as high as 80 percent. CHP is a well-understood technology with a long history. Ongoing technological advances give it great potential for energy savings and economic benefits in industrial and community energy systems.

New, efficient gas turbine technologies, in a range of sizes for a variety of manufacturing, thermal and electricity needs, have increased the opportunities for industrial CHP at reduced costs. In conjunction with advanced combustion turbines – or in the future with fuel cells – very high efficiencies, plus low air emissions, are possible.

Estimates of CHP additions for the Clean Energy Development Plan are based on national analyses in *America's Global Warming Solutions* (WWF and EF 1999). National process steam load and energy projections in the manufacturing industries were adjusted to reflect each state's mix of industries and their energy use. This analysis assumes that the electric capacity, generation and fuel inputs in the industrial CHP are incremental to meeting the thermal demands, and that there is no fuel switching. The study also assumes that natural gas is used in the displaced boilers and that additional natural gas is used to produce the same thermal output plus electricity in the CHP facilities. The net effects are incremental electricity output, natural gas input, emissions, and capital and operating costs – all of which occur on site. There is a corresponding drop in electricity, fuel inputs, emissions and costs from central station power plants.

4 Most hydrogen today is produced from natural gas using well-established conventional chemical processes, at a conversion efficiency of roughly 70 percent. Another renewable option is to produce hydrogen from biomass, using an analogous process, but costs are likely to be much higher in the near term.

District Energy Systems

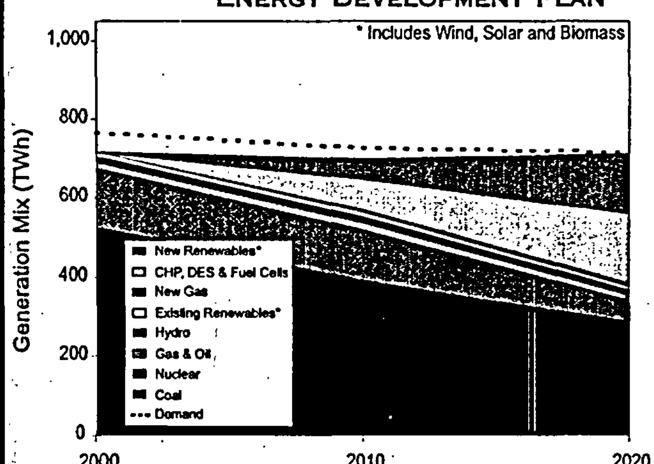
District energy systems provide thermal energy via steam or hot water pipelines to multiple customers within a specific geographic area for space heating, water heating, cooling or industrial processes. The district may be as small as several adjacent buildings within a commercial or industrial complex, or as large as a whole city. Frequently, district energy systems co-generate electric power along with thermal energy, for use by district energy customers or for sale to a local electric utility.

During the first half of the 20th century, citywide district heating systems were common in many northern U.S. cities. Citywide DES are still common in several European countries, including Denmark, Finland and the Netherlands. With the proper incentives, DES could see a major resurgence in this country. Today, low-emitting natural gas combined cycle plants can be sited in even the smoggiest of urban areas. DES have great potential to reduce energy costs and pollutant emissions by replacing building boiler systems and central station electricity with co-generated heat and power.

Average construction costs for district energy systems are about one-third above those for conventional heating and cooling technologies (DOE 1999). Significant fuel savings over the project's lifetime can offset the higher initial capital costs. In order to guarantee eventual capital recovery, however, DES developers must procure long-term contracts from potential district heating or cooling customers and/or power sales agreements with local utilities.

The DES potential in the Clean Energy Development Plan is based on assumptions and estimates in *America's Global Warming Solutions* (WWF and EF 1999). That study indicates that 45.2 TWh of DES could be installed in the 10 Midwestern states by 2010. *Repowering the Midwest* assumes that this amount of DES will be installed in the region by 2020 – a conservative estimate. DES replace building level commercial gas boilers and the resulting electricity is generated with a marginal efficiency of 73 percent – far higher than typical existing or new power plants.

Figure 3.3 Portfolio of Electricity Generation Sources: Clean Energy Development Plan



3.4 The Clean Energy Development Plan for the Midwest

Overview

The Clean Energy Development Plan presents an electric industry with much more diverse, sustainable and environmentally friendly practices than the business-as-usual forecast. The plan proposes developing underutilized energy efficiency measures and largely untapped homegrown renewable energy resources to form a cleaner, more reliable and more diverse electricity portfolio for the Midwest that can spur job creation in this emerging economic sector. These new clean power options displace substantial coal plant generation and reduce the need for new gas power plants. Appendix 3 discusses the methods and assumptions in the Clean Energy Development Plan model.

Figure 3.3 describes this preferable Midwestern electricity portfolio by 2020 under the Clean Energy Development Plan, which features the following changes from the business-as-usual scenario:

1. Energy efficiency measures reduce electricity generation from power plants in the Clean Energy Development Plan. Instead of growing steadily at 1.0 to 1.3 percent per year in the business-as-usual case, electricity demand declines slightly after 2000.

2. Coal generation declines significantly as renewable energy resources with increasingly lower operating costs generate more power in the Midwest.

3. Nuclear generation declines to the same extent as under the business-as-usual scenario, as the nuclear plants in the Midwest retire, on average, at their scheduled license termination dates. Some nuclear plants may operate longer by obtaining license extensions, while others may shut down earlier.

4. New, efficient natural gas plants provide 10 percent of generation in 2010 and 25 percent of generation in 2020.

FIGURE 3.4 ANNUAL SO_2 AND NO_X EMISSIONS (MILLION TONS)

	2000	2010	2020
SO_2: business-as-usual case	3,409	3,550	3,771
SO_2: Clean Case	3,409	2,350	1,670
NO_X: business-as-usual case	1,555	794	924
NO_X: Clean Case	1,555	395	271

5. Fewer new conventional natural gas plants are needed than under the business-as-usual scenario because less capacity is needed to meet demand.

6. Renewable energy resources – wind power, biomass and solar photovoltaics – supply roughly eight percent of generation by 2010 and 22 percent by 2020.

ENVIRONMENTAL IMPROVEMENTS

The Clean Energy Development Plan cuts SO_2 and NO_X emissions, as shown in Figure 3.4. In the business-as-usual scenario, SO_2 emissions increase slightly by 2020 from increased coal capacity, while NO_X emissions decline significantly in 2010, as states comply with the U.S. EPA regulations. Emissions rise thereafter. In the Clean Energy Development Plan, both SO_2 and NO_X emissions are far less, due to lower load growth and the increased use of renewables. Decreasing SO_2 emissions reduces acid rain falling on the Great Lakes and the inland lakes and forests of the upper Midwest, while the reduced NO_x emissions will decrease smog and its associated public health impacts.

SO_2 emissions are currently covered by a cap-and-trade system under the Clean Air Act, and NO_X emissions in the eastern Midwestern states also are likely to be covered by a cap-and-trade system. When Midwestern coal plants reduce emissions of these pollutants, they may be able to sell the allowances to power plant owners in other states or regions. Consequently, the regional or national emissions of SO_2 and NO_X will not be reduced as much as implied by Figure 3.4. Nonetheless, Midwesterners will benefit from reduced SO_2 and NO_X pollution, because cleaner air means fewer local health and environmental problems.

Over time, the Clean Energy Development Plan also yields dramatic CO_2 emission cuts, thereby mitigating the harmful effects of global warming. By 2020, emissions are half the level as under business-as-usual practices, and 36 percent lower than emissions in 2000. As shown in Figure 3.5, the Clean Energy Development Plan puts the Midwest electric industry on target to exceed the goals of the Kyoto Protocol in 2010 and would produce significant CO_2 emission reductions in later years.

RELIABILITY IMPROVEMENTS

The more diversified electricity portfolio in the Clean Energy Development Plan will improve electricity reliability throughout the Midwest. Today, the Midwest relies almost entirely on older coal and nuclear plants to supply electric power needs. In contrast, the Clean Energy Development Plan deploys a mix of energy efficiency, renewable energy and natural gas resources, along with the coal and nuclear plants. Energy efficiency reduces demand and improves the reliability of generating plants and strained transmission and distribution systems. Adding substantial renewable resources, along with natural gas plants, makes the region less vulnerable to dramatic changes in coal supply and to nuclear plant risks.

COSTS

This cleaner, more efficient energy future is achieved with only a modest increase in electricity costs. Implementing energy efficiency measures costs far less than conventional power sources, thereby offsetting any increased marginal costs associated with renewables. The Clean Energy Development Plan is projected to increase total electricity costs by \$765 million in 2010 – which represents a 1.5 percent increase across the Midwest on average. By 2020 the Clean Energy Development Plan will increase total electricity costs by \$1,780 million – a 3.4 percent increase. The actual impact

FIGURE 3.5 CO_2 POLLUTION REDUCTION FROM THE CLEAN ENERGY DEVELOPMENT PLAN

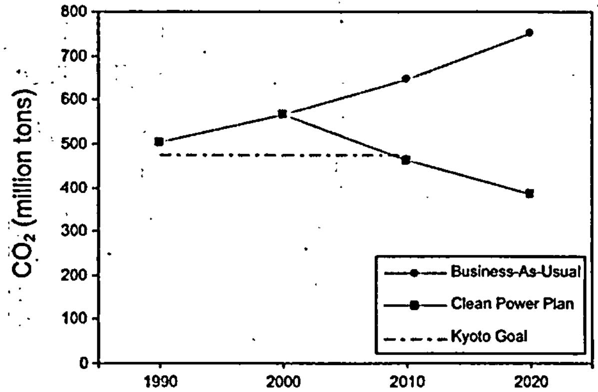
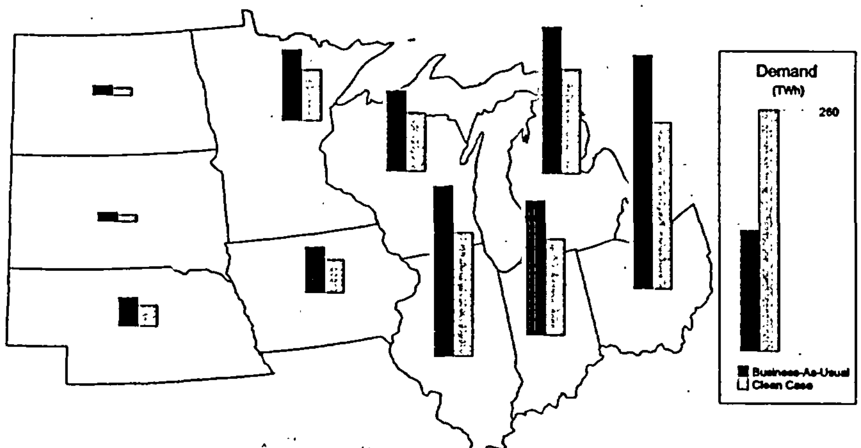


FIGURE 3.6 2020 ENERGY DEMAND BY STATE: BUSINESS-AS-USUAL CASE COMPARED TO THE CLEAN ENERGY DEVELOPMENT PLAN



on a customer's electricity bill will depend upon the extent to which the customer adopts energy efficiency measures, as well as future regulatory policy and market behavior regarding electricity rates and prices.

These cost estimates do not account for the federal production tax credit (PTC) for wind and biomass, and thus may overstate the costs incurred by renewable generators. Although the PTC is scheduled to expire at the end of 2001, there is broad bipartisan federal support to extend it to at least July 1, 2004, and to expand it to include additional biomass resources, biomass co-firing and residential solar technologies. If the PTC is extended through 2010, it would reduce the cost of the Clean Energy Development Plan by $433 million in 2010. If the tax credits are extended through 2020, the cost of the Clean Energy Development Plan would be reduced by $1,634 million in 2020. Extending these tax credits should be a priority for the Midwest's congressional delegation.

3.5 STATE-BY-STATE BENEFITS ACHIEVED BY THE CLEAN ENERGY DEVELOPMENT PLAN

The study's electricity system model includes three National Electric Reliability Council (NERC) regions, containing all 10 Midwestern states plus all or parts of Kentucky, Missouri, Pennsylvania and West Virginia. State-by-state modeling requires two steps: (1) subtracting the electricity load and electricity generation of the four states outside of the Midwest; and (2) allocating the electricity load and generation of the remaining region to the 10 Midwestern states.

Electricity generation, as well as associated costs and emissions, is allocated to states based on the physical location of power plants. Thus, a plant's generation and impacts are assigned to the state where it is sited, even if its output crosses state boundaries. Electricity demand is allocated based on each state's historic fraction of demand in the NERC regions and utility transmission areas.

FIGURE 3.7 NEW CLEAN POWER CAPACITY ADDITIONS BY STATE IN 2020

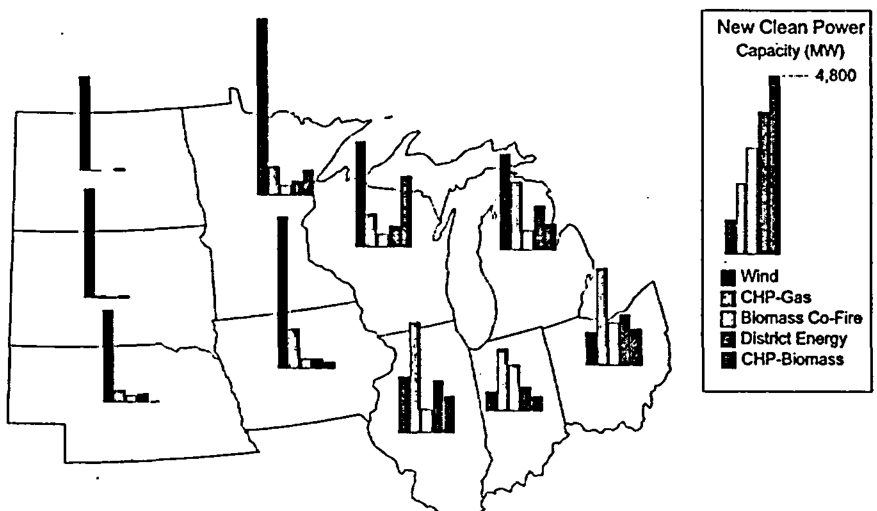
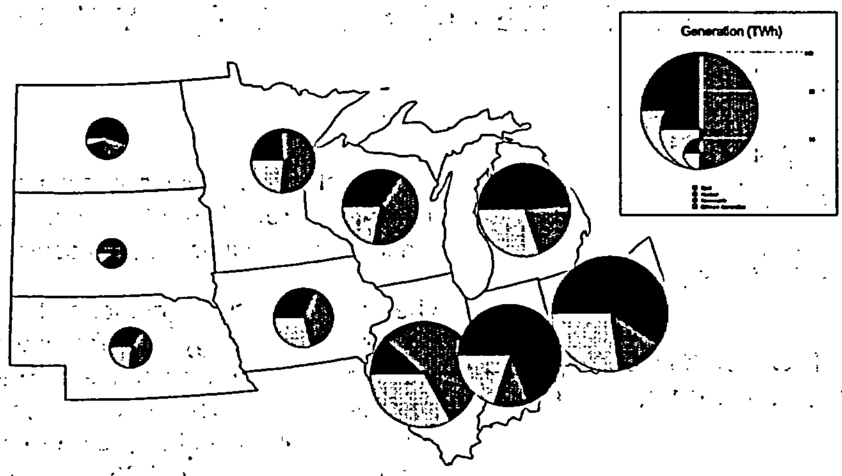


FIGURE 3.8 GENERATION FUEL MIX BY STATE IN 2020: CLEAN ENERGY DEVELOPMENT PLAN



It is noteworthy that most states show a difference between electricity demand and electricity generation. Some states will be net exporters, where electricity generation exceeds demand; others will be net importers. This section provides an overview of the modeling results for the different states. More detailed state-by-state results are described in Appendix 1.

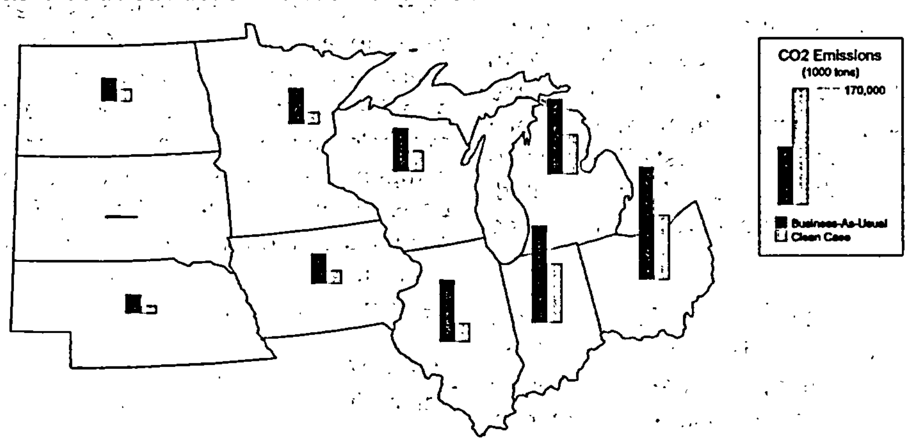
Figure 3.6 shows electricity efficiency savings per state by 2020, as a result of comparing the business-as-usual demand to the Clean Energy Development Plan demand. The total amount of saved energy (in TWh) is greater for states with more electricity demand. Hence, electricity savings are largest for eastern states, and lowest for western states.

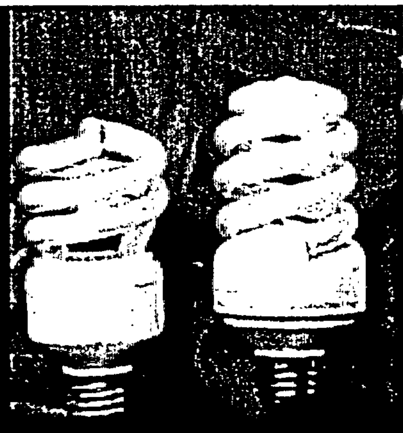
Figure 3.7 summarizes new clean power capacity additions by state in 2020. The western states show the highest amount of new wind installations, because of greater resource availability. Ohio, Illinois, Indiana and Michigan have higher amounts of CHP because of their concentration of industrial facilities. These states also have more biomass co-firing than other states in the region because of their higher numbers of existing coal plants.

Figure 3.8 illustrates electricity generation under the Clean Energy Development Plan by fuel type for 2020. This figure is comparable to Figure 2.2, which shows generation by fuel type for the year 2000. In the Clean Energy Development Plan far more electricity is generated by renewable resources. In Minnesota, South Dakota and Nebraska, most electricity is generated by renewable resources and efficient gas generation by 2020.

Figure 3.9 summarizes CO_2 emissions in 2020, comparing the business-as-usual scenario and the Clean Energy Development Plan. Most CO_2 emissions are produced in the eastern states. Accordingly, most of the gross CO_2 emission cuts are for eastern states. Minnesota obtains large CO_2 reductions as a byproduct of its wind power installations.

FIGURE 3.9 CO_2 EMISSIONS IN 2020: BUSINESS-AS-USUAL COMPARED TO THE CLEAN ENERGY DEVELOPMENT PLAN





4. The Potential for Energy Efficiency in the Midwest

4.1 Efficiency Potential in the Residential and Commercial Sectors

The estimate of the potential for energy efficiency in the Midwest is based primarily on the study entitled *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond,* prepared by a working group of five national laboratories (Five Labs 1997). That study included an investigation of the costs and performance of energy efficiency technologies available to reduce energy consumption and achieve significant reductions in CO_2 emissions.

The Five Labs study relies upon the EIA's 1997 AEO for a forecast of energy under a "business-as-usual," or reference, scenario. It then identifies the efficiency savings that are technically achievable and cost-effective, relative to this reference scenario. The AEO reference scenario forecast used in the Five Labs study includes reductions in electricity demand due to naturally occurring efficiency improvements, as well as efficiency standards, building codes and utility DSM programs.

The Five Labs study identifies hundreds of technically and commercially available efficiency measures that can be installed when existing electricity end-use measures naturally reach the end of their useful lives. Efficiency measures also include technologies, designs and practices that can be applied when buildings are renovated or new buildings are constructed. The study assumes that at times of stock turnover or building renovation the most efficient cost-effective measures available in 1997 are installed, instead of measures that represent the typical practice in 1997 (Five Labs 1997).

The Five Labs study estimates the cost of saved energy for each efficiency measure, by dividing the annualized incremental cost of the efficiency measure by the lifetime energy savings of the efficiency measure. The potential for cost-effective savings is estimated by ranking the measures from lowest to highest cost, and then eliminating the highest-cost measures (Five Labs 1997).

The Five Labs study goes one step further to identify the amount of energy efficiency savings achievable in practice. The study assumes two levels of efficiency savings could be achieved, as a consequence of two different levels of public policy support. The "Efficiency Scenario" assumes that 35 percent of the technically achievable, cost-effective measures are implemented, through a moderately vigorous effort to reduce energy use and carbon emissions. The "High Efficiency/Low Carbon Scenario" assumes that 65 percent of the technically achievable, cost-effective measures are implemented, through a vigorous effort to reduce energy use and carbon emissions.

This study applies the results of the Five Labs analysis to each Midwestern state by first identifying the demand of each relevant electricity end-use for residential and commercial customers and then using the energy efficiency savings potential associated with each end-use from the Five Labs study. These residential and commercial end-uses and the percentage of their respective loads that can be reduced through efficiency (efficiency savings potential) are listed in Figures 4.1 and 4.2.

The Five Labs study does not account for certain currently available cost-effective efficiency measures, such as duct sealing, commercial office equipment, commercial building shell measures, ground source heat pumps, and advanced heat exchangers. In addition, the study does not account for any new measures that have become available since 1997 or that will become available over the next 20 years. The Five Labs study also does not account for substantial efficiency savings available from retrofitting existing end-uses. In order to compensate for these opportunities missed by the Five Labs study, the Clean Energy Development Plan assumes that, on average, 85 percent of the efficiency measures are implemented by 2010, instead of the 65 percent assumed in that study.

Not all Midwestern states are assumed to achieve the same efficiency savings (in terms of the percent of load

FIGURE 4.1 EFFICIENCY SAVINGS AND COSTS FOR RESIDENTIAL END-USES (2010)

End-Use Type	Efficiency Savings Potential (percent)	Cost of Saved Energy (¢/kWh)
Space Heating	10	4.3
Space Cooling	14	4.3
Water Heating	29	4.1
Refrigeration	13	4.3
Lighting	51	3.7
Other	30	4.5

Notes: The "Other" category includes: cooking, clothes drying, freezing and miscellaneous uses. Cost of saved energy is in 1999 dollars.

that can be reduced through efficiency). Those Midwestern states that have invested more money in utility DSM programs in the past are assumed to have slightly lower efficiency savings, while those with less DSM experience are assumed to have slightly higher savings. Similarly, states with electricity prices that are higher than the national average are assumed to achieve slightly more efficiency savings, while those with lower than average prices are assumed to achieve fewer savings. Most Midwestern states have lower than average electricity prices.

The Five Labs study provides little guidance regarding the potential for efficiency savings in 2020. While it contains a description of the many measures and designs that are expected to produce substantial efficiency savings by 2020, it does not provide quantitative estimates. The Clean Energy Development Plan assumes that advancements in efficiency savings potential will continue after 2010, but that the increase in efficiency savings potential (relative to a business-as-usual scenario) will slow down as efficiency measures become more frequently used in common practice. Consequently, this study assumes that the efficiency savings potentials presented in Figures 4.1 and 4.2 will increase by 60 percent by 2020.

The estimated costs of saved energy also are presented in Figures 4.1 and 4.2. These are based on the saved energy costs in the Five Labs study, increased by 20 percent to represent the implementation costs that may be necessary to achieve the higher adoption rates we assume. Commercial lighting measures are assumed to have negative costs (i.e., net savings) due to reduced labor costs associated with less frequent lightbulb replacement. The Five Labs study does not estimate saved energy costs in 2020, so this study assumes that they remain unchanged from 2010, in real terms.

For the residential sector, the greatest efficiency savings can be found in more efficient lighting and

FIGURE 4.2 EFFICIENCY SAVINGS AND COSTS FOR COMMERCIAL END-USES (2010)

End-Use Type	Efficiency Savings Potential (percent)	Cost of Saved Energy (¢/kWh)
Space Heating	25	0.5
Space Cooling	27	0.5
Ventilation	26	0.5
Water Heating	7	4.1
Lighting	21	-3.1
Cooking	0	4.5
Refrigeration	25	2.0
Office Equipment	0	4.5
Other	33	4.5

Notes: The "Other" category includes: ventilation, transformers, traffic lights, exit signs, telecommunications equipment, medical equipment, and miscellaneous uses. Cost of saved energy is in 1999 dollars.

water heating. For example, compact fluorescent lamps (CFL) produce the same amount of light as conventional incandescent light bulbs, but use only one-quarter as much electricity, and last 12 times longer. Replacing one incandescent bulb in a high use area with a CFL saves a Chicago-area consumer almost $50 in electricity costs over the life of the CFL.

The greatest efficiency potential for the commercial sector is found in lighting technology and space cooling. For example, installing modern, energy-efficient lighting ballasts in new commercial buildings or through retrofits of existing buildings produces rapid paybacks and operating cost savings in almost all settings.

4.2 Efficiency Potential in the Industrial Sector

The calculation of the industrial sector end-use efficiency savings relies on the Long-Term Industrial Energy Forecast model developed at Argonne National Laboratory. This model was used to estimate industrial efficiency in the Five Labs study, as well as several previous studies, including *Energy Innovations* and *America's Global Warming Solutions.*

The LIEF model is based on fits to historic data on industrial energy investments and use, using a variety of parameters, including energy prices, hurdle discount rates (which reflect the cost of money, capital constraints and various market barriers) and capital recovery period (together reflected in capital recovery factors), and the implementation rate for efficiency measures. These fits result in a different relationship (e.g., elasticity) between these factors for both electricity and fossil fuel use for each industry analyzed. The industry specification broadly follows the 2-digit standard industrial classification (SIC), but departs somewhat by groupings into energy-intensive, fast growing and general manufacturing. These are then re-aggregated to the usual SIC groupings and the totals summed up for each state.

The Clean Energy Development Plan analysis included a range of efficiency technologies that cut across process- or product-specific operations in the industrial sector, including improved motor systems, more efficient heating and cooling technologies, better maintenance, greater process control, and increased feedstock recycling.

The LIEF model was applied to each state in the region, using that state's electricity prices, the electric intensity for each sector (based on national data per unit of economic activity), each sector's current economic activity (i.e., contribution to the gross state product), and each sector's forecasted growth in the state. The hurdle discount rate of 27.8 percent was used in the business-as-usual case projections for each state's industrial sector electricity demand. This hurdle rate was also used to benchmark the national industrial electricity demand to the AEO 1999 projection. This method resulted in a region-wide projection in agreement with AEO projections for the region.

To estimate the potential for electricity efficiency improvements, the industrial customer hurdle discount

Figure 4.3 Efficiency Savings and Costs for Industrial End-Uses

	2010 Efficiency Savings (percent)	2010 Cost of Saved Energy (¢/kWh)	2020 Efficiency Savings (percent)	2020 Cost of Saved Energy (¢/kWh)
Illinois	12	2.4	26	2.1
Indiana	13	1.8	25	1.6
Iowa	15	1.8	28	1.6
Michigan	14	2.3	29	2.1
Minnesota	14	2.1	28	1.9
Nebraska	16	1.7	30	1.5
North Dakota	17	2.0	32	1.8
Ohio	13	2.0	26	1.8
South Dakota	17	2.1	32	1.8
Wisconsin	14	1.8	27	1.6
Midwest Region	14	—	27	—

Note: Cost of saved energy is in 1999 dollars.

rate is reduced to 12.3 percent. The reduced hurdle rate represents reduced market barriers, fewer capital constraints and reduced transaction costs as a consequence of aggressive policies to promote energy efficiency. These policies are described in Chapter 8. The LIEF model is neutral on the policy mechanisms used to achieve these savings.

The results are given in Figure 4.3. The table shows, for each state, the percentage savings in industrial electricity use in 2010 and 2020 from additional energy efficiency beyond that in the business-as-usual case, along with the costs of saved energy in that year. For each year, the energy savings are from additional investments in more efficient equipment made between 2001 and that year, and the cost of saved energy represents the annualized cost in that year for those additional equipment purchases.

Because some of the model's parameters are based on national averages for various industries, the results of this model may overcount the savings available in some states, while undercounting others. Yet regionwide, the results for 2010 are comparable with the Five Labs study projections for that year.

There is significant potential for cost-effective electric savings across all industrial sectors, by deploying more efficient industrial motors and drives; more advanced heating, ventilating and cooling; and better lighting technologies. The highest potential reduction in electricity usage is in the metals fabrication industry, with 28 percent of the total industrial electricity savings in the region. This is followed by rubber and plastics (at 13 percent), primary metals (at 12 percent), and agricultural industries (at 11 percent). These savings are shown in Figure 4.4.

The state with the largest absolute savings in industrial energy usage was Ohio, which represents about one-quarter of the region's total industrial electric savings in 2020. The metals fabrication industry led in Ohio, representing nearly one-third of the energy saved in that state's industrial sector. The two states with the highest percentage of industrial electricity saved, however, were the Dakotas, which are each capable of cost-effectively reducing their industrial electric demand by almost one-third. The total electric savings in 2020 in North and South Dakota were highest in their agricultural sectors.

FIGURE 4.4 EFFICIENCY SAVINGS IN MIDWESTERN INDUSTRIAL SECTORS

Industrial Sector:	Percent Reduction 2010	Percent Reduction 2020
Agriculture	17.1	33.3
Mining	16.5	31.8
Construction	17.2	33.7
Food	14.8	28.3
Paper	6.8	12.8
Chemicals	6.8	12.9
Petroleum Refining	6.8	12.9
Rubber & Plastics	25.0	46.4
Stone, Glass, Clay	5.7	11.0
Primary Metals	8.7	17.0
Metals Fabrication	17.7	33.8
Other Mfg.	17.2	33.2
Total Reduction	13.4	26.8

4.3 SUMMARY OF ENERGY EFFICIENCY POTENTIAL

Figure 4.5 summarizes the efficiency savings available for the Clean Energy Development Plan by customer type. In total, implementing new, as well as tried-and-true, energy efficiency measures can reduce electricity demand by nearly 17 percent by 2010 and roughly 28 percent by 2020. These efficiency savings will result in the average annual electricity load declining by roughly 0.5 percent from 2000 to 2020, instead of increasing by roughly 1.0 to 1.3 percent.

FIGURE 4.5 SUMMARY OF EFFICIENCY SAVINGS IN THE CLEAN ENERGY DEVELOPMENT PLAN

	2010 Savings (percent)	2010 Savings (TWh)	2020 Savings (percent)	2020 Savings (TWh)
Residential	22.3	61.9	33.8	107.1
Commercial	16.5	39.5	26.4	72.2
Industrial	13.4	48.2	26.8	110.3
Total	16.6	149.6	28.1	289.7

By 2020 the efficiency savings in the Clean Energy Development Plan could reduce electricity demand by almost 290 TWh. This amount of energy is roughly equivalent to the output of 100 coal plants at 500 MW each.

4.4 Case Studies of Energy Efficiency in the Midwest

Minneapolis Public Housing Authority

The Minneapolis Public Housing Authority (MPHA) operates 4,856 apartments in 40 high-rise buildings located throughout Minneapolis. All of these buildings were constructed between 1958 and 1974, when little or no consideration was given to achieving low levels of energy and water consumption. As the buildings aged, frequent failures in the mechanical, electrical and plumbing systems caused high maintenance costs and increased resident discomfort.

In 1994, the MPHA began taking advantage of the U.S. Department of Housing and Urban Development's (HUD) Energy Savings Contracting Opportunities program. This is a shared savings program, where an energy services contractor guarantees annual savings on utility bills that, at a minimum, equal the cost of the efficiency improvements. The savings due to lower utility bills are shared between the housing authority and the contractor.

The financing for the MPHA efficiency improvements was achieved through a $3.2 million bond sale and a $2.8 million lease agreement. A frozen baseline of energy consumption was developed for a 10-year financing period. Utility bill savings relative to this baseline are guaranteed by the contractor, and are used to pay the debt service from the bond sale and lease agreement. In addition, MPHA (80 percent) and the contractor (20 percent) share any savings in excess of those guaranteed by the contractor.

Efficiency measures were applied to both the high-rise apartment buildings and the agency's staff office buildings. The contractor targeted electricity, natural gas, water and sewer systems. The electricity savings were achieved by installing energy efficient lighting in all common areas, installing variable frequency drives on ventilation fans and pump motors, and installing constant air regulators. The latter two measures allow for optimal usage of, and reduced demand on, boilers and furnaces, resulting in gas and electricity savings. An energy management system (EMS) also was installed to monitor equipment remotely, allowing staff to not only control the equipment but also to diagnose and anticipate problems.

The total project cost was $5 million, and the guaranteed utility savings were set at $5.4 million over the 10-year financing period. The contractor originally projected that actual savings would exceed these guaranteed savings by roughly $1.1 million dollars. Experience with the first years of the program indicates that actual savings will be much greater, and are expected to exceed the guaranteed savings by roughly $3.7 million. This means that the overall benefit-cost ratio for the project is 1.82. Other benefits of the project cited by the MPHA include improved resident comfort levels, improved ability to respond to resident complaints due to the EMS, reduced maintenance costs, freed-up funds to be used for other housing improvements, and environmental benefits.

The MPHA is so pleased with the success of the project that it has begun a second phase, using a similar financing approach. This will include roof top fans, super-efficient refrigerators, and additional improvements to the heating, ventilation and air conditioning system. The MPHA is also considering a third phase, with additional efficiency measures to be installed in the future (MPHA 2000; MPHA 1999).

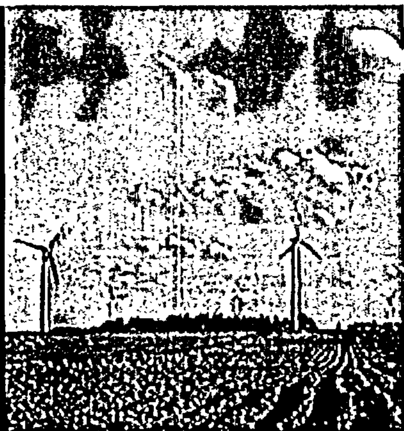
Fifth Third Center Tower, Cincinnati

Fifth Third Center Tower is a 32-story office building in downtown Cincinnati, with a five-story attached building. One of the principal owners of the building, Fifth Third Bank, is also one of its largest occupants. Hence, the owners have a financial stake in improving the efficiency of the building in order to reduce energy bills. The owners invested their own money to achieve the efficiency upgrades, based on the expectation of lower operating costs in the future.

The project has included the following efficiency improvements:

1. A computerized Energy Management System (EMS) was installed to optimize energy consumption patterns.
2. The heating, ventilation and air conditioning system was upgraded. The former constant-volume reheat system was replaced with an efficient variable air-volume system controlled by the EMS. The EMS allows single floors to be isolated for after-hours heating and cooling, if necessary.
3. Efficient T-8 fluorescent light bulbs and electronic ballasts were installed and connected to the EMS to provide zone control on various floors. High pressure sodium lamps were installed on the loading dock and parking garage. Exit signs and interior "can" lights were retrofitted with efficient bulbs.
4. High efficiency motors and variable speed drives were installed on fans and pumps as the old equipment was replaced.
5. To address concerns about air quality and proper ventilation, CO_2 sensors were installed and linked to the EMS.

As a result of these measures, the building's electricity consumption has been reduced by 58 percent and gas usage has been reduced by 83 percent. These savings have reduced annual electric and gas bills by $400,000. All of these savings were highly cost-effective – each efficiency project had a payback period of two years or less. Additional benefits include better quality lighting, comfortable temperatures and improved indoor air quality. The lighting measures also resulted in reduced cooling requirements (Power Boosters 1995; Fountain Square Management Company 1996).



5. The Potential for Renewable Energy Resources in the Midwest

5.1 Overview

Reducing the Midwest's reliance on fossil fuels demands not just an improvement in energy efficiency but also a sustained commitment to the use of clean, renewable energy resources. Fortunately, the Midwest has clean renewable energy in abundance. Wind power, biomass (such as energy crops and conventional crop residues) and solar energy can all play an important part in moving the Midwestern states toward a less polluting mix of energy resources.

Several states have already taken steps toward developing renewable sources of electricity (Figure 5.1). Minnesota and Iowa have moved to the forefront of wind energy development with the installation of more than 500 MW of wind capacity.[5] Wisconsin, though it starts with much less windy land than its neighbors to the west, has already installed 23 MW and plans an additional 30 MW. Michigan leads in the use of biomass for electricity generation with nearly 400 MW of capacity, about 40 percent of the total for the region, and Wisconsin is not far behind. In a few states, small solar systems have been connected to the power grid, and many more are used in situations where grid connection is impractical or very expensive.

Still, compared to its potential, renewable energy is not being widely installed. The Clean Energy Development Plan shows how it is both practical and affordable for the Midwest to obtain 22 percent of its electricity from renewable energy resources by 2020. This is not pie-in-the-sky – there are plenty of wind, biomass and solar resources to produce far more than that at a reasonable cost, and the technologies to do so are already on the market or near at hand.

The following sections describe the three key renewable resources in this study – wind, biomass and solar – in-depth and assess their market prospects, the quantity and distribution of resources, and technological advancements. The assumptions used in this study are then summarized and several case studies of successful projects that can be replicated elsewhere are presented.

5.2 Wind Energy

Market Assessment

Wind energy has come a long way since the boom-and-bust period of the 1980s. For the past 10 years it has been the fastest growing energy resource in the world, with installed capacity rising annually at a 25 percent clip. Worldwide sales of wind turbines and related equipment and services already measure in the billions of dollars. Although U.S. installations have not been growing as fast as in other parts of the world – largely because of comparatively weak and inconsistent federal and state policies – the United States began to experience renewed growth in the late 1990s, much of it in the Midwest. For example, nearly 400 MW of wind power is being developed in the Buffalo Ridge area of southwestern Minnesota (as part of utility commitments for 825 MW), a 112.5 MW wind farm is operating in Alta, Iowa, and a new 30 MW wind power project is planned in Iowa County, Wis.

What is driving the growing use of wind energy in the United States? A combination of factors, including growing awareness of the environmental and economic benefits of wind energy, the declining cost and improving performance of wind plants, and a variety of federal and state policies.

Federal and State Policies

The federal production tax credit (PTC) has been vital to the financing of many wind projects. The PTC is currently valued at about 1.7¢/kWh. Since it only applies for the first 10 years of a plant's life, however, its impact on the levelized cost of wind energy (calculated over 20 or 30 years) is less. The PTC was originally enacted through mid-1999, but has been extended by Congress.

[5] Because wind plants do not run often at full capacity, the output of 500 MW of wind capacity is roughly equivalent to that of a 200 MW coal plant.

FIGURE 5.1 CAPACITY OF GRID-CONNECTED RENEWABLE PLANTS (1999)

	Hydro MW	Biomass MW	Wind MW	PV MW	Total MW	Fraction of Total (percent)
Illinois	40	114	0	0.03	155	0.5
Indiana	91	6.4	0	0.00	102	0.5
Iowa	134	7.5	258	0.01	410	5.1
Michigan	2,412	384	1	0.08	2,896	12.4
Minnesota	213	111	275	0.07	743	8.1
Nebraska	184	0	4	0.00	188	3.3
North Dakota	518	9	1	0.00	528	11.2
Ohio	129	42	0	0.00	211	0.8
South Dakota	1,741	0	0	0.00	1,741	62.9
Wisconsin	511	246	23	0.09	818	6.3
All	5,974	920	560	0.27	7,790	5.3

Source: National Renewable Energy Laboratory Renewable Electric Plant Information System (online). Note: Biomass capacity excludes municipal solid waste.

State directives have played an even more important role. For example:

1. Minnesota's Prairie Island Mandate requires XCel Energy (formerly Northern States Power) to develop 825 MW of wind by 2012 in return for permission to store nuclear waste in dry casks. Virtually all of Minnesota's 275 MW of wind capacity in 1999 was developed in response to this law.

2. Iowa required that utilities purchase or generate the equivalent of two percent of their electricity from renewables by 1999. Though once challenged by utility companies, the law has led to the installation of 258 MW of wind in the state.

3. Wisconsin required the state's four eastern utilities to install or purchase the output of 50 MW of renewable capacity by the end of 2000. Wisconsin also adopted a renewable portfolio standard requiring that 1.7 percent of the state's electricity come from renewable resources by 2011. So far, most of the capacity that has been installed or planned is wind power.

Technological Trends

In the early 1980s wind energy had a reputation for being costly and unreliable. These criticisms are no longer true. The long-run cost of wind energy from large machines has dropped from more than 30¢/kWh in the early 1980s to 3-6¢/kWh today (DOE 2000). The cost of wind energy includes the annualized capital cost and ongoing operating costs. The range of costs reflects the windiness of the site, the size of the plant, the availability of tax credits and other factors. The lower end of this range compares favorably with wind's leading fossil fuel competitor, natural gas-fired combined-cycle plants. At the same time, the efficiency and reliability of wind equipment has soared. Today, individual wind turbines are typically available for operation 98 percent of the time - better performance than many fossil-fueled power plants.

Environmental Benefits

The fact that wind turbines produce no air pollution, greenhouse gases or solid wastes makes them an attractive option for states and communities interested in addressing these problems. Furthermore, by applying responsible siting practices, wind projects can have minimal impacts on wildlife and natural resources. Minnesota's Prairie Island Mandate, for example, endorsed wind energy as a way to offset the perceived environmental and safety risks of dry cask nuclear fuel storage.

The Algona Wind Project

Although wind energy is a proven technology, not every utility company manager feels comfortable embarking on a large wind project without first gaining some experience on a smaller scale. The Algona, Iowa, wind project shows that effective federal and state policies can help even small municipal power companies overcome this initial hurdle - and generate a substantial amount of clean power at the same time (DOE 1999a).

The instrumental policy was the U.S. Department of Energy's Wind Turbine Verification Program (TVP), which provides funds to demonstrate new wind turbines. But the groundwork was laid much earlier by an Iowa law requiring investor-owned utilities to use wind-generated electricity. Municipal utilities were not bound by this law, but many saw the writing on the wall and expected to eventually become wind producers themselves. They were also responding to strong customer support for clean power initiatives.

Seven municipal utilities were thus primed to respond to a 1996 TVP request for proposals. The project they proposed cost $2.8 million, of which $1.3 million was funded by TVP while the rest was paid by the utilities. The result was the Iowa Distributed Wind Generation Project. The lead utility is Cedar Falls Utilities, and the project is located in the service territory of Algona Municipal Utilities, which maintains the turbines. The other participating utilities are Ellsworth, Esterville, Fonda, Montezuma and Westfield, Iowa.

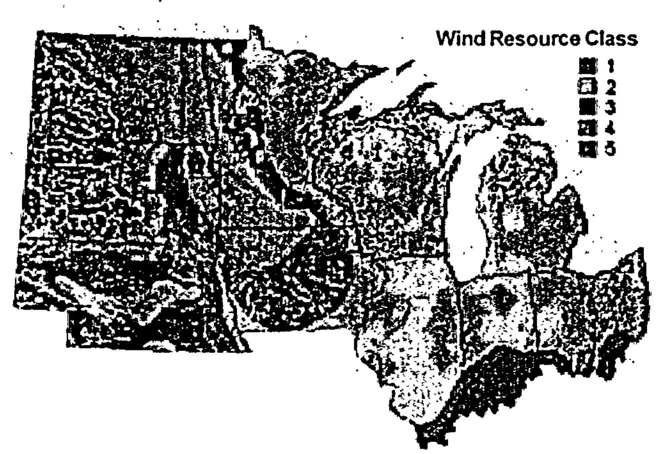
The Algona project, which went into operation in September 1998, uses three Zond 750 KW turbines mounted on 160-foot (50 meter) towers, creating a total (peak) plant capacity of 2.25 MW. The power output at the plant has already exceeded expectations thanks to good winds, high turbine performance and high equipment reliability. From November 1998 to October 1999 the plant ran at a 33.1 percent average capacity factor, almost 13 percent higher than projected (EPRI 12/1999).

Economic Benefits

The economic benefits of wind energy for the communities where plants are located are another important factor behind its resurgence in some Midwestern states. In agricultural areas, farmers can increase their incomes by 50 percent or more by leasing a small portion of their land for wind turbines and access roads; farming operations on the rest of the land are unaffected. For example, a wind energy company has paid $1 million to farmers in Edgeley, N.D. for five-year options to lease their land for wind turbines. Wind energy can also help the local economy by increasing the tax base. The opportunity to promote rural economic development and the support of farming communities has been critical to the success of wind energy in states such as Minnesota and Iowa. Likewise, the creation of new windpower manufacturing jobs by NEG Micon in Champaign, Ill. and LM Glasfiber in Grand Forks, N.D. has spurred interest and support.

Wind energy nonetheless faces challenges in making further inroads into Midwestern markets. Where state directives do not exist, wind projects must usually compete on cost alone; and although the cost of wind energy has

FIGURE 5.2 GEOGRAPHICAL DISTRIBUTION OF WIND RESOURCES



Wind Energy Environmental and Siting Issues

Wind energy is a clean source of energy but that does not mean it raises no environmental or siting issues. Fortunately, the once widespread concerns that wind power plants might result in the deaths of many birds or have other serious impacts on wildlife have gradually diminished with experience in many different settings. The only wind plant area in the United States where bird deaths have been reported as a serious problem has been the Altamont Pass in California (Biosystems 1996); no serious problems of this nature have been reported in the Midwest. Since 1992 the National Renewable Energy Laboratory has worked with environmental groups, utilities, government agencies, university researchers, consumer advocates, utility regulators, government officials and the wind industry to study wildlife-wind energy interactions. While it may be too early to lay the issue to rest, it appears likely that with careful, responsible siting practices, wind projects will have minimal impacts on wildlife (NWCC 1997).

Public concerns about visual and noise impacts of wind plants may place limitations on where wind projects can be developed. This is an especially important challenge for the wind industry in densely populated states with fewer good wind resource sites to choose from. In Wisconsin, for example, concerns have been expressed about the impact of wind projects on property values. Some people object to the sight of wind turbines either near their communities or in scenic areas or are concerned about the noise turbines may generate.

Several positive trends in wind turbine design may help mitigate these problems. For instance, as wind turbines get bigger, far fewer are needed to supply the same power - and 10 large turbines have a much smaller visual impact than 50 small ones. And the tubular tower design of modern turbines is more pleasing to the eye than the old lattice towers. Modern wind turbines also are far less noisy than their predecessors. A single turbine located 400 feet away actually produces less noise than wind rustling trees only 40 feet away (NWCC 1997). With appropriate setback distances from houses and buildings, noise should not pose a serious problem.

come way down and is continuing to drop, it is still not low enough to beat new natural gas combined-cycle facilities in most cases. The intermittence of wind output complicates the cost equation. Although studies show that wind makes a valuable contribution to the reliability of power supply (Tellus Institute 1994), power companies sometimes regard it merely as an energy saver and accordingly pay less for it.

Other challenges include transmitting power from distant windy sites to major load centers; a lack of familiarity with the technology among decision-makers such as power company managers; obstacles to Native American tribes developing wind on their land; and contracts that limit the flexibility of municipal and cooperative utilities to choose their power suppliers. These barriers - as well as ways to overcome them - are discussed in more depth in Chapters 7 through 9.

THE WIND RESOURCE

The wind blows often and strong in many parts of the Midwest. Figure 5.2 depicts the geographical distribution of the wind resource according to the latest regionwide assessment (UCS 1993).[6] This map assigns areas a range of predicted average annual wind speeds. With today's wind technology, most utility-scale wind plants are being installed in class 4, 5 and 6 areas, but projected improvements should make class 3 areas attractive in the future. (Smaller wind turbines for residential and farm applications are designed to run in lower wind speeds.) The windiest areas are in the Great Plains, including western Minnesota, Iowa, Nebraska and the Dakotas. Portions of other states - particularly

[6] The Union of Concerned Scientists' resource map was developed through a GIS-based analysis of the National Wind Resource Atlas (DOE 1987). Although the Great Plains have been extensively studied, the lack of wind resource maps developed using up-to-date methods remains a significant barrier to wind development in other parts of the Midwest.

hilltops and the shores of the Great Lakes – have favorable winds as well. A wind measurement program in Wisconsin, for example, has revealed areas of class 3-4 suitable for wind projects:

However it is measured, the wind energy potential of the Midwestern states is enormous. Even after excluding environmentally sensitive areas and considering only class 3 and better resource areas, several states could theoretically supply all of their electricity demand with indigenous wind resources - and still have plenty for export. In addition, many windy areas are quite close to existing transmission lines, making it relatively inexpensive to connect them to the power grid (NREL 1994).

Assumptions for This Study

A GIS was used to identify suitable wind sites and rank them in order of increasing cost for the Clean Energy Development Plan. First, the annual output of a wind turbine located at any point in the region was estimated using the wind resource map. Second, the cost of constructing a wind plant of 100 MW size at any point, including the cost of building a new line to connect with the existing transmission grid, was calculated. (National parks and forests were excluded.) Third, the levelized cost of electricity was estimated by combining the output and the capital and operating costs. A cost-supply curve with this information was constructed for each state. Finally, the effects of bulk transmission constraints and wheeling charges, as well as the cost of wind generation itself, on the likely distribution of wind plants among the states in the region were considered.

In developing this scenario, several possible constraints on wind energy, including difficulties in siting new wind projects, the cost of wheeling power to load centers, and possible constraints on transmission capacity were considered.

Siting Issues. In the Great Plains, where most Midwestern wind development has taken place, siting issues have not been a serious problem. Many farmers are eager to have wind turbines on their properties to increase their income, and wind plants in general are a good fit with agricultural uses of land. Given the extraordinary abundance of windy agricultural land in those states, siting difficulties are unlikely to pose a major constraint until well after 2020 (the end point of the Clean Energy Development Plan), if at all.

The same cannot necessarily be said for states in the eastern part of the Midwest, where population densities are higher and the number of suitable wind sites smaller. Potential issues include the visual and noise impacts of wind plants, possible conflicts with other environmental interests such as endangered species protection, and perceptions that property values will go down. These challenges can be met if the states and communities concerned and the wind industry follow some important guidelines. Foremost among them is the need to involve the affected public early in the process and in a significant way. The importance of addressing this issue is discussed further in Chapter 9.

Transmission Constraints. Wind developers often lack choice about where to build a wind project - they must go where it is windy and where landowners and communities are receptive. This means that wind projects must sometimes pay a significant cost to send power where it is to be used. In fact, the Clean Energy Development Plan includes a large increase in transfers over certain parts of the transmission grid because of wind energy. The increase in transmission of wind energy will be offset to some degree by reductions in the transmission of conventional power. Three types of wind-related transmission costs were considered:

1. An assumed average construction cost of $240,000 per mile (DOE 1999), was added to the construction cost of the wind projects to address the cost of building a transmission line from a wind project to the nearest point on the transmission grid.

2. Many regions face constraints on transmission capacity.[7] With the moderate wind deployments projected for 2010 in the Clean Energy Development Plan, only a portion of the transmission grid would need upgrading at an average cost of $32,000 per mile. By 2020, however, the upgrades will be much more extensive and will cost an average of $120,000 per mile. The distance is calculated along the existing transmission grid from each wind project to the nearest major town or city.

[7] A study of the transmission constraints on wind energy in the Dakotas conducted by the Western Area Power Administration and the National Renewable Energy Laboratory concluded, "The MAPP region (covering western Minnesota, Iowa, the Dakotas and Nebraska) is limited by the ability of the (transmission) interfaces... to transfer power after a disturbance without severe swings in voltage or power, rather than by facility thermal overloads." Specifically, the study found that at most interconnection points wind additions were limited to about 100 MW without the need for grid strengthening (NREL/WAPA, 2000).

3. The Clean Energy Development Plan places substantial wind capacity in the windy Great Plains states where power demand is relatively modest. Much of the power produced would be exported to points east, resulting in likely transmission bottlenecks. The cost of overcoming this limitation was estimated with the PROSYM model by estimating the change in energy transfers between transmission areas, and then increasing the line capacity between certain areas to keep line loadings within tolerable levels. The average upgrade cost was estimated to be $500 per MW-mile (EIA 1999a).

Overall, the transmission upgrades add almost $75/kW, or almost 10 percent, to the total cost of wind energy in 2020 in the Clean Energy Development Plan.

In addition to addressing these constraints in the technical analysis of wind energy, options for mitigating these transmission issues are discussed further in Chapters 8 and 9.

Hydrogen Transmission Opportunities

Renewable resources, such as wind power, are often located far from electricity load centers. Generation from remote renewables can be carried to loads by electrical transmission wires. A promising alternative, however, is energy transmission in the form of hydrogen delivered by pipeline. For example, it is possible to convert wind-generated electricity in the Dakotas to hydrogen by electrolysis, and transmit the hydrogen by pipeline to population centers such as Chicago, where it can be used to produce electricity in fuel cells. Despite the conversion losses and additional technology costs involved in using hydrogen as the long-distance energy carrier, this hydrogen transmission scenario is worth considering for several reasons: (1) the Dakotas' wind energy is an underutilized resource; (2) the electrical transmission system in the Dakotas is potentially insufficient to handle large-scale introduction of wind-generated electricity to the grid; (3) hydrogen offers useful storage that can help match the timing of intermittent wind generation to the timing of loads; and (4) transmission of energy by hydrogen is less costly than transmission of electricity by wire.

An analysis of hydrogen transmission was conducted as part of this study. The analysis found that while transmission of wind energy by hydrogen is not currently economic, there are various developments that could make it attractive by 2010. Specifically, with substantial improvements in fuel cell technology, increases in natural gas prices, and higher than expected pricing of CO_2 emissions, transmitting wind power as hydrogen can be realized at a lower cost than transmitting wind power as electricity.

It is important to note that the development of hydrogen as an energy carrier is likely to be driven by developments in the transportation sector. If policies and technology for hydrogen-fueled vehicles evolve quickly, then hydrogen's role in the electric sector will be enhanced as well. Key uncertainties affecting hydrogen's success in the transportation sector include fuel cell technology cost reductions, fuel cell efficiency improvements, and climate change policy.

The report, *Transmitting Windpower from the Dakotas to Chicago: A Preliminary Analysis of a Hydrogen Transmission Scenario*, is available online at www.synapse-energy.com and www.repowermidwest.org.

WIND TECHNOLOGY

Utility-scale wind power plants consist of one or more individual wind turbines, each of which generates electricity through a generator in its housing. The power output of the turbines - carefully modulated by power electronics - is collected and the voltage is boosted at a transformer to the correct level for long-distance transmission. An above-ground transmission line may be required to bring the power from the site to the grid.

Although in the early years of the wind industry companies experimented with many different designs, most of today's wind turbines are of the horizontal-axis type, with two or three blades facing upwind on a tubular or lattice tower. While their basic design has not changed much in the past decade, wind turbines have become larger as companies have sought to capitalize on economies of scale. In 1981, a typical new wind turbine produced a maximum of 25 kW, had a rotor 10 meters (32 feet) in diameter, and cost $2,600 per kilowatt. Today's turbines typically generate 750-900 kW, have rotors spanning 50 meters or more, and cost around $800 per kilowatt. Despite their growing size, today's wind turbines are far less noisy and more attractive than their predecessors.

Wind plants range enormously in size, from a single turbine for a small community to hundreds of turbines producing enough power to supply thousands of homes. The largest wind plant in the world is a 112.5 MW plant located near Alta, Iowa. Although there are economic advantages to building large wind plants with many turbines, smaller facilities have a different kind of appeal. There is increasing interest in this development path, more common in Europe, which features individual or small clusters of large machines owned by landowners, farmers' cooperatives or similar groups and connected to the low-voltage distribution system for power sales to the local utility. In addition, some Midwestern utilities have installed small wind clusters supported by revenue from utility-run "green pricing" programs.

Although the focus of this study is on large wind turbines and power plants because they offset the most fossil fuel use, small wind turbines have an important part to play. The United States is a leading manufacturer and exporter of these systems, which are aimed primarily at two markets: remote or off-grid power, such as villages in developing countries; and grid-connected residential or farm applications. Small wind turbines designed for residential and commercial applications occupy a significant and growing market niche in the Midwest. (See Sacred Heart Monastery below.) Although their costs per kilowatt-hour tend to be higher than their larger cousins, small turbines have the virtue of operating near, or at the end of, the distribution grid where they displace higher-cost energy and capacity. They also function in lower-speed winds. The installed cost for a typical 10 kW turbine on a 30-meter tower is approximately $3,300 per kilowatt, including all parts, shipping and installation (Bruce Bailey, AWS Scientific, personal communication). This cost may decrease in the future as the industry's production grows.

Small Wind Turbines: The Sacred Heart Monastery

The Sacred Heart Monastery in Richardton, N.D., has been generating wind power since June 1997.[8] Using two used Silver Eagle turbines (which were upgraded with new components) that each generate around 90,000 kWh annually, the monastery has managed to reduce its annual electricity bill by almost $12,000, or one-third. The savings reflect one of the key advantages of small wind systems compared to their larger cousins: they offset electricity at retail rates (in this case 8.75¢/kWh) rather than much lower wholesale rates.

Of course, the monastery sees many benefits of its wind project aside from just saving money. Their members have the satisfaction of knowing they are helping to reduce their contribution to air pollution and global warming. The project has also drawn much attention and interest from people who spy the turbines from a nearby interstate.

The main complaint associated with the project is that the utility company does not pay the full retail rate, or anywhere near it, for electricity produced in excess of the monastery's needs. If it did, the monastery would be able to earn a greater return than what is possible by simply reducing the amount of power they draw from the grid. Net metering is a key strategy for increasing the use of small wind systems around the Midwest and is discussed in more detail in section 8.3.

Assumptions for This Study

There is substantial experience with wind energy in the Midwest to provide ample data on current costs,

[8] Mick Sagrillo, "Monastery Pleased with Wind Turbine Performance," American Wind Energy Association (2000). Information can also be obtained at the monastery's Web site, http://www.rc.net/bismarck/shm/bwitness.html.

and the technology is sufficiently mature that projections can be regarded as fairly reliable. Consistent with studies by the Department of Energy and the Electric Power Research Institute, the Clean Energy Development Plan projects gradual but steady declines in the cost of wind power plants and similar increases in their efficiency and output. Though year-by-year changes are likely to be modest, the cumulative impact over the 20 year period of this study will be substantial. The study's assumptions are summarized in Figure 5.3.

Another characteristic of wind energy is its intermittence. It would be incorrect to represent wind in the PROSYM model as a steady or firm power source, because its fluctuations will affect the type and cost of fuels it displaces, as well as loads placed on bulk transmission systems. This required assumptions about the statistical characteristics of wind plants so they could be simulated correctly.

An individual wind plant was represented in the model as having a certain probability of being either "on" or "off." Because there is some spatial and temporal correlation of winds, however, there is a tendency for several wind plants in the same area to be "on" or "off" at the same time. If they are all modeled independently, the result would be that the wind output would appear too steady throughout the year.

Analysis of wind data from numerous meteorological stations in the Midwest indicated that to avoid this pitfall all wind plants within an area covering roughly 200x200 kilometers should be modeled as a single block. This means, for example, that all of the wind plants located in the western MAPP region (the Dakotas, western Minnesota and Nebraska) are represented by 5 "super-plants", each with an independent probability of being either "on" or "off". The result is approximately the correct statistical behavior of overall wind plant output in the PROSYM model.

FIGURE 5.3 CURRENT AND PROJECTED WIND ENERGY COSTS AND PERFORMANCE[9]

	2000	2010	2020
Capital ($/kW)	1100	810	660
O&M (¢/kWh)	0.8	0.5	0.4
Capacity Factor			
Class 3	24.5 percent	27.4 percent	29.6 percent
Class 4	28.9 percent	32.4 percent	35.0 percent
Class 5	33.0 percent	37.0 percent	39.9 percent

Electric System Stability and High Wind Penetration

Electrical system operators face the challenge of instantaneously, or nearly instantaneously, matching a constantly fluctuating demand for electricity with supply from a large array of power plants with unique operating characteristics. Electrical system dispatch is complicated when the supply of electricity also fluctuates, as it is caused by the varying output from wind turbines in response to wind speed increases or decreases. This volatility leads to concerns about the stability of the electrical system when wind, or other intermittent resources, provide a significant share of the electricity supply.

The British Wind Energy Association estimates that the fluctuation caused by the introduction of wind to the system is not discernible above normal system fluctuations – until electricity generated from wind turbines reaches approximately 20 percent of the total system supply. Several regions in northern Europe are approaching this figure. According to the European Wind Energy Association, wind energy now accounts for 13 percent of domestic electricity demand in Denmark. The state of Schleswig-Holstein in Germany serves 18 percent of its demand with wind power. Under the Danish national energy plan, new offshore and onshore wind turbines are expected to increase wind generation to the point where it provides more than 50 percent of total electricity consumption before 2030. With this amount of installed capacity, the wind turbines will periodically cover more than 100 percent of Danish electricity demand.

Some renewable electricity technologies are unavoidably intermittent and will need to be supplemented with less intermittent energy supplies. Currently, that means conventional electricity plants, but in the future the electricity supply could be regulated through the use of baseload biomass gasifiers, hydrogen fuel cells, hydrogen pipelines and other storage technologies. In addition, increased energy efficiency helps to lower customer demand, thereby contributing to system stability.

The renewable resources in the Clean Energy Development Plan are not likely to create electrical system stability problems. The intermittent resources (wind and PV) in the plan represent roughly 12 percent of generation in the region in 2020, which is below amounts that have been successfully implemented in Europe.

[9] Source: AWS Scientific, Inc. based on industry and government data. Assumes an average new wind plant size of 50 MW in 2000 and 100 MW in 2010 and 2020. The capacity factor increases reflect projected improvements in technology and increases in tower height from 60 to 80 meters in 2010 and 100 meters in 2020. The capacity factors include expected electrical, mechanical and wake losses. Capital costs do not include transmission interconnection.

5.3 Biomass Energy

Market Assessment

Like wind energy, biomass experienced a boom in the early 1980s thanks to favorable federal and state policies and incentives put in place in response to the oil crisis. Since then biomass use in the power sector has continued to grow, although much more slowly. As Figure 5.1 indicates, there is currently almost 920 MW of biomass capacity operating in the region (excluding plants using municipal solid waste), with most concentrated in Michigan, Minnesota and Wisconsin. The majority of the plants produce both heat and electricity – CHP facilities. They mainly burn wood residues from pulp and paper production and from logging; they are owned by pulp and paper mills and paperboard manufacturers.

There is enormous potential to expand the use of biomass energy in the Midwest for two basic reasons. First, the biomass resource is very large thanks mainly to the abundance of agricultural land from which both crop residues (left over from farming) and energy crops (grown expressly for energy) can be extracted. Second, the Midwest has a large number of facilities that can be converted, at relatively low cost, to generate electricity from biomass. The two most important near-term opportunities are: (1) the conversion of inefficient steam-only boilers in the pulp and paper sector to efficient CHP; and (2) the co-firing of biomass and coal in existing coal plants.

Increasing the use of biomass in the form of crop residues and energy crops would have substantial economic and environmental benefits. Employment impact studies have demonstrated that biomass facilities create many more jobs than they displace in other sectors, because money flowing into agriculture creates a disproportionately large number of jobs (UCS 1993). Furthermore, biomass is rarely shipped long distances, so money spent on biomass fuel tends to remain in communities near the power plants. At the same time, biomass has a major environmental advantage: when produced in a sustainable manner its combustion generates no net CO_2. (Other types of air pollution must be controlled just as they are in fossil fuel plants.)

There are, however, significant challenges to be overcome before biomass can supply a much larger share of the region's electricity generation. First, biomass feedstocks (aside from mill and logging residues, which are virtually free) are more expensive than coal, which is their main competitor. Even crop residues, which cost nothing lying on the ground, become expensive relative to coal when the costs of collecting, transporting and processing them are taken into account.

Second, there is a lack of infrastructure for the production of new biomass feedstocks. Most crop residues are left on the ground, so farmers would have to make significant investments of time and money to collect and deliver them to power customers. They are unlikely to do so without the prospect of a stable and growing market for their product. From the power companies' standpoint, the absence of experienced fuel suppliers creates significant risks for any new biomass power project that might be contemplated. Similar issues confront the use of energy crops.

Third, there is insufficient incentive for owners of existing biomass steam-only plants to convert to efficient CHP. The conversion will, of course, require an investment which must be offset somehow - either by using the power generated to lower the industry's electricity bill or by selling the power to a utility company. Industrial electricity prices and utility buy-back rates are not high enough to make conversion attractive to most plant owners.

Biomass Resources

Biomass energy comes in many different forms, including dedicated energy crops and crop, mill and logging residues. Mill and logging residues are already widely used for energy and other needs in the pulp and paper sector; here, the main opportunity is increased efficiency of energy conversion through modern CHP.

Crop residues (stalks and leaves) are usually left in the field after harvesting. To prevent excessive erosion it is not desirable to remove all such residues, but a portion can be collected and converted to energy. Residues of corn cobs and stalks, as well as straws from cereal grains, are often produced in quantities that far exceed levels necessary for erosion control. Furthermore, they contain few nutrients and, consequently, are of little value as fertilizer.

Research has been conducted for a number of years on a variety of energy crop types. The most promising for the Midwest appears to be switchgrass, a perennial that is native to the Great Plains and is deep-rooted, very persistent and less susceptible to drought than other options. Switchgrass is already used as a cover crop for erodible land not in active cultivation.

Assumptions for This Study

Estimates of the amount of each type of biomass that would be available at different prices were taken primarily from research by the Oak Ridge National Laboratory (ORNL) (Walsh, et al., 2000). The ORNL model considers environmental constraints, such as limits on agricultural and logging residue removal, as well as economic factors. A summary of the assumptions for each feedstock type is provided below.

Logging Residues. No increase in logging is assumed, only the more efficient use of logging residues that are currently being left in the forest or burned off. The ORNL model classifies the total forest inventory by the several wood categories and by volume, haul distances and equipment operability constraints. Environmentally responsible retrieval practices are then applied carefully. For example, this inventory is revised downward to reflect the quantities that can be recovered in each class due to constraints on equipment retrieval efficiencies, road access to a site (e.g., no new roads are built), and impact of site slope on harvesting (e.g., no harvesting on slopes steeper than 20 percent). The estimated delivered price of forest residues includes collection, harvesting, chipping, loading, hauling and unloading costs; a stumpage fee; and a return for profit and risk.

Mill Residues. Mill residues are excluded because they are being used almost entirely as fuel or to produce fiber products.

Crop Residues. Millions of acres in the Midwest are planted in corn, wheat, grain sorghum, soybeans, hay and other crops. The ORNL analysis of crop residues was limited to the two most important sources of feedstock – corn stover and wheat straw. Although many acres in the Midwest are dedicated to soybean production, soybean residues are not produced in great quantities and tend to deteriorate rapidly in the field, limiting their usefulness as an energy feedstock. Other potential residue sources include barley, oats, rice and rye.

The amount of corn stover and wheat straw theoretically available in each state was estimated by first calculating the total quantities of residues produced, and then calculating the amount that could be collected without harming soil quality and erosion control. The estimated prices of corn stover and wheat straw include the cost of collecting the residues, a premium paid to farmers to encourage participation, and transportation costs. The premium paid to farmers, \$10-15/dry ton, is based on the experience of several companies that purchase corn stover or wheat straw for bedding, insulating materials, particle board, paper and chemicals. The transportation cost of \$5 - \$10/dry ton covers hauling crop residues a distance up to 50 miles.

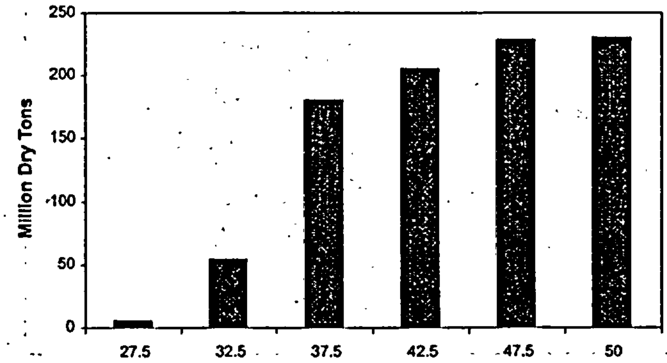
Energy Crops. Dedicated energy crops include herbaceous crops such as switchgrass. Currently, dedicated energy crops are not produced in the United States, but could be if they were sold at a price that ensured the producer a sufficient profit. The ORNL POLYSYS model was used to estimate the quantities of energy crops that could potentially be produced at various energy crop prices. POLYSYS is an agricultural sector model that includes all major agricultural crops (wheat, corn, soybeans, cotton, rice, grain sorghum, barley, oats, alfalfa, other hay crops); a livestock sector; and food, feed, industrial, and export demand functions.

Energy crop yields vary within and among states, and are based on field trial data and expert opinion. Energy crop production costs are estimated using the same approach that is used by the USDA to estimate the cost of producing conventional crops. Recommended management practices (planting density, fertilizer and chemical applications, rotation lengths) are assumed. The POLYSYS model estimates the farm-gate price; an average transportation cost of \$8/dry ton (representing a mean haul distance of 50 miles) is added to determine the delivered price.

A special run of the POLYSYS model was performed by ORNL for this study to provide county-level production estimates for prices ranging from \$27.50/dry ton to \$47.50/dry ton. Estimates for the last model year, 2010, were used.

Summary. Figure 5.4 shows the projected total amount of biomass from crop residues, energy crops and forest residues that could be available over a range of prices. One dry ton of biomass has an average

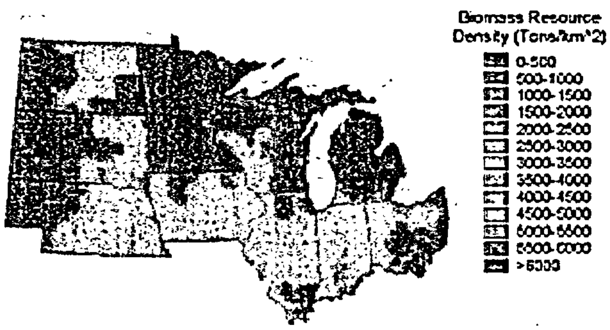
FIGURE 5.4 PRICE SUPPLY CURVE FOR BIOMASS FEEDSTOCKS



heating value of 17 million British thermal units (BTU). One hundred million dry tons of biomass is sufficient to supply about 23,000 MW of biomass plant capacity at an average heat rate of 10,000 BTU/kWh and average capacity factor of 85 percent.

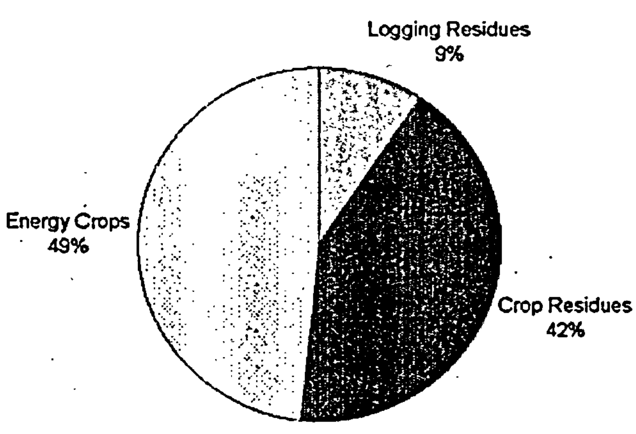
Figure 5.5 shows the distribution of estimated biomass availability by county across the region at a price of $37.5/dry ton. Reflecting the importance of crop residues and energy crops, the largest resource densities are in the Corn Belt areas of Iowa, Illinois, Indiana and Ohio. The resource distribution at each price point was used to determine the resources available for conversion of coal plants to co-firing, as described in Section 5.3.3.

FIGURE 5.5 DISTRIBUTION OF BIOMASS RESOURCES AT $37.5/DRY TON



Finally, Figure 5.6 shows the approximate breakdown of biomass feedstocks consumed in 2020 in the Clean Energy Development Plan. The energy crop component consists entirely of switchgrass. Logging residues rely upon better use of residues from existing logging operations; no new logging is included in the Clean Energy Development Plan.

FIGURE 5.6 BREAKDOWN OF BIOMASS RESOURCES IN CLEAN ENERGY DEVELOPMENT PLAN (2020)



CO-FIRING BIOMASS WITH COAL

A relatively low-cost, near-term option for converting biomass to energy is to co-fire it with coal in existing power plants. Co-firing means mixing the biomass with the coal to reduce the amount of coal used. Co-firing has been practiced, tested or evaluated for a variety of boiler technologies, including pulverized coal boilers of both wall-fired and tangentially-fired designs, coal-fired cyclone boilers, fluidized-bed boilers, and spreader stokers. Demonstrations and trials have shown that biomass can effectively substitute for 15 percent or more of coal use (DOE 1999b).

Preparation of biomass for co-firing involves well-known and commercial technologies. After "tuning" the boiler's combustion output, there is little loss in total efficiency. Test results indicate that a 0.5 percent decrease in the boiler's overall thermal efficiency with 10 percent biomass co-firing is appropriate. Since biomass generally has much less sulfur than coal, there are reductions in SO_2 emissions, and, to a lesser degree NO_x emissions.[10]

The cost of converting a coal plant to co-firing varies widely depending on the size of the plant, the type of boiler, the available space for storing biomass, and the fuel drying and processing facilities required. For cyclone-type boilers, the cost may be as low as $50/kW of biomass capacity. Such boilers, however, are not common in the Midwest. Conversion costs tend to be higher for the far more common pulverized coal (PC) boilers. The Department of Energy estimates a median cost of $180-$200/kW of biomass capacity. As shown in Figure 5.7, we assume a cost of $200/kW and a supplemental O&M cost of $10/kW-yr.

The potential for co-firing in the Midwest is large because of its many coal-fired power plants. Counting only newer and larger coal plants that are likely candidates for co-firing,[11] there are 90 plants with a total capacity of 49,200 MW that could be adapted to

[10] Concerns have been raised that some types of biomass fuel, as well as some types of coal, with a high alkaline content may contaminate the catalyst used in selective catalytic reduction (SCR), a form of NO_x pollution control that may be required of many coal plants in the future. (David Tillman, Foster Wheeler, personal communication.) This study assumes that alternative catalysts will be developed by the time co-firing is widely deployed. See Section 9.2.7.

[11] Newer and larger coal plants tend to run more often. This means that an investment in co-firing conversion can be recovered more quickly.

FIGURE 5.7 CHARACTERISTICS OF BIOMASS CO-FIRING RETROFITS

	Plant Boiler Types	
	Cyclone	PC
Capital ($/kW)	50	200
Fixed O&M ($/kW-yr)	2.5	10
Heat Rate Penalty	5 percent	5 percent

co-fire biomass. Assuming an average co-firing fraction of 10 percent, that equates to a potential of 4,920 MW, representing a feedstock demand of roughly 20 million dry tons of biomass per year. As shown in Figure 5.5, the biomass resource in the Midwest is large enough to sustain such a deployment at an average price below $32.5/ton or $1.9/MBTU.

It is important, however, to consider how much biomass might be available - and at what price - within a feasible trucking distance of the plants. A GIS was used to assess this question. First, biomass resource density was mapped at each price point from $27.5 to $47.5 per dry ton. Then the estimated annual biomass demand from each coal-fired plant in the PROSYM database was overlaid on these maps (assuming it was converted to 10 percent co-firing and retained its current average capacity factor). Finally, those plants that would be able to obtain sufficient biomass to meet their needs within a 50 mile radius at each price point were modeled. The lowest price at which a plant acquired enough biomass was assumed to be the price of biomass for that plant.

The average biomass price derived by this method in the Clean Energy Development Plan is almost $31/dry ton ($1.8/MBTU). For some plants the price is as low as $27.5/dry ton ($1.6/MBTU) and for others it is as high as $52.5/dry ton ($3.1/MBTU).

Although this scenario assumes 10 percent co-firing at all larger and newer coal plants, it is likely that the co-firing fraction will be higher at some plants than at others, and that some plants will not be converted to co-firing at all. The most favorable locations for co-firing will generally be where the coal price is relatively high and biomass price relatively low. In addition, plants with relatively high capacity factors will be able to recover the capital investment in co-firing more quickly than plants that run less often.

The Chariton Valley Co-Firing Project

The sponsors of the Chariton Valley (Iowa) Co-Firing Project are aiming to create a new market for a homegrown energy crop: switchgrass (Iowa DNR2000; CVRCD 2000). Switchgrass once grew abundantly in southern Iowa before crops were planted on the land. It is still used as a cover crop for erodible land enrolled in the Conservation Reserve Program because its deep roots and perennial nature hold the soil. Now, a group called Chariton Valley Resource Conservation and Development has persuaded a utility company - Alliant Energy - to test switchgrass as a fuel in the Ottumwa Generating Station in Chillecothe, Iowa. Four thousand tons of switchgrass were harvested in preparation for the test burn, which occurred in fall 2000.

This was not the first time switchgrass or similar biomass was burned with coal in a power plant. In Denmark, three power plants get nearly 10 percent of their fuel from wheat straw, a practice that reduces CO_2 and some pollutant emissions while causing no damage to the plant boiler, according to Danish plant operators. And several coal plants in the United States have burned waste wood.

But this will be one of the first demonstrations of integrating energy crops with co-firing. The objectives of the first test burn were to evaluate switchgrass grinding size, handling and processing, and the impact on the power plant operations and emissions. Fuel delivery and long-term plant performance will be evaluated in two additional co-fire tests scheduled for 2001 and 2002.

The project supporters - who received a grant from the U.S. Department of Agriculture - hope that Alliant Energy will permanently convert this plant to co-firing, thereby helping to maintain switchgrass's important role in controlling erosion and conserving the soil as the Conservation Reserve Program expires.

Combined Heat and Power

The most efficient use of biomass fuel is in CHP applications. New CHP plants can convert biomass to useable forms of energy with almost 90 percent efficiency. Because the pulp and paper industry produces large quantities of biomass waste each year, it has traditionally been the industrial sector with the highest rate of biomass fuel utilization. Installed CHP capacity in the pulp and paper industry comprises roughly a third of the CHP capacity in the region. Most of these plants burn some combination of fossil fuels (generally coal in older CHP plants and gas in the newer ones) and biomass. This study assumes that biomass provides about 60 percent of the fuel consumed at CHP facilities in the pulp and paper industry. Biomass CHP in the pulp and paper industry represents the vast majority of the region's current biomass use for electric generation. Potential exists in the region for both increased usage of biomass CHP, and replacement of existing CHP systems with modern and more efficient systems that can provide additional electric output for onsite usage and/or exports to the grid.

Projections of biomass-based CHP use in the Clean Energy Development Plan are based upon national process steam load and energy projections in the pulp and paper industries. CHP use in manufacturing, where the fuel is mainly natural gas, is discussed in Chapter 6. For the pulp and paper industry, this study assumes that the national mix of 40 percent steam-only and 60 percent CHP holds for each state, and the national mix of 40-60 gas to biomass consumption ratio also applies. The study further assumes that existing steam-only facilities (at an average of 70 percent efficiency) would be switched to CHP at 75 percent efficiency with a 40-60 steam-electric ratio. This analysis assumes that 15 percent of the steam-only plants convert to CHP in this manner by 2010, and double that by 2020. As for facilities that already co-generate electricity, this study assumes that co-generation facilities with 70 percent average efficiency and just 17 percent electric output are replaced by units with 75 percent overall efficiency and 37 percent electric output. Forty percent are assumed to make this conversion by 2010, and twice that by 2020. The projected cost of CHP conversion is shown in Figure 5.8.

The pulp and paper industry is expected to maintain its market share of CHP in the region and to continue to be the largest user of biomass fuels for CHP through 2020. Based on these assumptions, roughly one-fifth of all new CHP added in the region is expected to be biomass-fueled CHP in the pulp and paper industry. This translates into almost 1.67 GW of new biomass-fueled CHP capacity being added in the region by 2010 and 3.53 GW by 2020, in addition to the 1.56 GW of currently installed biomass CHP. On an energy basis, biomass CHP generation in the region would total 19.8 TWh by 2010 and 31.2 TWh by 2020.

Gains in new biomass-based CHP capacity outside the pulp and paper industry are expected to be modest by comparison. Recent advances in biomass combustion technologies, however, have made biomass-fueled CHP systems cost-effective for many other industries, as well. New research and development into wood-gasification

District Energy St. Paul

One example of a new combined heat and power project in which biomass would be used is District Energy St. Paul (DESP). DESP recently announced plans to add a new 98 MW (combined thermal and electricity production) wood chip-fired CHP plant to replace its coal and gas boilers, which supply the downtown business district with electricity and heat. When completed in 2002, the upgrade will make DESP the largest biomass-based district energy system in the country. The biomass upgrade will enable DESP to expand its recently added district cooling services and to increase its power sales to XCel Energy (formerly Northern States Power) to 25 MW. The new plant will also enable the city of St. Paul to meet its entire commitment to reduce greenhouse gases under its agreement with the International Council for Local Environmental Initiatives (DESP 1999; DESP 2000). DESP's decision to fuel their new CHP plant with biomass rather than natural gas was likely driven in part by a state mandate that XCel Energy increase its biomass electric output or purchase more electricity generated from biomass. The additional sales to XCel Energy helped DESP finance the biomass conversion and upgrade its system.

Figure 5.8 Characteristics of Biomass CHP

Heat Rate*	3900 BTU/kWh
Capital	$860/kW
Fixed O&M	$3.7/kW-yr
Variable O&M	$3.7/MWh
Biofuel Fraction	60 percent
Natural Gas Fraction	40 percent

**Increase over steam-only*

technologies and fast-growing energy crops will likely further increase biomass generation efficiency and fuel supply, and cause the rate of growth of new biomass-based CHP systems to continue to increase.

Biomass energy projects have the added economic advantage of creating far more local jobs (particularly in slow-growth rural areas) than other types of energy projects, because biomass fuels are generally produced by local suppliers within a 50 mile radius of the site, while the average distance between production and consumption of fossil fuels is generally much greater. The use of biomass for CHP also can avoid the cost of extending pipelines to serve the plant with natural gas. Another advantage of biomass over gas for CHP is that, when the full fuel cycle is considered, "closed-loop" biomass energy systems (in which the rate of annual biomass fuel production meets or exceeds consumption) produce no net greenhouse gases. As noted above, the Midwest has the technical potential to fuel significantly more biomass-based CHP and reap these economic benefits. But, while increased employment in rural areas, a slower rate of climate change, greater energy self-sufficiency, etc., would undoubtedly yield benefits to the region's economies, such factors are often difficult to quantify (and are not directly accrued by the CHP developer).

The result is that biomass is often overlooked as a fuel for CHP, except by industries such as pulp and paper that already have access to vast supplies of cheap biomass that would otherwise be wasted. Despite significant advances in the efficiency of new biomass-based CHP systems, expanding the use of biomass for CHP applications to other industries is hampered by the fact that supply infrastructures to guarantee access to sufficient low-cost biomass fuel do not exist in most areas, but economies of scale adequate to lower costs are unlikely to develop without guarantees of sufficient demand. In recent years, recognition of biomass's full economic and environmental benefits compared with fossil fuel's has led several states (including Minnesota, Iowa and Wisconsin) to adopt modest quotas or other incentives to promote new biomass generation.

Dedicated Biomass Plants

Today's biomass-fueled power plants use mature, direct-combustion boiler/steam turbine technology. They tend to be small (the average size is 20 MW) and inefficient (average biomass-to-electricity efficiency is 20 percent), and both factors contribute to a relatively high cost of delivered electricity of 8-12 ¢/kWh. That explains why most biomass plants use waste feedstocks, which are free or may even earn money for the plant owner by providing a waste-disposal service.

The next generation of stand-alone biomass power plants will be both less expensive and more efficient. One of the most promising near-term technological options is gasification-combined-cycle systems, the biomass equivalent of the natural gas combined-cycle (NGCC). Gasification involves the conversion of biomass in an atmosphere of steam or air to produce a medium- or low-energy-content gas. This biogas powers a combined-cycle power generation plant (combined-cycle means it has both a gas turbine "topping" cycle and a steam turbine "bottoming" cycle, making use of both high- and low-temperature heat generated in combustion).

There are many different gasifier designs. Some of the variables include gasification medium (oxygen or no oxygen), gasifier operating pressure, and gasifier type. Many of the critical technologies were developed through research on coal-based gasification combined-cycle systems, which involve similar principles. Ultimately, biomass gasifiers may provide fuel for fuel cells.

Biomass gasification combined-cycle systems are not yet commercially available, although one small plant is operating in Sweden. The Department of Energy projects that the first generation of biomass gasification combined-cycle systems would have efficiencies of nearly 40 percent, and in co-generation applications they could exceed 80 percent. The cost of the first commercial systems in this country is projected to be in the $1,800-$2,000/kW range. With learning, the cost may drop rapidly to reach $1,400/kW by 2010. (The cost assumptions of our study are shown in Figure 5.9.) Even this capital cost is still high for utility-scale power generation, indicating biomass gasification combined-cycle systems will enter the market more slowly than co-firing or CHP, and will probably require a continuing subsidy.

Figure 5.9 Characteristics of Biomass Gasification Combined-Cycle Power Plants

	2000	2010	2020
Heat Rate (BTU/kWh)	10,000	9,730	8,670
Plant Size (MW)	75	100	110
Capital ($/kW)	1,939	1,500	1,289
Fixed O&M ($/kW-yr)	44.5	44.5	44.5
Variable O&M (¢/kWh)	0.5	0.5	0.5

Environmental Implications of Biomass

The use of biomass for energy can raise significant environmental issues. For example, taking too much agricultural residue off the land can increase erosion and reduce soil quality. Cultivating energy crops on a large scale requires land, as well as energy and other inputs. The combustion of biomass, of course, produces air pollutants such as NO_x that must be controlled. There are additional questions concerning how large-scale biomass production might displace or compete with food production, encourage unsustainable forest use, or (in co-firing) provide an incentive to keep dirty and inefficient coal plants in operation.

On balance, however, the environmental benefits of biomass use outweigh these risks when sensitive practices are used. It is important to first consider the activities displaced by biomass production and use, starting with coal mining and the pollution generated by coal plants. A major advantage of biomass - if sustainably produced, as proposed in this study - is that it does not contribute to global warming, since the CO_2 that is emitted into the atmosphere during combustion is absorbed as plants are grown to replace the biomass consumed.

Right now, agricultural residues are often burned in the open to make way for new plantings, producing far more pollution than would be generated if the residues were collected and consumed in a controlled power plant. Moreover, the removal of residues from the field does not lead to erosion if a sufficient amount is left in place, as our study assumes in its price and supply projections. Lastly, the leading energy crop, switchgrass, has far fewer impacts on land and wildlife than food crops. Unlike food crops, energy crops are not replanted every year, so their roots systems remain in place to hold the soil. In fact, switchgrass is commonly used as a cover crop on erodible or fragile soils enrolled in the Conservation Reserve Program. In the right locations, they can even act as chemical buffers to absorb agricultural runoff before it enters river systems.

Still, it is clear that biomass use must be carefully monitored and regulated to avoid unwanted impacts. For example, co-fired or dedicated biomass power plants should be required to meet the same air pollution regulations as others; potentially contaminated feedstocks (such as municipal wastes) should not be used in biomass power plants; regulations should require that sufficient crop residues be left on the soil to prevent erosion; and the use of forest wood should be strictly controlled to avoid placing a greater burden on forest ecosystems. All of these guidelines were followed in developing estimates of biomass use in the Clean Energy Development Plan.

5.4 Photovoltaics

Market Assessment

Photovoltaic systems convert sunlight directly into electricity using semiconductor materials without moving parts. Their remarkable simplicity and flexibility - they can be built in sizes ranging from watts to megawatts - make them suitable for a wide variety of applications, including central-station power plants, substation power plants for distribution support, grid-tied systems for home or business use, and off-grid systems for remote power.

Generally speaking, PV costs remain high compared to conventional alternatives in most applications except off-grid systems. The off-grid market, along with aggressively subsidized markets for grid-connected systems in Germany and Japan, has driven remarkable growth in PV installations worldwide. Total shipments in 1999 topped 200 MW, a 60 percent increase over the 125 MW shipped in 1997. Growth is likely to continue over the next several years, with annual sales possibly passing the 1000 MW mark before 2010.

Solar power development provides substantial environmental and public health benefits because it creates no air pollution, greenhouse gases, or radioactive and other dangerous wastes. In addition, there are significant economic development opportunities for Midwestern solar companies that manufacture both for domestic use and export to developing countries (see sidebar in Section 5.4.3). Chicago, in particular, is seizing these solar development opportunities by supporting Spire Solar's new solar panel manufacturing plant on a former "brownfield" site, installing solar panels on the rooftops of nine major museums, and planning to build the largest single photovoltaic assembly (2.5 MW) in the country to provide cleaner and greener power for public use.

Despite PV's impressive potential and proven track record around the world, it faces major hurdles to penetrating the Midwestern energy market in any significant way. A key problem is the lack of a strong PV industry presence in the region, which can be traced to a preference within the industry to seek "easy pickings" in markets where demand for PV systems already exists (such as the heavily subsidized German and Japanese markets and the well-developed market for remote PV systems in developing countries).

The Solar Resource

The amount of sunlight available for generating power varies greatly across the region. Figure 5.10a depicts the resource distribution as the capacity factor, or average output divided by peak output, of a typical present-day flat-plate system.[12] On average, the incoming solar radiation (insolation) is highest in Nebraska and decreases gradually toward the north and east. Nebraska and the western Dakotas have a very good solar resource, equal to parts of northern California and eastern Texas. Ohio, Michigan and the other northeastern states receive about 30 percent less radiation.

The total insolation includes two components: direct radiation, which is light received directly from the sun; and indirect or diffuse radiation, which is light reflected or scattered by clouds and dust in the atmosphere. The distinction is important because PV systems with lenses or mirrors to concentrate sunlight require direct radiation, whereas fixed and tracking flat-plate systems can use both direct and indirect radiation.

An important attribute of the solar resource is that it often is strongly correlated with consumer demand for electricity. In many parts of the Midwest, peak electricity demand is driven by air conditioning on hot summer days, precisely the time when solar radiation is highest. Since peak loads are expensive for power companies to meet, solar PV systems are sometimes attractive even in areas with below-average amounts of sunlight. This concept is expressed as the effective load-carrying capability, or ELCC, which is the average plant output in peak load hours. Analysis shows that in virtually all of the Midwestern states, PV systems have an ELCC exceeding 60 percent (Fig. 5.10b) (Richard Perez, personal communication).

Figure 5.10a Geographic Distribution of Solar Insolation

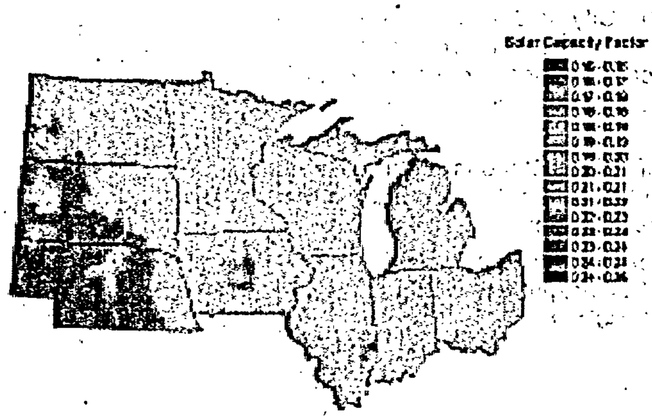
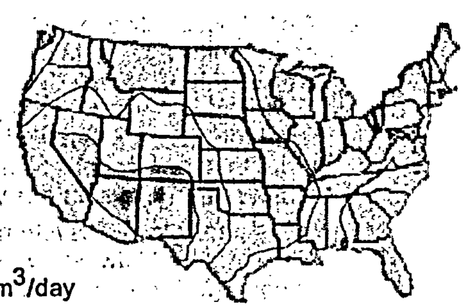


Figure 5.10b. Coincidence of PV Output with Utility Peak Loads

PV ELCC map of U.S.
(based on 500 utility loads)



"Traditional" solar energy map

[12] This resource map was developed by Richard Perez of the Atmospheric Sciences Research Center, State University of New York, Albany, using solar resource data provided by the National Renewable Energy Laboratory.

PV Technology

PV cells - the most basic component of a PV system - come in many varieties, from flat, thin films made of amorphous (non-crystalline) silicon to pure crystals of silicon or other materials on which direct sunlight is concentrated in intense beams. By and large, the crystalline cells achieve good efficiencies of conversion of light into electricity but are expensive to manufacture. Thin films are less efficient but cheaper to make. As yet, no single technology has proven to be decisively superior to the others. On the contrary, each has found a niche reflecting wide variations in the quality of the resource and the needs of customers.

Individual PV cells are assembled into modules that produce direct current power. Depending on the application, PV modules are either fixed flat plates, tracking flat plates, or concentrating. The fixed flat-plate modules face in one direction all the time, whereas tracking flat plates and concentrating modules are turned to face the sun. The concentrating systems in particular must be finely controlled to maintain an orientation so sunlight is focused precisely on the comparatively small cells. Again, there is a trade-off between efficiency and cost - more efficient designs tend to cost more.

PV modules are combined with other components, such as power conditioners and inverters, tracking motors and mounting structures, to form a complete PV system. For remote applications, the system is often hooked to a battery to provide continuous power or the ability to produce power over several cloudy days. Here the emphasis is on highly reliable operation with little or no maintenance, which argues for fixed flat-plate systems. Grid-connected systems use the transmission system as a whole for backup. At night and on cloudy days, the consumer draws power from the grid; but when there is plenty of sunlight the consumer draws power from the PV system and may, in fact, become a net power producer. In appropriate locations, larger grid-connected systems may be able to take advantage of the higher efficiencies available with concentrating systems.

Photovoltaics for Grid-Connected Applications

The biggest near-term market for photovoltaics is in specialized off-grid and remote applications, such as warning signs and battery recharging for communications relays. But several initiatives are helping to expand the use of grid-connected photovoltaics around the Midwest. What follows are snapshots of just a few of them. PV manufacturers BP Solar, First Solar, Spire Solar, Unisolar and Powerlight are actively engaged in these projects.

1. The U.S. Department of Energy's "Million Solar Roofs" program is supporting the use of roof-mounted PV systems (in the 1-5 kW range) around the country. In Wisconsin, for instance, 500 homes will be equipped with rooftop systems by 2005. Several dozen schools equipped with 20-50 kW systems are planned in Ohio, Illinois and Wisconsin.
2. A city-based initiative in Chicago may be reflective of future PV deployment opportunities in the Midwest. The "Brownfields to Bright Fields" project, is a partnership between Spire Solar and the City of Chicago. It features a commitment by the city to purchase PV for local deployment at sites already used for industry ("brownfields"), in exchange for the development of a PV manufacturing capability in the city. The purchase commitment will amount to hundreds of kilowatts per year.
3. BP is deploying PV systems at many of its gas stations around the world, including the Midwest. One of the main benefits of this program is that it may encourage "copy-cat" initiatives by other companies.
4. The city of Toledo, Ohio, working in partnership with First Solar (a relatively new, thin-film PV manufacturer based in Ohio) and Powerlight, is planning several 100 kW PV projects at schools and large commercial buildings.

The challenging interconnection rules imposed by some utility companies date back to the days when there was concern in power engineering circles about whether grid-connected PV systems would adversely affect the quality of power. Experience has demonstrated conclusively, however, that well-designed PV systems can be safely and reliably interconnected with the utility grid.

PV System Costs

The cost of PV installation mainly depends on the installation's size and the degree to which it uses standard, off-the-shelf components. The technology (thin film versus crystalline) does not appear to be a consistent price differentiation factor. For small, one-of-a-kind grid-connected PV systems (1,000-3,000 W residential), the complete cost ranges between $9,000/kW and $11,000/kW. The addition of emergency battery storage may add $1,000/kW.[13]

For mid-size grid-connected building-integrated PV installations where the roof or walls may be used as structure, the current cost ranges from $6,000/kW to $8,000/kW. For bulk orders of small standardized systems, the cost could be as low as $5,000/kW to $6,000/kW, based on experience with a program conducted by the Sacramento Municipal Utility District.

The costs of large grid-connected PV systems are not well-known, since most of the ones that have been built are one-of-a-kind prototypes designed with little emphasis on cost efficiency. A reasonable estimate, based on discussions with system manufacturers, indicates that the cost of such systems might range from $5,000/kW to $6,000/kW today.

A Road-Map report recently released by the U.S. PV industry provides a view of the future of the industry based on market and cost projections. All major PV manufacturers (Siemens, Astropower and BP Solar) participated in the preparation of this report along with universities (Purdue and MIT), Idaho Power, and Trace Engineering. The Industry Road-Map report establishes a goal of $3,000/kW (including capitalized operations and maintenance costs) in 2010, and $1,500/kW in 2020.

Assumptions for This Study

Because of the relatively low amount of direct, normal solar radiation available in some parts of the Midwest, this study considers only flat-plate systems. Furthermore, in the interest of allowing for the widest possible variety of PV applications, the output of fixed flat-plate systems suitable for a variety of rooftop mountings were modeled.

Finally, the study considers only grid-connected systems. As noted, off-grid applications are the most promising market in the near term, but to displace substantial amounts of fossil fuel, PV must begin to penetrate the grid-connected market. Initial deployments of grid-connected systems will be of intermediate size (10-100 kW), and designed to provide support to the grid in areas of heavy peak summertime loads. This could include rooftop systems on buildings in cities, as well as systems located near heavily loaded electrical substations. As the market for PV expands and costs decline, residential rooftop PV systems will become more attractive and more important in the energy mix.

Figure 5.11 presents the projected costs of grid-connected PV systems for this study (including the 10 percent investment tax credit available for solar installations). The cost trajectory is consistent with technological assumptions from the 2000 Annual Energy Outlook (DOE 1999) and current business-as-usual industry growth projections. Following EIA's method, a technological optimism factor of 1.12 was applied to the estimated current overnight capital cost of $4,836/kW, yielding a current cost of $5,416/kW. Then, cost reductions of 20 percent were assumed for each of the first three doublings of global PV capacity over today's capacity, five percent for the next five doublings, and one percent for all doublings thereafter. Lastly, the analysis assumes that the global installed PV capacity will grow at an average annual rate of 17.5 percent over the next 20 years (in the middle of the range of global business-as-usual growth rates projected in the Road-Map report).

FIGURE 5.11 CHARACTERISTICS OF GRID-CONNECTED FIXED FLAT-PLATE PV SYSTEMS

	2000	2010	2020
Capital ($/kW)	5,416	2,877	2,275
Fixed O&M ($/kW-yr)	56	23	17

[13] All costs reported here refer to the power output PVUSA test conditions (PTC) rating, which is defined as the AC output at 25 degree celsius ambient temperature. Caution should be used in comparing PV systems costs from other sources, as the cost per kilowatt at standard test conditions (STC), which refers to DC at 20 degrees celsius, will appear lower.

The projected system capacity factors were calculated assuming a typical fixed flat-plate PV system and using gridded solar resource data provided by the National Renewable Energy Laboratory. The average capacity factor for each state was calculated and input into the PROSYM model. No changes in capacity factor are projected over time, as the capacity factor is not driven mainly by changes in the efficiency of cells, but by the solar resource and (for fixed flat-plate systems) the module orientation. With more efficient PV modules, both the peak output and average output per unit area increase, with little change in capacity factor.

5.5 Summary of Renewable Energy Resource Potential

Figure 5.12 presents a summary of the levelized costs of renewable and efficient generation technologies, in ¢/kWh, assumed in this study. These figures include all costs associated with construction, fuel, and operations and maintenance (O&M), based on the information described in the previous sections. The investment tax credit for solar energy is included, but the production tax credit for wind energy is included only for 2000 because of its uncertain future. Extending this tax credit will make renewable resources more economical for generators. Biomass CHP and co-firing offer the least expensive forms of generation. Wind power costs are lower in areas with greater wind resources, and are expected to decline over time. Photovoltaics are expected to be significantly more expensive than other options currently available, but costs will decline over time.

Figures 5.13 and 5.14 present a summary of the renewable resources included in the Clean Energy Development Plan. Wind turbines present the most significant opportunity for new renewable capacity, particularly in the latter half of the study period. Combined heat and power using biomass offers the second largest potential for new renewables. Biomass gasification and photovoltaics play a much smaller role due to their relatively high costs, but are expected to become more commercially viable in later years.

Figure 5.12 Levelized Costs of Renewable Generation Technologies (¢/kWh) as Modeled in the Clean Energy Development Plan

	2000	2010	2020
Wind*			
Class 5	4.7	3.7	2.8
Class 4	5.4	4.2	3.2
Class 3	6.4	4.9	3.7
Solar PV			
CF 18 percent	48	25	20
CF 23 percent	37	20	15
Biomass**			
Co-Firing	2.5	2.5	2.5
CHP	2.3	2.3	2.3
Gasification CC	6.4	5.6	5.0

Note: All costs are at the busbar and are in constant 1999 dollars.
**Assumes a production tax credit in 2000 with a levelized value of 1 ¢/kWh. Not included in 2010 and 2020.*
***Assumes capacity factor = 85 percent and biofuel price = $1.9/MBTU for all biomass technologies.*

FIGURE 5.13 SUMMARY OF RENEWABLE RESOURCES INCLUDED IN THE CLEAN ENERGY DEVELOPMENT PLAN (2010)

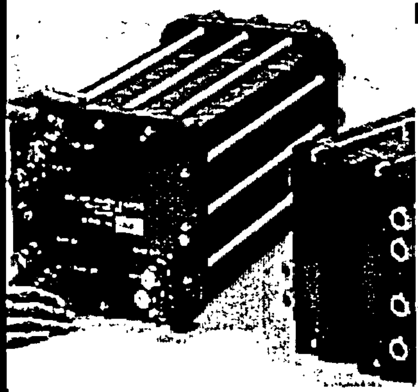
Generator Type	Installed Capacity (MW)	Percent of Total Capacity	Generation (GWh)	Percent of Total Generation
Wind Turbines	6,698	4.2	21,283	3.0
CHP – Biomass	2,949	1.8	23,881	3.4
Biomass Co-Firing	1,850	1.2	9,778	1.4
Photovoltaics	161	0.1	196	0.0
Biomass Gasification	75	0.0	536	0.1
Total	11,733	7.3	55,674	8.0

Note: This includes all renewables added after 2000. Totals may not add up precisely due to rounding.

FIGURE 5.14 SUMMARY OF RENEWABLE RESOURCES INCLUDED IN THE CLEAN ENERGY DEVELOPMENT PLAN (2020)

Generator Type	Installed Capacity (MW)	Percent of Total Capacity	Generation (GWh)	Percent of Total Generation
Wind Turbines	24,510	13.2	80,795	11.3
CHP – Biomass	6,003	3.2	48,527	6.8
Biomass Co-Firing	4,807	2.6	22,113	3.1
Photovoltaics	482	0.3	571	0.1
Biomass Gasification	575	0.3	4,049	0.6
Total	36,377	19.6	156,055	21.9

Note: This includes all renewables added after 2000. Totals may not add up precisely due to rounding.



6. Efficient Generation Technologies: Making the Most of Natural Gas

The Clean Energy Development Plan shows that it is possible to greatly reduce the Midwest's use of polluting fossil fuels. Nevertheless, it is unrealistic to expect that they will be replaced entirely by energy efficiency and renewable resources. The Midwest will continue to rely on fossil fuels to supply a large part of its energy demand. Thus, cleaner and more efficient fossil-fuel technologies should be deployed. To minimize carbon dioxide and other pollutant emissions, the new fossil-fuel technologies should use natural gas, which is a cleaner fuel than coal. Although natural gas plants emit less SO_2, NO_x, particulates and mercury pollution than coal plants, they also produce considerable CO_2 emissions that exacerbate climate change. Moreover, it is important that community environmental values be respected in determining where to site these large power plants. Natural gas should be viewed as a transitional fuel from our current energy path to a more sustainable energy future, rather than a long-term solution. The Clean Energy Development Plan focuses on three highly efficient technologies to use natural gas: fuel cells, combined heat and power systems, and district energy systems.

6.1 Fuel Cells

Background

As a modular, combustion-free power technology, fuel cells hold great promise for the future. Over the next two decades, they could be applied in cars, basements and central utility generating stations, replacing engines, boilers and turbines, and producing almost no noise or pollution. In the longer term, they could be an essential ingredient in a major transition to a hydrogen-based renewable energy economy.

Less than 30 MW of fuel cells are currently installed nationwide, but as major breakthroughs have recently been achieved, and more seem imminent, research budgets are skyrocketing. Fuel cell companies, automobile manufacturers and government agencies are expected to spend nearly $2 billion over the next few years to bring fuel cells to full-scale commercialization (California Air Resources Board July 1998). Driving them are four major attractive features of this technology: (1) generation efficiencies that could exceed 80 percent, higher than combustion technologies can achieve; (2) virtual elimination of most energy-related air pollutants; (3) modularity that will enable fuel cells to serve central, distributed and mobile applications, including the cogeneration of heat and power; and (4) the lack of moving parts, and therefore, nearly silent operation and reduced maintenance (Kartha 1997).

Simply put, fuel cells combine hydrogen (from the fuel source) and oxygen (from the air) in the presence of a catalyst to generate electricity, heat and water. Fuel cells are not new. First developed by Sir William Grove in 1839, they were considered little more than high school physics experiments until the late 1960s, when NASA used them to power the electrical systems of Gemini and Apollo spacecrafts. Steady progress now has brought fuel cells to the verge of commercialization.

Several companies are competing with variants of five basic fuel cell types: phosphoric acid, proton exchange membrane, molten carbonate, solid oxide and alkaline. Because automobile manufacturers expect the first fuel cell-powered cars to be market-ready by 2003-2005, PEMFCs have been attracting considerable press. PEMFCs also are suitable for small-scale distributed applications, such as building co-generation systems for homes and businesses. Higher temperature SOFCs or MCFCs may be more appropriate for larger utility-scale applications, however, because their potential for very high efficiencies (through reuse of high-temperature waste heat) may offset their higher initial cost. Westinghouse, Siemens and others are currently developing and testing hybrid systems that combine a SOFC with a gas turbine bottoming cycle to generate electricity from natural gas at efficiencies higher than 70 percent.

Widespread penetration of fuel cells now awaits major cost reductions resulting from research and development, and accumulated experience in manufacture and use. Today, PAFCs are commercially available at roughly $3,000/kW, but costs continue to drop across all fuel cell technologies. PEMFC technologies could, if mass

FIGURE 6.1 SELECTED FUEL CELL TYPES

	Proton Exchange Membrane	Phosphoric Acid	Molten Carbonate	Solid Oxide Ceramic
Projected application	Vehicles, mobile applications, residential systems	Medium-sized stationary power	Medium and large stationary power	Stationary power, potentially with hybrid turbine
Development Status	Demonstration units up to 50kW; 250kW within a few years	200kW commercial systems since 1993; one 11MW unit tested	Demonstration units up to 2 MW	Demonstration units up to 100 MW

produced, reach levels as low as $200/kW once the technology is fully mature. The other major challenge for fuel cells is the supply of hydrogen. Solar and wind systems will likely be the ultimate sources, by converting intermittent electricity into a dispatchable hydrogen resource through electrolysis of water. Fossil fuels, however, are likely to be the more cost-competitive hydrogen sources in the near term.[14]

Assumptions for This Study

Just as the strategy to create sustainable biomass markets through co-firing relies on the transitional use of coal, a strategy to commercialize fuel cells (for grid electricity) will likely rely on the use of natural gas in the near term. Grid applications for fuel cells, however, will require a significant policy commitment and market push, driven by the goals of technology learning, market development and local pollution reduction.

This analysis assumes that such policies would result in small numbers of fuel cells installed in each Midwestern state. Based on unpublished manufacturer estimates, central station fuel cells would cost $1,000/kW with a fixed O&M cost of $15/kW per year, and variable cost of $0.005/kWh. Insofar as this study does not consider the more promising near-term market for smaller-scale distributed fuel cells, this approach could be viewed as pessimistic.

6.2 COMBINED HEAT AND POWER

Combined heat and power (CHP), or co-generation, is a well understood technology with a long history. Because of ongoing technological improvements, CHP has great potential for energy savings, economic benefits and environmental improvement in industrial and community energy systems.

In the absence of CHP, manufacturing firms typically purchase electricity for various uses including motors, lighting and electro-chemical processes; they also purchase fuels for combustion in on-site boilers or furnaces to generate thermal energy (e.g., steam) for process requirements. The purchased electricity is generated at power plants distant from the industrial site, with an efficiency of 30 to 40 percent, as most of the energy content of the fuel is released as heat into the surrounding environment. Furthermore, energy losses of up to 10 percent occur in transmission and distribution of electricity from the power plants to the industrial site. The on-site thermal energy is produced at efficiencies in the neighborhood of 70 percent. Instead of such separate, and wasteful, generation of electricity and process heat, CHP systems generate electricity onsite and use the otherwise wasted heat to meet thermal requirements. With overall system efficiencies of up to 90 percent, the incremental efficiency of co-generating the electricity can be greater than 80 percent. For example, the McCormick Place Convention Center in Chicago uses a CHP system operated by Trigen Energy to achieve an 81 percent fuel efficiency rate, while reducing pollution from NO_x, CO_2 and SO_2. McCormick Place has received an EPA Energy Star award for environmental performance.

The development of new, efficient gas turbine technologies in a wide range of sizes suited to a variety of manufacturing, thermal and electricity needs, has increased the opportunities for industrial CHP at reduced costs. Expenditures for CHP equipment and increased on-site fuel use can be exceeded by reductions in electricity costs. With these advanced combustion turbines (or in the near future with fuel cells) using natural gas or biomass-based fuel inputs, very high efficiencies can be achieved along with low air emissions. Thus, industrial energy use, carbon emissions and pollutant emissions would be dramatically reduced, while continuing to provide a variety of needed energy services.

[14] Today, most hydrogen is produced from natural gas using well-established conventional chemical processes, at a conversion efficiency of roughly 70 percent. Another renewable option is to produce hydrogen from biomass, using an analogous process, but costs are likely to be much higher in the near term.

Estimates of policy-induced CHP in each state were derived from the national analyses in *America's Global Warming Solutions* (WWF and EF 1999). National process steam load and energy projections in the manufacturing industries were adjusted to reflect the mix of industries and their energy use in each state. The analysis of CHP in the paper and pulp industry is discussed in Chapter 5. For the manufacturing industries, this study assumes that on average, a mix of new and existing gas-fired industrial boilers (averaging 70 percent thermal efficiency) would be displaced by on-site gas-fired CHP at 75 percent efficiency (with 37 percent of the output as electricity and 63 percent as thermal). This would reflect a range of sizes, operating conditions, electricity/thermal mix, etc., and a range of costs (e.g., it is more costly to replace an existing boiler than a new one, and smaller units tend to be more costly). This study further assumes that 15 percent of manufacturing steam load would be shifted from boilers to CHP by 2010 and that this figure would double by 2020.

The analysis assumes that electric capacity, generation and fuel inputs in industrial CHP are incremental to meeting the thermal demands, and therefore there is no fuel switching. It also assumes that natural gas is used in the displaced boilers, and that additional natural gas is used to produce the same thermal output plus electricity in the CHP facilities. The net effects are incremental electricity output, natural gas input, emissions, and capital and operating costs – all of which occur onsite. Correspondingly, there will be reduced electricity, fuel inputs, emissions and costs from central station power plants.

6.3 District Energy

District energy systems provide thermal energy via steam or hot water pipelines to multiple customers within a specific geographic area for space heating, water heating, cooling or industrial processes. The district may be as small as several adjacent buildings within a commercial or industrial complex, or as large as a whole city. Frequently, DES co-generate electric power along with thermal energy for use by district energy customers or sale to a local electric utility.

DES have been around as long as there has been electric power generation. During the first half of the 20th century, citywide district heating systems were common in many northern U.S. cities. Residents and businesses would be supplied with heat from dedicated thermal plants or waste heat from nearby central station electric power plants. After World War II, low fuel prices made building-scale central heating systems more affordable, and migration to the suburbs shifted the markets for heating supply. Thus, large urban buildings were increasingly heated individually. Sometimes, the difficulties in siting new power plants in urban areas also were a factor, and that limited the expansion of district energy systems as urban populations grew. The result was a nationwide decline in DES usage, and an overall decrease in energy efficiency in U.S. cities.

Citywide DES are common in several European countries, including Denmark, Finland and the Netherlands. Although they no longer supply whole cities in the United States, some large district energy systems continue to supply thermal energy to customers in downtown areas. According to the U.S. Energy Information Administration, today there are almost 5,800 district energy systems in the United States – supplying thermal energy primarily to military bases, universities, hospitals, downtown office complexes and apartment buildings. Together they serve more than eight percent of commercial floorspace (DOE 1999). Most of the older district energy systems in this country are powered by old coal or oil-burning power plants. In most cases, these plants were originally built to supply electricity to the surrounding region. Back then, they supplied heat to local homes and businesses as a byproduct of their electric generation; today many often generate only steam, or may generate electricity only as the byproduct of their continued district heating service. Many other district energy systems upgraded their systems in the 1980s and 1990s, taking advantage of federal incentives under PURPA. Most of these newer plants are powered by highly efficient combined-cycle natural gas plants.

With the proper incentives, DES could see a major resurgence in this country. Today, low-emitting natural gas combined-cycle plants can be sited in even the smoggiest of urban areas. DES have great potential to reduce energy costs and pollutant emissions by replacing building boiler systems and central station electricity with co-generated heat and power.

One of the most significant areas for new growth potential with DES is in providing cooling services for downtown areas, especially where there is a large amount of commercial floorspace located in a relatively small area. With new high-efficiency absorption chillers driven by the thermal energy of steam or hot water, district cooling systems can enable buildings to reduce air conditioning costs, while helping to increase electric system reliability by reducing peak load. Nationwide, more than $1.7 billion was invested in DES over the last 10 years, mainly for new cooling systems; at least nine Midwestern municipal DES provide cooling (Thornton 1999).

FIGURE 6.2 EFFICIENT GENERATION TECHNOLOGIES INCLUDED IN THE CLEAN ENERGY DEVELOPMENT PLAN - 2010

Generator Type	Installed Capacity (MW)	Percent of Total Capacity	Generation (GWh)	Percent of Total Generation
CHP – Natural Gas	5,650	3.5	45,422	6.5
District Energy Systems	3,223	2.0	25,309	3.6
Fuel Cells	282	0.2	2,267	0.3
Total	**9,155**	**5.8**	**72,998**	**10.4**

Note: This includes all renewables added after 2000. Totals may not add up precisely due to rounding.

Construction costs for DES are on average about one-third higher than those for conventional heating and cooling technologies (DOE 1999). Significant fuel savings over the project's lifetime can offset the higher initial capital costs. In order to guarantee eventual capital recovery, however, DES developers must procure long-term contracts from potential district heating or cooling customers and/or power sales agreements with local utilities. The current restructuring of U.S. electric markets may make it more difficult to obtain long-term contracts for many new projects. Without such guarantees or specific incentives to invest, DES projects in many areas may find it difficult to attract investors. Moreover, DES projects are sometimes hampered by institutional barriers. Successful DES projects require close cooperation of local and state governments, and the community as a whole, to address the legal, financial, siting and logistical issues involved.

This analysis is based on the scenario assumptions for co-generation DES in *America's Global Warming Solutions* (WWF and EF 1999). That study assumed that 18.8 GW of capacity are installed by 2010, which will generate 152 TWh of electricity and nearly 328 trillion BTU of useful thermal energy (about 60 percent electricity and 40 percent thermal energy), for an overall efficiency of almost 74 percent. This study assumes that an additional two GW of capacity are displaced by thermally driven absorption chillers that replace some electric space cooling. As this study is only interested in the electricity production provided by DES, it assumes that building level commercial gas boilers are displaced by DES, with the marginal heat rate of electricity generation taken as the extra fuel needed for the DES divided by the electricity generated. Here, the marginal heat rate is 4.69 million BTU per MWh, an efficiency of 73 percent, which is far higher than typical existing, or even new, power plants.

The cost of the DES facilities, including the co-generation power plant and thermal energy delivery systems, is $1,578/kW installed, with O&M at $1.84 per MWh. Seventy-five percent of the electric capacity provided by the DES is assumed to contribute to reliability, to account for the fact that, notwithstanding the coincidence of heating and cooling demands with system seasonal peaks, the DES electricity is not strictly dispatchable. To obtain the impacts in the states studied in *Repowering the Midwest*, this analysis assumes that: (1) the 152 TWh would be reached by 2020 and half that by 2010; and (2) each state's share of the national total DES would equal the ratio of the state to national space heat plus hot water demand.

6.4 SUMMARY OF EFFICIENT GENERATION TECHNOLOGIES POTENTIAL

Figures 6.2 and 6.3 provide a summary of the efficient generation technologies included in the Clean Energy Development Plan. CHP offers the greatest potential, especially by 2020. Fuel cells play a much smaller role due to their relatively high costs, but are expected to become more commercially viable in later years, after the conclusion of the study period.

FIGURE 6.3 EFFICIENT GENERATION TECHNOLOGIES INCLUDED IN THE CLEAN ENERGY DEVELOPMENT PLAN - 2020

Generator Type	Installed Capacity (MW)	Percent of Total Capacity	Generation (GWh)	Percent of Total Generation
CHP – Natural Gas	12,230	6.6	98.286	13.8
District Energy Systems	6,446	3.5	50,470	7.1
Fuel Cells	3,257	1.8	25,925	3.6
Total	**21,933**	**11.9**	**174,681**	**24.5**

Note: This includes all renewables added after 2000. Totals may not add up precisely due to rounding.

7. Barriers to Implementing the Clean Energy Development Plan

The clean energy options described in the previous chapters are now technologically achievable and economically realistic. They will not, however, reach their full potential without significant public policy support. Coal plants and nuclear energy currently receive substantial financial subsidies and policy benefits. Implementing the Clean Energy Development Plan will require thoughtful and aggressive action beyond current business practices and regulatory policies. Energy efficiency and renewable energy resources are hindered by a variety of "market barriers" that prevent them from competing against coal and nuclear plants on a level playing field. Public policy steps to overcome these market barriers are needed to obtain the benefits of more energy efficiency and wind, biomass and solar power for a more diverse Midwestern electricity market.

Several Midwestern states have recently taken important steps to promote clean energy. Notable examples include the renewable resources and energy efficiency investment funds established in Illinois, the renewable set-aside requirements in Minnesota and Iowa, the green pricing programs in Wisconsin and Michigan, and the net metering provisions established in several Midwestern states.

Much more can be done, however. The Clean Energy Development Plan will not be achieved under current business practices and regulatory policies. Legislators, regulators, utilities, generation companies, producers of efficiency products and electricity consumers will have to make a concerted effort to shift away from current practices that rely heavily upon conventional fuels and less efficient processes.

The barriers to energy efficiency, renewable resources and distributed generation are discussed below. Policy options for overcoming these barriers are presented in Chapters 8 and 9.

7.1 Barriers to Energy Efficiency

Energy efficiency technologies offer customers a cost-effective means of lowering electric bills. Many efficiency options provide customers with savings as much as two to three times the cost of the measure. A wide variety of efficiency technologies have been commercially available for years, and more are brought into the market each year.

Despite the availability and economic benefits of efficiency, experience demonstrates that efficiency measures will not be realized without significant public policy support. Most customers are unaware of the wide variety of energy efficiency technologies that can lower their electric bills. Some efficient products are more difficult to obtain than conventional products, and they frequently require higher up-front costs in order to achieve robust economic savings. In sum, a number of market barriers inhibit energy efficiency from being adopted by customers and becoming a part of conventional market practices. The most prominent market barriers are summarized below (Geller 1999; Energy Innovations 1997).

1. There is a lack of information and training. Electricity customers often do not know enough about energy efficiency measures as an alternative to electricity consumption, even in those states where customers are provided a "choice" of electricity suppliers. Residential, business and government consumers need more information on the economic, productivity and environmental benefits of efficiency measures.

2. Some energy efficiency measures are produced and distributed on a limited scale and are not readily available to customers, builders, contractors or industries.

3. Residential customers, businesses and industries may lack the up-front capital for an energy efficiency product that can provide large economic savings over time, or may prefer to apply available capital to other investments.

4. Obtaining information, making an informed purchase and installing energy efficiency measures may incur high transaction costs of time, money and hassle.

5. Those in a position to implement energy efficiency measures often have different financial interests than the electricity customers who would benefit from the measures. For example, landlords and building owners make capital purchases and maintain buildings, while tenants frequently pay the energy bills. Similarly, at the time of new construction, a builder may have an incentive to minimize short-term costs, while the new owner would benefit from lower electricity bills over the long term.

6. Many buildings are constructed, products purchased and facilities renovated on the basis of minimizing short-term costs, not on minimizing long-term life-cycle costs, including electricity costs.

7. Customers may be skeptical of potential energy efficiency savings or may have doubts about whether an unfamiliar energy efficiency measure will work properly, which leads to risk avoidance.

8. Customers and producers seeking to minimize their own costs often do not account for the societal benefits of energy efficiency – particularly the environmental and economic development benefits.

9. There are institutional and regulatory barriers. Traditional rate-of-return regulation and rate caps reward electric utilities for increased sales. Hence, utilities may oppose otherwise sensible energy efficiency measures.

In economic terms, these barriers represent failures in the electricity market. They prevent producers and consumers from implementing the most cost-effective electricity resources. Consequently, the public policies presented in Chapter 8 are needed to address these market failures and enable energy efficiency resources to achieve their full economic potential.

7.2 Barriers to Renewable Resources

As described throughout this report, renewable resources offer a variety of benefits to generation companies, utilities, electricity customers and society in general. They offer fuel diversity, price stability, environmental benefits, improved reliability and economic development opportunities. Many renewable resources – particularly in the Midwest, with its vast wind potential – are affordable.

Despite all of these benefits, most renewable resources are underutilized. As is the case with energy efficiency, renewable resources face a variety of market barriers and market failures that inhibit their development. These barriers are summarized below (Geller 1999; UCS 1999).

1. There is limited infrastructure as some renewable technologies require equipment, fuels, materials and training that are less readily available than those for conventional electricity technologies. Manufacturers, distributors, installers, operators and others in the production chain are unwilling to develop a market where demand is limited; low demand increases early costs, which in turn slows any increase in demand.

2. Production scales are small. The current demand for renewable technologies is not enough to achieve the economies of scale through mass production that would drive down production costs.

3. Renewable resources tend to have relatively long payback periods because they require relatively high initial investments that are offset over time with low fuel and operating costs. Developers and utilities might be reluctant to accept the financial risks associated with long payback periods. They also might be wary of the costs and operational uncertainties associated with newer, unproven technologies.

4. Developers frequently have difficulty obtaining financial backing for renewable technologies because of the long payback periods. In addition, renewable developers sometimes must pay relatively high interest rates for financing because they incur greater transaction costs, and lenders assume that these unfamiliar technologies are a greater risk.

5. Because of their intermittent nature and remote locations, some renewable resources are subject to inequitable transmission policies. Current transmission pricing practices and developing regional transmission organizations focus primarily on policies that support large conventional generation facilities.

6. Many small renewable technologies, including distributed generation technologies, face a variety of institutional, interconnection and regulatory barriers when attempting to connect to a utility distribution grid. These barriers are discussed in Chapter 9.

7. One of the most important market failures is that the environmental, public health and other external costs of using fossil fuels and nuclear power are not included in the price of electricity, making it difficult for renewables to compete.

Policies to address these barriers to renewable energy development are presented in Chapter 8.

7.3 Barriers to Distributed Generation

Distributed generation resources are small generation facilities that can be deployed at many locations throughout an electric distribution system, often to meet a customer's load.[15] There are a variety of distributed generation technologies. Renewable technologies, such as small wind turbines and photovoltaics, can be used as distributed generation, as can efficient generation technologies, such as fuel cells, combined heat and power, and district energy systems. These will result in environmental benefits in the form of lower air emissions and reduced need for distribution facilities or even central generation facilities. Conventional technologies, such as gasoline and diesel generators, are frequently used as distributed generation. These should not be encouraged as part of the Clean Energy Development Plan, however, because of high air emissions.

Distributed generation technologies tend to face unique institutional, technical and regulatory barriers. Policies should be designed to overcome these barriers and to support those distributed generation facilities that provide environmental benefits (Greene and Hammerschlag 2000). In general, this would include technologies that do not rely upon combustion of fossil fuels – such as fuel cells, wind turbines and PV systems. Distributed generation technologies that use a combined heat and power process also tend to provide environmental benefits because they consume fossil fuels more efficiently than conventional technologies.

Policies to promote distributed generation technologies will play an essential role in the development of renewable resources. Many small renewable technologies currently face a variety of barriers that prevent them from connecting to a utility distribution grid. According to a recent study by the National Renewable Energy Laboratory, there are three main types of barriers facing distributed generation resources (NREL 5/2000):

1. Technical barriers arise from utility requirements to ensure engineering compatibility of interconnected generators with the grid. The most significant barriers include requirements to install equipment to protect utility property and maintain power quality. There frequently is a lack of clarity and understanding regarding whether and how distributed generation technologies should meet such technical requirements. In addition, technical standards for interconnection vary from state to state and from utility to utility. Even where such standards are reasonable in themselves, their diversity confuses customers and merchants, and hampers manufacturers in designing generators with regional appeal.

2. Business practice barriers are due to: (1) unclear or complex utility contracting practices; (2) utility procedures for approving interconnection; (3) utility application and interconnection fees; (4) insurance requirements; and (5) utility operational requirements. According to an NREL study, the "lack of utility experience in dealing with such issues may be one of the most widespread and significant barriers to distributed generation, particularly for small projects" (NREL 5/2000).

3. Regulatory barriers are created by tariff structures that apply to customers owning distributed generation facilities. For example, backup charges, exit fees and unfavorable buy-back rates make the distributed generation facility less economical. In some cases, utilities offer customers discounted electricity rates in order to prevent the installation of distributed generation facilities.

All of these barriers pose significant, although not insurmountable, challenges. To fully seize the potential for energy efficiency and renewable energy outlined in the Clean Energy Development Plan, the public policies presented in Chapter 8 need to be implemented.

[15] Sometimes the term "distributed resources" is used to include energy efficiency as well as generation facilities. Since energy efficiency is discussed separately, the term "distributed generation" in this section refers only to generation facilities.

8. Public Policies to Remove the Barriers to Clean Energy

The array of barriers to the robust development of smart and clean energy efficiency and renewable resources creates a compelling basis for aggressive public policies to enable the Midwest to fully tap its clean energy potential. These clean energy efficiency and renewable energy resources are technologically achievable and economically realistic. They will not, however, reach their full potential without significant public policy support.

Coal plants and nuclear energy currently receive enormous financial subsidies and policy benefits. Implementing the Clean Energy Development Plan will require thoughtful and aggressive action beyond business-as-usual practices and current regulatory policies. Energy efficiency and renewable energy resources are also hindered by a variety of market barriers that prevent them from competing against coal and nuclear plants on a level playing field. Public policy steps to overcome these market barriers are needed to obtain the benefits of more energy efficiency and wind, biomass and solar power for a more diversified Midwestern electricity portfolio.

Several Midwestern states have recently taken important steps to promote clean energy, but much more remains to be done. The key policies and action steps necessary to achieve the fundamental energy policy shifts and reach the goals of the Clean Energy Development Plan are presented below.

8.1 Policies to Promote Energy Efficiency Development

Public policies to promote energy efficiency should be designed both, to increase the market penetration of tried-and-true energy efficiency products and measures that produce demonstrable energy and cost savings, and to accelerate the use of new energy efficiency technologies in homes, businesses and public buildings. Market transformation strategies can be designed to overcome barriers in order to make efficiency technologies and practices commonplace and easily accessible to electricity consumers. The most important public policy options for promoting energy efficiency are listed in Figure 8.1 and presented below, in detail.

Figure 8.1 Policies to Promote Energy Efficiency Development

Energy Efficiency Investment Fund*	**Consistent Pollution Control Laws and Regulations**
Independent Third-Party Administrators for Energy Efficiency Investment Funds and Programs*	• Eliminate "grandfathering" of Old Coal Plants • Fair Allocation of Emission Allowances • CO_2 Reduction Policies
Improved Efficiency Standards and Building Codes*	**Tax Incentives for Energy Efficiency**
Implementation of Energy Efficiency Programs by Municipal Aggregators	**Wholesale Power Market Demand-Side Bidding**
Government Investment in Energy Efficiency	**Challenges for Utility-Directed Energy Efficiency Programs**

**Policy options marked with an asterisk are the leading policies recommended to achieve the Clean Energy Development Plan's energy efficiency development goals.*

Recommended Policies

Energy Efficiency Investment Fund

Each Midwestern state should establish an Energy Efficiency Investment Fund, or an equivalent mechanism, supported by a non-bypassable charge of 0.3¢ per kWh (less than one-third of 1¢) to support the robust energy efficiency initiatives of the Clean Energy Development Plan. All electricity customers should invest in the Fund, just as various decommissioning charges, franchise fees, utility taxes and other utility charges already apply to all customers on their electric utility bills. All customers will benefit from the cleaner air and improved health resulting from developing energy efficiency opportunities. The Energy Efficiency Investment Fund should be implemented as soon as possible and maintained at this level until at least 2010. At that time, the impacts of energy efficiency investments should be evaluated, and public officials and stakeholders should assess whether to modify the funding levels in order to fully achieve the Clean Energy Development Plan's energy efficiency target for 2020. Furthermore, ***Congress should enact legislation to provide substantial matching energy efficiency investment funds that can be used by the states to supplement or partially offset their investment funds.***

The concept of investing in energy efficiency is not new. An Energy Efficiency Investment Fund provides a competitively neutral source of funding for energy efficiency initiatives. As of August 2000, 17 states had established programs to promote energy efficiency. Illinois and Wisconsin have recently established new energy efficiency funds. These programs should be expanded significantly throughout the Midwest in order to achieve the full potential for energy efficiency identified in the Clean Energy Development Plan.

The Clean Energy Development Plan includes an annual investment in energy efficiency of roughly $3.5 billion by 2010. Investing 0.3 ¢/kWh, as proposed, would raise sufficient funds to cover about two-thirds of this investment. The customers participating in the efficiency programs would pay the remaining investments. This opportunity for smart energy efficiency improvements should be seized throughout the Midwest.

The Energy Efficiency Investment Fund approach can be used to: (1) provide financial and technical support for electricity customers to install energy efficiency measures in their homes, businesses, commercial and public buildings, and manufacturing plants; (2) develop statewide market development programs for new, highly energy-efficient appliances, such as refrigerators and clothes washers, and other technologies such as efficient lighting and motors; (3) design education, training, development and demonstration projects to help overcome specific institutional barriers to energy efficiency; and (4) directly install energy efficiency technologies and measures in targeted high-opportunity locations.

Direct installation programs often are among the most effective uses for energy efficiency investment because the entire market is supported – the manufacturing of energy efficiency products; the distribution and stocking of these products in stores; the training of the architects, engineers and contractors to use modern energy efficient products and technologies; and the education of customers who purchase these energy efficiency products.

Independent Third-Party Administrators for Energy Efficiency Investment Funds and Programs

The Energy Efficiency Investment Fund should be managed by an independent and highly capable third-party administrator – a not-for-profit organization or foundation or an appropriate public agency. A board including environmental and consumer organization representatives, state energy officials, and energy efficiency industry representatives should oversee the Energy Efficiency Administrator. The overall mission of the Administrator should be to transform the markets for energy efficiency products and services, and to maximize the long-term economic and societal benefits resulting from energy efficiency. The new $225 million Illinois Clean Energy Community Foundation, with its mission to improve energy efficiency and develop renewable energy resources, among other things, is one model of a third-party Energy Efficiency Administrator.

Third-party administrators avoid the conflicting incentives that utilities and power generators face. Third-party administrators can consider the successful development and implementation of aggressive efficiency programs to be the central mission and overriding business objective. Although some utilities have implemented energy efficiency programs in the past, many utilities and generation companies today are not really supportive of energy efficiency programs, because they have a strong financial incentive to maximize electricity sales at almost all times other than peak. That is why, for example, Wisconsin is transferring the management of energy efficiency and renewable initiatives from the utilities to public agencies and organizations. The Vermont Public Service Board also recently approved the creation of an Energy Efficiency Utility that would provide uniform energy efficiency programs throughout the state, using a single delivery mechanism.

Energy efficiency administrators should consider competitive bidding systems to identify efficiency initiatives with the greatest potential for achieving electricity savings and transforming the market. Competitive bidding can reduce costs and increase the effectiveness of efficiency initiatives.

The following principles should be considered as part of program design in order to maximize the benefits from increased implementation of energy efficiency:

1. Programs should overcome existing market barriers, both to ensure that energy savings are achieved in the short to medium term, and to promote the transformation of the efficiency market over the long term.

2. Programs should minimize lost opportunities that occur when efficiency measures are not installed when it is most cost-effective to do so (e.g., the construction of a new building or facility, or the purchase of new appliances or equipment).

3. Programs should provide efficiency savings to all customer classes and subclasses. Programs should be designed, however, to especially target residential, small business and public agency customers that generally lack internal energy engineering and technical capabilities, and have not yet been effectively reached by private sector energy services and management companies. Larger commercial and industrial customers typically have their own internal engineering and technical capacity, as well as available financing, or are targeted by specialized energy services companies.

4. Programs should be cost-effective: the program costs should be less than the long-term benefits of the efficiency savings, which include societal benefits, such as reduced environmental impacts, economic development gains and assistance to low-income customers.

Improved Efficiency Standards and Building Codes

More stringent energy efficiency standards and building codes should be applied throughout the Midwest. Commercial lighting improvements, more energy efficient windows, daylighting, and heating, venting and air conditioning (HVAC) efficiency are some of the most cost-effective opportunities for better environmental performance in the Midwest. Each of the Midwestern states should: (1) evaluate its current efficiency standards and building codes; (2) upgrade outdated codes and standards; and (3) establish monitoring and enforcement practices to ensure that revised standards and codes are implemented. States should coordinate their efforts to provide regional consistency.

Efficiency standards are key for new appliances and other equipment that are used on a mass basis and consume electricity. Ratcheting up the efficiency of refrigerators and air conditioners, for example, can produce huge overall energy savings. Similarly, building code reforms that set minimum efficiency standards for the design and construction of new and renovated buildings target some of the biggest opportunities for energy savings.

Efficiency standards and building codes directly transform the market for energy efficient products, designs and services. Over time, they can permanently remove certain inefficient products and practices from the market. They encourage all manufacturers, designers, architects and builders equally and simultaneously. They also encourage all customers, not just those who are better informed, more motivated or more concerned about energy consumption and environmental impacts. They create a technology "pull" on the market for more efficient products, and they immediately overcome many of the market barriers to energy efficiency.

There are significant opportunities to improve existing efficiency standards and building codes in the Midwest. While the federal government has already established efficiency standards for some appliances and products through the National Appliance Energy Conservation Act of 1987 (NAECA) and the 1992 Energy Policy Act, these standards can often become out-of-date as technologies improve. Similarly, many states have efficiency-related building codes on the books, but most are behind the times. The Energy Policy Act requires all states to adopt at least the "good practice" commercial building code, and to consider upgrading their residential building code to meet or exceed the "good practice" code.[16] Nevertheless, not all states have complied with the Act's requirements and suggestions. Furthermore, these codes do not always incorporate the best efficiency practices, and often they are not adequately monitored or enforced.

Efficiency standards and codes are most effective when they cover a broad region, thus applying consistent requirements to manufacturers and easing the education and training of designers, builders and building code officials. That is why it is preferable, and likely to be more cost-effective, for the Midwestern states to coordinate their efforts. Still, individual states can adopt more aggressive standards and codes on their own. California's groundbreaking 1974 efficiency standards paved the way for other states to adopt similar requirements, and eventually for the existing national standards. In the Midwest, Minnesota has strict energy efficiency standards in its building codes for commercial and multi-family construction.

Efficiency standards and building codes are cost-effective means of achieving energy savings. They increase the economies of scale for producing efficiency measures by making efficient products and designs the normal practice. One study found that, by the year 2015, the U.S. efficiency standards required by NAECA and the Energy Policy Act would reduce U.S. annual energy use by 4.3 percent, save energy consumers approximately $140 billion (in 1993 present value dollars), and eliminate the need for roughly 80,000 MW of new generation capacity. The benefit-cost ratio of these standards is more than 3:1 – i.e., $3 of energy savings are produced for every $1 spent on more efficient measures. The energy savings from the federal efficiency standards are among the highest of any conservation policy pursued in the United States – substantially greater than utility-run energy efficiency programs (ACEEE 1996).

In addition to the success of the federal efficiency standards, states can cost-effectively achieve additional savings by going beyond those standards. A recent study estimated that the 10 Midwestern states can achieve electricity savings of roughly 7,785 MWh by 2010 and 20,499 MWh by 2020 by updating the federal efficiency standards for seven key electricity end-uses: clothes washers; fluorescent ballasts; central air conditioning and heating pumps; water heaters; transformers; commercial air conditioners and heat pumps; and commercial furnaces and boilers. Upgrading these efficiency standards would create a net economic savings of $3,676 million in 2010 and $8,029 million in 2020 for the 10 Midwestern states(ASAP 2000).

A 1994 study of efficiency standards in Illinois identified 14 product types that were not already covered by standards, but for which standards are probably justified. The study also concluded that although many individual municipalities in Illinois had adopted building energy codes, the lack of consistency resulted in poor compliance levels (ACEEE 1994).

Additional Policies

The policies described above are the most important for achieving the Clean Energy Development Plan's goals. However, the following additional policy options should also be considered.

Implementation of Energy Efficiency Programs by Municipal Aggregators

Municipal aggregators may be well positioned to implement energy efficiency programs. Ohio, for example, has passed legislation that allows municipal governments to act as power supply aggregators. This approach helps ensure that all customers – regardless of size, type or means – will have an aggregator seeking to purchase the best power supply on their behalf.[17]

Municipal aggregators are a natural entity for implementing energy efficiency programs. States could provide them, rather than the local utility, with funds to implement energy efficiency programs. Municipal aggregators will likely take a fundamentally different approach to energy efficiency than utilities – one that is more consistent with an overall goal of lowering electricity costs.

There are other reasons to recommend municipal aggregators. They may have a broad network of local contacts – town halls, schools, churches, hospitals, chambers of commerce and other civic organizations – to assist with marketing and delivery of efficiency programs and with market transformation in general. Municipal aggregators can provide a number of forums, such as town meetings, for residents and customers to

[16] Good practice residential energy code is defined as the 1992 (or more recent) version of the Model Energy Code, and good practice commercial energy code is defined as the ASHRAE 90.1 – 1989 model standard (ACEEE 12/1999).

[17] Municipal aggregation laws usually have an opt-out provision, to ensure that customers who wish to use other power suppliers can do so.

express their views on the types of energy efficiency programs that can best meet their needs. Municipal aggregators have an interest in local economic development and environmental improvement, and they can factor these benefits into their cost-effectiveness assessments. Finally, municipal aggregators are not motivated by the financial impacts on any particular utility, and can therefore offer societally cost-effective fuel-blind and fuel-switching programs.

Government Investments

Federal, state and local government agencies should implement smart and sensible energy efficiency technologies and practices to save electricity. Government as a whole is the largest single consumer of energy and electricity in the nation. Public agencies' investments in energy efficiency can significantly advance the infrastructure for manufacturing, distributing, installing and operating efficiency products. In short, government can help transform the market for efficiency measures and products.

Government investments in energy efficiency can save taxpayers money by reducing energy bills and can produce environmental benefits that are enjoyed by all citizens, but tend to be undervalued in the electricity market. Likewise, efficiency investments can promote job creation and economic development in this sector.

Consistent Pollution Control Laws and Regulations

Environmental regulations perform a vital role in protecting public health and achieving environmental goals. Pollution control regulations applied to the electricity generating sector will tend to support energy efficiency by increasing the costs of conventional generators and placing greater value on cleaner electricity resources.

Environmental regulations must be properly designed and uniformly enforced to ensure that they are applied fairly to all electricity resources. The federal Clean Air Act applies many regulations in a differential manner to coal plants built before 1977 (so-called "old sources") and plants constructed later ("new sources"). The pollution control standards for new sources are much more stringent, and the grandfathering of the highly-polluting older coal plants allows the owners to avoid the costs of installing modern pollution control equipment, thereby providing an unfair competitive advantage over newer fossil fuel plants and cleaner electricity resources such as energy efficiency.

Two steps are necessary to ensure that the pollution control laws treat energy efficiency resources fairly. First, the grandfathering provisions in the Clean Air Act should be eliminated. Second, cap-and-trade systems should be designed to ensure that energy efficiency resources obtain a fair amount of free emission allowances. For example, states that establish NO_x allowance trading schemes in response to the EPA's SIP Rule should require that qualified efficiency resources are provided with NO_x allowances on the same basis as existing coal plants. This also is important for renewable resources and is discussed in Section 8.2.2

Furthermore, as presented in Section 8.4, environmental policies that are explicitly designed to reduce CO_2 emissions will provide substantial support for energy efficiency, which is the most cost-effective means to achieve this goal.

Tax Incentives

Tax credits can be provided to individuals and businesses that purchase and install qualifying, innovative energy efficiency measures. The goal is to reduce the financial barriers that many customers face when purchasing energy efficiency equipment, and to stimulate the development of certain advanced technologies that have not yet reached commercialization. Tax credits could come from both federal and state governments.

It is important that tax incentives be designed to achieve the greatest impact on the efficiency market. The following key principles should be considered in designing tax incentives (ACEEE 7/1999):

1. Seek to stimulate commercialization of advanced technologies that have not yet been established in the marketplace.

2. Establish performance criteria for manufacturers to meet, and pay the incentives as qualifying products are sold.

3. Pay incentives large enough to influence business and residential consumers' decision-making, and to cover a sizable fraction of the incremental, up-front cost of the energy efficiency product.

4. Apply tax incentives to only those technologies where the initial investment is a major barrier.

5. Be flexible with respect to what entity receives the tax credits: in some cases it may be most effective to provide the incentives to manufacturers, while in others it may make more sense to target technology users.

6. Complement other policy initiatives, such as the Energy Star labeling programs and other market transformation efforts.

7. Select priorities based on potential impact, cost-effectiveness, private sector interest and support, and likelihood of success.

8. Allow adequate time for qualifying technologies to become commercialized.

Wholesale Power Market Demand-Side Bidding

In regions where the electric industry has been restructured and there is a wholesale electricity spot market, demand-side bidding could be implemented to allow customers to be paid the market clearing price for curtailing their load. Demand-side bidding offers many benefits to the electricity system as a whole, including increased reliability, less price volatility and reduced market power problems. Demand-side bidding provides many benefits over traditional utility-based interruptible programs because it offers payments to customers based on market prices, and is far more flexible in terms of which customers can participate and when.

Challenges for Utility-Directed Energy Efficiency Programs

Repowering the Midwest recommends using new, independent third-party Energy Efficiency Administrators to design and implement state programs to improve energy efficiency for the reasons presented in Section 8.1.1. In the past, many electric utilities implemented energy efficiency programs. Utilities were a logical choice because they have an existing delivery mechanism, their customers could benefit from reduced electricity costs, they have the necessary infrastructure for raising capital, and these actions could be encouraged through state utility regulatory processes.

As the electricity services market becomes more regional and competitive, however, many utilities have been reluctant to implement energy efficiency programs in their local service territories because the energy savings can lead to lower sales and revenues. Throughout the United States, utility investments in energy efficiency and load management have declined from a peak of $2.7 billion in 1993 to $1.6 billion in 1998 (ACEEE 2000); for energy efficiency, as opposed to peak-shaving load management, they are probably even lower today. Distribution-only utilities face many of the same financial impacts from energy efficiency actions as vertically integrated utilities, and most do not see improved energy efficiency on the customer-side of the meter as a preferred business strategy, except in limited cases (e.g., where there are transmission or distribution constraints) for responding to the new market structure.

The Midwestern states are at a transitional time when it comes to implementing changes in their historic utility regulatory systems. Two states – Illinois and Ohio – have enacted comprehensive restructuring legislation. Two other states – Michigan and Wisconsin – have passed significant legislation that has restructured the prior system in major ways. On the other hand, other Midwestern states have generally maintained their longstanding utility regulatory systems and have not enacted significant deregulation laws. Moreover, even the traditional utility regulatory system differed significantly from state-to-state on the ratemaking treatment related to energy efficiency programs.

At this time, utility-directed energy efficiency programs may make sense in limited circumstances or in particular states, but the independent third-party Energy Efficiency Administrator is the preferred approach to best achieve the potential of the Clean Energy Development Plan.

8.2 Policies to Promote Renewable Energy Resource Development

Policies to encourage renewable resources should acknowledge and help overcome the market barriers discussed above. It is important to recognize that renewable energy technologies tend to follow a product cycle – typical of all new technologies – that has five stages of development: (1) basic science and research; (2) bench-scale testing; (3) prototype development; (4) initial commercial availability; and (e) competitive, mature product (Jefferiss and Haddad 1999). Some of the renewable technologies proposed in the Clean Energy Development Plan have already reached the initial commercial availability stage, while others are still in the developmental stages. Public policies should recognize that various renewable technologies might be at different stages of development, and should explicitly seek to advance these technologies through the product cycle.

One key strategy for advancing the commercial availability of renewable technologies is through "sustained orderly development." This explicitly recognizes that in order to become mature, competitive products, renewable technologies must be manufactured and deployed at a high enough rate to achieve economies of scale and lower production costs. Sustained orderly development is a technique for jumpstarting the renewable energy industry by promoting enough resource development to achieve high manufacturing rates and enable the technologies to become commercially viable.

The most important public policy options for promoting renewable energy resources are listed in Figure 8.2 and presented below, in detail.

Recommended Policies

Renewables Portfolio Standard

Each Midwestern state should promptly establish a Renewables Portfolio Standard (RPS) that requires all retail electricity suppliers to include a specified percentage of renewable resources in their generation mix. The RPS percentage requirement should increase steadily each year to reach eight percent by 2010 and 20 percent by 2020. In states that have adopted electric industry restructuring legislation, the RPS should apply to all customers, including "standard offer" or "default" customers served by electric distribution companies. RPS standards should be applied to each product provided by a retail electricity seller, as opposed to being applied to the company's overall sales on average. This ensures that the RPS will be applied for the benefit of all customers. **Ideally, a national RPS would be enacted, in addition to a regional RPS policy for the Midwest as a whole.**

A RPS is one of the most important policies for promoting renewable resources. It is market-based, and relies upon competing generating companies to develop the technologies necessary to achieve the targeted level of renewable resources. As of August 2000, minimum renewable energy requirements have been adopted in Connecticut, Iowa, Maine, Massachusetts, Minnesota, Nevada, New Jersey, Pennsylvania, Texas, Arizona, New Mexico and Wisconsin (UCS 2000). A RPS also has been proposed in at least six federal electricity restructuring bills.

The RPS percentage standard should be met by only new renewable energy generation so that it will support the development and commercialization of new resources and technologies. Otherwise, generators would simply repackage existing wind and solar power, and no net environmental and economic development benefits would be obtained. The RPS should not be applied to hydropower and other technologies that are already mature and cost-effective.

Figure 8.2 Policies to Promote Renewable Energy Resources Development

Renewables Portfolio Standard*	**Policies to Support Green Power Marketing** • Environmental Disclosure Requirements • Systems to Account for Generation Attributes • Certification Standards
Renewable Energy Investment Fund*	
Independent Third-Party Administrator for Renewable Energy Investment Funds and Programs*	**Consistent Pollution Control Laws and Regulations** • Eliminate grandfathering of Old Coal Plants • Fair Allocation of Emission Allowances
Fair Transmission Access and RTO Policies*	
Federal Production Tax Credit for Renewables*	**CO_2 Reduction Policies**
Additional Tax Incentives	**Government Purchases of Renewables**
	Elimination of Fossil Fuel and Nuclear Subsidies

**Policy options marked with an asterisk are the leading policies recommended to achieve the Clean Energy Development Plan's renewable energy resources development goals.*

Policymakers should consider including a renewable credit trading system in the RPS that is designed to assure improvements to local air quality through renewables development in all states. Qualifying renewable energy generators in the Midwest would produce credits that could be sold to all retail electricity suppliers in the region. Tradable credits would make the renewables market significantly more flexible and fluid, and would enable all states to take advantage of the most cost-effective renewable resources available in the region. They also ease administration of an RPS by providing a concrete and verifiable system for reporting how much renewable generation was purchased by each retail supplier.

Renewable Energy Investment Fund

Each Midwestern state should establish a Renewable Energy Investment Fund, or an equivalent mechanism, supported by a non-bypassable charge of 0.1¢ per kWh (one-tenth of 1¢) to support the robust development of wind power, biomass energy and solar power. All electricity customers should invest in this Fund because, just as with the Energy Efficiency Investment Fund, various decommissioning charges, franchise fees, utility taxes and other utility charges already apply to all customers on local electric utility bills. All customers will benefit from the cleaner air and improved health resulting from developing renewable energy resources. The Renewable Energy Investment Fund complements the Renewables Portfolio Standard, which largely supports technologies that are already close to commercial viability. The Investment Fund also will advance technologies that are still in the developmental stages. The Renewable Energy Investment Fund should be implemented as soon as possible and maintained at this level until at least 2010. At that time, the impacts of the renewables investments should be evaluated, and public officials and stakeholders should assess whether to modify the funding levels in order to achieve the Clean Energy Development Plan's renewable energy resources target for 2020. Furthermore, **Congress also should enact legislation to provide substantial matching renewable energy investment funds that can be used by the states to supplement or partially offset their investment funds.**

The Renewable Energy Investment Fund should focus on development and demonstration projects that:

1. Support technologies that are not immediately competitive (even with an RPS) but offer great long-term potential, such as solar photovoltaics, fuel cells and small wind turbines.
2. Leverage private investment and familiarize private investors with the potential for renewable energy.
3. Support training, education, development and demonstration projects to help overcome specific institutional barriers to renewable resources.
4. Target those technologies that offer special economic or environmental benefits for a particular state.

The investment of 0.1¢/kWh would raise about $730 million per year throughout the Midwest. This opportunity for renewable energy investment and development should be seized throughout the Midwest.

Independent Third-Party Administrators for Renewable Energy Investment Funds and Programs

The Renewable Energy Investment Fund should be managed by an independent and highly capable third-party administrator – a not-for-profit organization or foundation or an appropriate public agency – that should be overseen by a board including environmental and consumer organization representatives, state energy officials and renewable energy industry representatives. Competitive bidding processes, such as "reverse auctions," should be emphasized to most effectively deploy these renewable energy investment and development funds. Funding should generally focus on production incentives which are typically more efficient than investment incentives, because they encourage least-cost electricity production, not just capital investment. Financial incentives should take into account the above-market costs of the renewable technologies on a life-cycle basis. The rationale for the creation of independent third-party administrators for the Renewable Energy Investment Funds' programs is largely the same as presented above for the Energy Efficiency Investment Funds.

Fair Transmission Access and RTO Policies

Transmission pricing policies and power pooling practices should treat renewable energy resources fairly. They must account for the intermittent nature of wind and solar power operations, and their generally smaller scales and remote locations. Transmission policy reform is necessary to ensure that renewable energy generators have full and fair access to the grid. Some of the most important transmission reform steps are:

1. The regional transmission Independent System Operators (ISO) and Regional Transmission Organizations (RTO) should have governance structures that reasonably include representation of both environmental advocacy organizations and renewable energy generators. They should not be dominated by transmission owners or owners of conventional generation technologies.

2. Pancaked transmission rates – the practice of layering on new transmission charges in each utility or control area that power is delivered through – should be eliminated wherever possible and minimized elsewhere.

3. Postage stamp rates – where one price is applied to transmit power anywhere within a region – should be encouraged.

4. Real-time balancing markets should be established to allow generators to buy or sell firm transmission capacity that deviates from the amount reserved in advance.

5. Spot-market bidding systems should not penalize renewable energy producers that have intermittent and unpredictable generation patterns.

6. Transmission congestion management systems should not impose penalties on, or deny benefits to, remote, intermittent renewable generators.

7. Ancillary services for renewables generators' purchases and sales should be priced fairly.

8. Public and private stakeholders should consider establishing renewable power exchanges in order to facilitate the scheduling and transmission of renewable generation.

9. Net metering and fairer interconnection policies should be implemented as explained in Section 8.3.

Federal Production Tax Credit

The federal production tax credit (PTC) for renewable energy should be extended. The PTC is currently scheduled to expire at the end of 2001, but it is justified by sound policy and should be extended in order to facilitate the robust development of renewable energy resources. The PTC currently covers wind and closed-loop biomass, but should be expanded to cover solar power as well. This tax incentive has been a powerful force in achieving the wind energy development seen in the Midwest to date, and can help renewable energy overcome existing market barriers.

ADDITIONAL POLICIES

The policies described above are the most important for achieving the Clean Energy Development Plan's goals. The additional policy options described below should also be considered.

Additional Tax Incentives

Federal and state governments should provide targeted tax incentives to support the development of renewable generators. In addition to the important extension of the federal PTC for renewables identified above, the following additional focused options should be considered:

1. Investment tax credits can provide the owner or developer of a renewable generator with a tax reduction based on some portion of the initial capital investment of the facility.

2. State and local sales tax reductions can be offered to the owners of renewable generators. The per-kWh sales tax is high for owners of renewable generators relative to owners of conventional generators, because fossil fuel inputs are exempt from sales taxes. A sales tax reduction for renewables helps offset this imbalance.

3. Property tax reductions can be offered to the owners of renewable generators. Because of their relatively high initial capital costs as opposed to very low fuel costs – $0 for wind and solar – renewable generation owners may sometimes pay relatively higher property taxes than owners of coal, gas and nuclear generation. A property tax adjustment for renewables can offset this imbalance.

4. Accelerated tax depreciation schedules can be used to provide tax benefits in the early years of a new renewable generator. The federal government already provides renewables with a five-year accelerated depreciation schedule. States can provide the same opportunity.

A few considerations are important when evaluating the opportunities for tax incentives. Production tax credits are sometimes favored over investment tax credits because they provide incentives for efficient construction and operation of the facility. Any tax reduction is only valuable to the extent that the renewable resource owner is subject to tax liability. Stability in the amount and duration of the tax incentive is very important for renewable project developers and financiers. Nonprofit and governmental agencies (e.g., cooperatives and municipal utilities) are not subject to taxes, and thus alternative support mechanisms should be considered.

Policies to Support Green Power Marketing

Some electricity customers have demonstrated a willingness to pay a premium for renewable resources, and some generation companies have offered such "green power" products as a way to differentiate themselves from competitors. Some regulatory policies are necessary to better enable customers to make an informed choice among green power products and ensure that the market works properly.

First, all retail electricity suppliers should provide consistent and comprehensive environmental data that informs all customers of the mix of the generation resources being offered and their environmental characteristics. Environmental disclosure removes informational market barriers. It enables consumers who wish to choose among competing electricity suppliers based on environmental characteristics to make an informed choice based on consistent data. Furthermore, state environmental disclosure laws prevent inaccurate or misleading claims by suppliers about how "green" their power is. Illinois has adopted a comprehensive disclosure law and set of administrative regulations that have been in operation for two years and can serve as a model for other Midwestern states.

Second, standards should be established to track and account for generation attributes (e.g., fuel type, air emissions, other environmental impacts) to ensure that green power marketers actually produce the promised green power and that the same renewable energy is not sold more than once.

Third, standards should be established to identify and certify generation that qualifies as green power. This will help to assure customers that the power they are purchasing will actually result in environmental improvements and reduce potential consumer confusion in determining what is green power and what is not.

Green power purchasing by individual residential and business consumers is important, but cannot alone substitute for the broader public policy and market development measures presented in this chapter. Utilities' green pricing programs do laudably spur renewables development, but they are not consistent with the widely-accepted "polluter pays principle" because they impose a cost on some customers but not others – even though all customers benefit from clean energy development and all equally bear the burdens of higher pollution and social costs from fossil fuel and nuclear plants.

Consistent Pollution Control Laws and Regulations

As discussed in Section 8.1, environmental regulations perform a vital role in protecting public health and achieving environmental quality goals such as clean air and water. Pollution control regulations applied to the electricity generating sector will tend to support renewable energy development by increasing the costs of conventional generators and placing greater value on cleaner electricity resources.

Two policy changes in the pollution control laws should be made. First, the "grandfathering" provisions in the Clean Air Act should be eliminated. These provisions support and, in effect, subsidize continued pollution from old, inefficient coal plants, create market distortions and thus reduce the potential for renewable energy resources development.

Second, SO_2 and NO_x cap-and-trade programs should be changed because they tend to attribute insufficient value to efficiency and renewable resources by primarily (or only) encompassing fossil fuel resources. The SO_2 allowance allocation scheme provides most of the initial allowances to existing fossil-fueled plants.[18] Most of the proposed NO_x cap-and-trade systems tend to heavily favor existing fossil fuel sources in the initial allocation of NO_x allowances.[19]

[18] The 1990 Clean Air Act Amendments included a reserve of allowances for energy efficiency and renewable resources, but the conditions placed on the reserve were such that they were underutilized.

[19] In the federal Ozone Transport Commission's NO_x Budget program, some states allocate all of the free NO_x allowances to existing fossil-fueled plants. In the EPA's NO_x Budget Trading Program, the EPA recommended setting aside some NO_x allowances for new sources, renewable resources and energy efficiency. However, new source set-aside allowances will ultimately be decided at the state level, and only a few states have proposed set-asides for renewables and efficiency (Synapse 1999).

When allowances are allocated primarily to existing power plants, opportunities to promote cleaner resources for meeting national air quality standards are bypassed. In addition, existing generation sources are provided with an inequitable competitive advantage in the electricity marketplace. The sum of the reduction in compliance costs from allocation of both SO_2 and NO_x allowances to existing sources could be as much as $3.5/MWh (Synapse 1999). This is approximately 10 percent of the cost of generating electricity, and will likely be an important factor in the operating economics of some generation units. This advantage to existing fossil fuel generators will be even larger if a similar cap-and-trade system is adopted for CO_2 emissions.

An emission performance standard (EPS) should be explored to replace existing regulations for NO_x and SO_2. The EPS would apply equally to existing and new generation plants. This standard would be determined in such a way as to achieve the desired environmental objective (e.g., New Source Review requirements and the EPA NO_x SIP Rule). It would determine caps on NO_x and SO_2 emissions, and allowances would be based on those caps. The emission performance standard should be output-based (i.e., lb/MWh), in order to encourage efficient approaches to reducing emissions.

NO_x and SO_2 emission allowances would be allocated to new natural gas plants, energy efficiency and renewable energy generators, as well as to existing plants.[20] Nuclear generators should not be allowed to receive any emission allowances, because nuclear plants produce large amounts of other pollutants (e.g., high-level and low-level radioactive nuclear wastes, air pollution from uranium processing, water pollution from thermal discharges) that impose significant environmental and public health costs on the public that are not covered in the Clean Air Act's emissions cap-and-trade programs. Similarly, hydro power plants should not be allowed to receive any emission allowances because they can also impose significant environmental quality costs.

Government Purchases

Federal, state and local government agencies can help drive and develop the clean energy market by purchasing renewable energy as part of their overall power procurement. Government is the largest single consumer of energy and electricity in the nation. Green energy procurement policies can help to: (1) jumpstart and develop the infrastructure necessary to support new renewable energy technologies; (2) overcome financial agencies' concerns about risk and uncertainty of future demand for renewables; and (3) promote economies of scale for the production of renewables technology that may also achieve local economic development benefits.

The City of Chicago has taken a national leadership role by spurring solar energy use and business development. The City's guaranteed purchase of solar photovoltaic panels – to be used on public schools, museums and public buildings – helped attract Spire Solar to build a new manufacturing plant on a brownfield area on the West Side of Chicago that will provide new jobs in the community.

The City of Chicago's green power purchase initiative, starting in 2001, for the city, certain suburbs and other local public agencies, will likely spur broader development of renewable energy in Illinois and the Midwest. The city's request for proposals, issued in 2000, calls for a total of 400 MW of electricity, including at least 80 MW of green power defined as "new" renewable energy resources. At least one-half of the green power is likely to be supplied by wind power. The city's RFP also includes preferences for green power to be developed in Illinois and for air pollution reduction measures.

Government procurement practices are important, but should not stand alone; rather, they should be part of a broader strategy to help commercialize renewables by building upon other public policies, market development and business network efforts.

Elimination of Fossil-Fuel and Nuclear Subsidies

Fossil fuel and nuclear generation currently enjoy massive federal and state government subsidies in the form of tax breaks, research and development, and protection from nuclear accident liability. In recent years, renewable technologies have also received much more modest public support through research and development funding and production tax credits. The overwhelming amount of government subsidies, however, has flowed to conventional generation technologies:

1. A recent study concluded that the federal government subsidies from 1943 through 1999 to nuclear, wind, photovoltaic and solar thermal electric generation technologies totalled $151 billion (in 1999 dollars). A staggering 96 percent of these subsidies ($145 billion) went to nuclear generation

[20] In this approach, there would be no need to create a "set-aside" for efficiency or renewable resources, because they would simply be allocated a share of emission allowances in proportion to the amount of electricity they produce or save. In the past, "set-asides" have tended to be unduly restrictive (Synapse 1999).

technologies, while only four percent ($5 billion) went to renewable technologies (REPP 7/2000).

2. The Department of Energy budgets have consistently favored coal and nuclear generation. For example, in fiscal year 1996, the DOE budget included a total of $1,300 million for nuclear technologies, radioactive waste and fossil fuels, but only $273 million for all renewable energy technologies combined (UCS 1999).

3. Renewable technologies have a higher tax burden than conventional generation technologies because they do not have fuel expenses to deduct, they cannot benefit from "depletion allowances" that allow companies to deduct the loss of fuels that have been mined or drilled, and they tend to pay higher property and income taxes (UCS 1999).

The amounts and allocations of these government subsidies do not reflect sound public policy and should be changed. Fossil fuel and nuclear generation produce environmental and public health harms. Their subsidies should be phased out and eliminated, both for sound public policy reasons and to create a more level playing field in the emerging competitive electricity services market.

8.3. Policies to Promote Clean Distributed Generation Development

Clean distributed generation resources – such as fuel cells, small wind turbines and solar panels – can be deployed at many locations throughout an electric distribution system. They can enhance generation reliability by providing power when and where most needed, as well as in remote locations where it is costly and/or difficult to run power lines. They can also enhance distribution reliability by providing grid support to relieve stress on aging electricity delivery systems especially in urban and suburban areas, such as Chicago, that have recently been plagued by recurring power outages. In some cases, distributed resources may avoid the need for transmission line extensions as sprawl pushes development beyond existing suburban areas. Policies should be designed to support clean distributed generation technologies, including small turbines, solar photovoltaic panels and fuel cells. There is a distinct difference between desired policy support for these clean technologies, as opposed to diesel generators and other dirty distributed generation that may also provide power to enhance reliability in specific locations, but at the cost of excessive air pollution.

The most important public policy options for promoting clean distributed generation are listed in Figure 8.3 and presented in detail below.

Recommended Policies

Regulatory policies to promote distributed generation should effectively target those most likely to take action – for example, customers or utilities. The policies discussed below are designed to encourage electricity customers to install and operate distributed generation whenever and wherever they will cost-effectively improve the reliability of the customer's service or reduce the customer's overall electricity costs.

Net Metering

Net metering for clean distributed generation technologies should be enacted and implemented in all Midwestern states. Federal legislation to adopt net metering nationally would be appropriate as well.

Net metering allows customers who own clean renewable generators to sell their excess power – beyond what they

FIGURE 8.3 POLICIES TO PROMOTE CLEAN DISTRIBUTED GENERATION DEVELOPMENT

Net Metering*	**Reduce Ratemaking Barriers to Clean Distributed Generation**
Uniform Safety and Power Quality Standards*	**Define Conditions for Customer's Right to Interconnect**
Standardization Interconnection and Business Terms*	**Focused Exploration of Niche Applications**
Apply Clean Air Laws and Regulations to Small (Dirty) Distributed Generators*	**T&D Planning and Upgrade Policies**

**Policy options marked with an asterisk are the leading policies recommended to achieve the Clean Energy Development Plan's clean distributed generation development goals.*

use at their homes and businesses – back to the grid. Customers should be paid the retail rate for this excess generation. Thus, the net metering customer is paid the same rate for power generated and sold to the utility as the rate that the customer pays to buy power from the utility to be used at the home or business. The fairness of this approach is obvious. Especially when wind power or solar power is provided to the grid at peak demand times, there is a strong argument for payment at a higher market rate, rather than the retail rate.

To date, 30 states have adopted net metering policies in some form. Ohio and Iowa have among the most effective net metering policies in place today. In Iowa, the net metering limit is based on the size of the customer's electrical demand, rather than on some arbitrary level. This means that large customers can install large, more cost-effective clean generation units, but customers cannot sell large quantities of power offsite. About 3.7 MW of renewables are now operating under net metering arrangements in Iowa, probably the largest amount in any state.

Uniform Safety and Power Quality Standards

Uniform safety and power quality standards should be developed throughout the Midwest in order to facilitate the process for customers and developers to reasonably, economically and safely interconnect to the electricity distribution system. Consistent standards for interconnection of clean distributed generation to meet safety, power quality and reliability requirements would reduce technical barriers and costs and address utility safety concerns. Fortunately, a number of nationally recognized standards for safety and performance have been adopted that could be used in the Midwest for distributed energy interconnection. For example, standards developed by the Institute of Electrical and Electronic Engineers (IEEE929) and Underwriters Laboratories (UL 1741) ensure safe photovoltaic interconnection that protects the consumer, the utility and its lineworkers. Similarly, where necessary, distributed generation equipment could be tested and certified to ensure that it meets interconnection and other operational standards. The combination of interconnection standards and pre-certification requirements should eliminate utilities' concerns about the impacts of distributed generation on their systems, and it should simplify the connection process for owners of distributed generation. Overall, interconnection standards should achieve the goals identified by the American Solar Energy Society: safety and reliability, simplicity, fairness, standardization and cost-effectiveness.

Standardized Interconnection and Business Terms

Utilities and state utility regulatory commissions across the Midwest should work cooperatively to establish standard business and interconnection terms and conditions that will help overcome existing institutional barriers to clean distributed generation technologies. Many distributed generation developers have found that utilities have inefficient business practices for the connection of clean distributed generation resources, and utilities' interconnection terms and conditions can create barriers in the form of delays, inequitable fees and unnecessary impediments. Standard protocols could address issues such as insurance requirements, indemnification clauses, power purchase contracts and siting provisions.

Utilities should also waive their interconnection charges for small wind power, solar photovoltaic panels and fuel cell installations because of the reliability and environmental benefits associated with these clean technologies. State utility regulatory commissions should require these steps if not undertaken voluntarily by the utilities.

Apply Clean Air Laws and Regulations to Small (Dirty) Distributed Generators

Federal and state environmental officials should apply clean air standards to small distributed generation sources so that clean power technologies are promoted and highly polluting diesel generators are discouraged. Congress should eliminate the exemption from federal Clean Air Act standards for small generation sources in light of the new realities of the electric power market. In today's circumstances, this exemption undermines the national air quality improvement goals, and it provides polluting diesel generators with an unfair competitive advantage. Diesel generators, for example, produce up to 30 times as much NO_x and particulate pollution as new combined-cycle natural gas plants and microturbines, but these generators are often the first choice for standby and peak power, particularly in areas where grid reliability is a concern. In addition to truly clean wind turbines, solar photovoltaic panels and fuel cells, there also are new relatively clean microturbines and other small generator technologies on the market that can achieve the benefits of distributed power resources without sacrificing environmental quality.

Additional Policies

The policies described above are the most important for achieving the Clean Energy Development Plan's goals. The following additional policy options should also be considered:

Reduce Ratemaking Barriers to Clean Distributed Generation

Some utilities have inflexible standby charges and backup rates that are designed for relatively large, independent generation plants, and they can create significant barriers for intermittent clean distributed generation. These types of ratemaking practices should be redesigned to encourage the development of renewable, efficient distributed generation.

Define the Conditions for a Customer's Right to Interconnect

Clean distributed generation developers and customers could be provided a "right to interconnect" to a utility's distribution grid, as long as they comply with interconnection standards, standard business terms and conditions, and regulatory principles. Utility regulators could clearly define the conditions necessary for a customer's or developer's right to interconnect, in order to streamline the interconnection process and minimize the need for dispute resolution or regulatory appeal processes.

Focused Exploration of Niche Applications

There are many niche locations – such as second-home development in remote rural areas and residential construction in ex-urban areas – where installing clean distributed generation may be preferable to interconnection with the existing electricity grid or transmission and distribution upgrades. Diesel generators also can be hybridized with wind, solar or PV to reduce emissions from existing installations. These applications should be explored through a combination of educating developers and active collaborations involving state utility regulatory commissions, utilities and public and private stakeholders.

Transmission and Distribution Planning and Upgrade Policies

Electric utilities (either vertically-integrated or distribution-only) should be required by state utility regulatory commissions to conduct periodic planning studies to assess the potential for deploying clean distributed generation to improve reliability or reduce transmission and distribution (T&D) costs. At a minimum, utilities should be required to explore and determine clean distributed resource options before seeking to undertake major T&D upgrades or line extensions. Clean distributed generation should be provided with "extra credit" in such determinations because of the positive environmental and social values.

8.4 CO_2 Reduction Policies

Legislators, regulators and public stakeholders seeking to reduce CO_2 pollution from coal and natural gas plants should also look beyond these clean energy proposals. Aggressive energy efficiency and renewable energy resources development can, indeed, play an important role in offsetting increased CO_2 pollution. However, coal plants produce the largest share of the Midwest's air pollution, and achieving significant CO_2 reductions will require reducing pollution from these plants.

Furthermore, over the next 20 to 30 years, many nuclear units in the Midwest and the United States are expected to retire. If this nuclear generation is simply replaced with natural gas combined-cycle generation, there will be significant increases in CO_2 emissions from the electric industry (Woolf and Biewald 1998). Aggressive policies designed to replace this retired nuclear generation with zero carbon resources may help keep CO_2 emissions from growing significantly, but they will be unlikely to achieve significant CO_2 *reductions* from the electric industry.

The best way to be sure of achieving reductions in CO_2 emissions from the electric industry is through policies explicitly designed to do so. State and federal policymakers should consider three basic approaches to achieve CO_2 reductions, described below.

Multi-Pollutant Regulation

Environmental regulations have traditionally treated each pollutant separately. Pollution regulations for SO_2, NO_x, CO_2, particulates and mercury should be strong, but also fully integrated in order to allow plant owners to pursue less costly compliance strategies, including repowering with natural gas or retirement of older coal plants. Treating pollutants separately has encouraged power plant owners to install pollution-specific control technologies (e.g., scrubbers for SO_2 and SCR for NO_x) in order to comply with each new regulation. Because previously installed control technologies are a sunk cost, they are not considered in the economic analysis as to whether to install another control technology for a newly regulated pollutant. But, if plant owners considered the costs of controlling all pollutants to be regulated in the near future, then they might adopt different control strategies. They might decide to repower a coal plant or to simply retire it. This approach is preferable from an economic and environmental perspective, and it would also help increase interest in renewable resources that produce few, or no, air emissions. The EPA has investigated opportunities to integrate the regulation of four key air pollutants – SO_2, NO_x, CO_2 and mercury – and found that "having advanced knowledge of potential requirements for all four pollutants could allow industry to pursue different and less costly compliance strategies than they would if the pollutants were addressed one-by-one" (GAO 2000).

CO_2 Cap-and-Trade Policies

CO_2 pollution from fossil-fueled power plants should be subject to a cap-and-trade system similar to that currently used for SO_2 emissions. An overall emissions cap would be set for the desired level of CO_2 emissions, and allowances within that cap could be traded between generators. Allowances also should be allocated to energy efficiency and renewable resources, on the same basis used for allocation to fossil-fired facilities. (Nuclear and hydro power plants, however, would not be allocated CO_2 allowances, because of the environmental and other costs they impose on society.)

Early Retirement of Older, Highly Polluting Coal Plants

In the absence of other CO_2 pollution reduction policies, legislatures, regulators and other public stakeholders should establish policies to encourage or require the retirement of older, less-efficient coal plants that produce high amounts of pollution. This could be achieved through voluntary negotiations, explicit requirements and other mechanisms. This would be the most direct approach for reducing CO_2 emissions, and it would also help achieve ambient air quality standards and address concerns about harmful local health impacts from air pollution.

9. Overcoming Specific Barriers to Developing Each of the Renewable Energy Technologies

The policy actions recommended in Chapters 7 and 8 will play a pivotal role in developing renewable energy resources and efficient generation in the regional electricity services market. However, the different renewables technologies often face different market, institutional and technical barriers. It is important to recognize the distinct barriers faced by wind power, biomass co-firing, biomass CHP, photovoltaics and fuel cells, and to implement specific action steps to help overcome them. This chapter provides resources and ideas for clean energy stakeholders to draw upon to overcome specific barriers to renewables development.

9.1 Wind Power

Introduction

Wind power technological developments have rapidly driven down costs and, over time, the current price differential should be reduced through targeted public policies, further technological improvements and increased production that will help to achieve economies of scale. There are, however, several specific barriers to wind power development that should be addressed in the near-term to accelerate the clean energy development process and obtain the environmental, reliability and economic development benefits sooner in the Midwest.

Transmission and Distribution

Issue

Infrastructure. The windiest areas in the Midwest and Great Plains are generally far from the electricity load centers in the major industrialized cities in the eastern part of the region. Consequently, significant new wind development will often require transmission upgrades and access in order to maximize the ability to deliver this power supply to where the market demand is located.

Solutions

Transmission Policies. The transmission access and pricing and Regional Transmission Organization policies described in Chapter 8 are essential for wind power development in the Midwest. Wind power must have reasonably-priced, available transmission access.

Engineering Study. Midwestern state energy offices and economic development agencies, in conjunction with the U.S. Department of Energy, environmental organizations and utilities, should arrange to conduct a comprehensive engineering study of the technical potential to improve and expand the availability of existing transmission corridors that are key for wind power market development. The study should investigate both physical upgrades to the transmission lines and equipment, and the use of advanced data metering, communications and computing technology that can improve operational performance.

Wind-only Transmission. The analysis of transmission upgrades and improvements should also examine potential ways of achieving new "wind-only" access that would facilitate wind power development that has strong public support, as opposed to providing more available transmission capacity that would allow increased utilization of highly polluting coal plants. For example, public and environmental organization support could potentially be obtained for increased transmission capacity to link wind power development in the Dakotas to the potential "green power" consumer demand in the major metropolitan areas to the east, but that support would evaporate if the added transmission became a conduit for increased generation from Basin Electric's very dirty lignite coal plants in the Dakotas.

Task Force. Midwestern state energy offices, in conjunction with the U.S. Department of Energy, should convene a task force including key public officials, economic development agencies, environmental organizations and utilities, to develop policies and programs to: (1) better achieve the potential of distributed wind development; and (2) adjust the dispatch of WAPA hydro and existing coal to accommodate wind power development in the Great Plains.

Public Attitudes

Issues

Decisionmakers. Many key public officials and policy "influentials" are uninformed about the current state of wind power technologies and development and the relatively high level of consumer support for clean energy.

Communities. Some individuals and communities are opposing the construction of new power lines or wind farm development because of fears that wind development may impair open spaces and lower property values. (By contrast, many farm families view wind power development as a new "cash crop" to support farming or ranching activities and forestall further suburban encroachment.)

Utilities. Utilities may resist investment or long-term strategic decisions while state and federal restructuring action hangs in the balance.

Solutions

Public Forums. Renewables companies, environmental advocates and foundations can sponsor forums and briefing sessions for public officials, policy "influentials" and community groups to learn more about wind power development opportunities.

Economic Development Studies. Midwestern state energy offices and economic development agencies, in conjunction with the U.S. Department of Energy, can fund studies on the economic development benefits, especially in rural communities, of wind power development.

Outreach. Midwestern state energy offices and economic development agencies, in conjunction with the U.S. Department of Energy, can fund outreach work involving local communities, environmental organizations and the wind power industry to develop codes of conduct, model siting procedures and other guidelines for wind development.

Polling. State regulators can direct utilities to arrange for a deliberative polling process to determine public and consumer support for clean energy development.[21]

Indian Country

Issues

In addition to the barriers described above, Native American tribes seeking to develop their wind resources face additional barriers.

Ownership. Tribal councils often prefer to develop their own projects, rather than sign long-term contracts with outside developers. This enables them to retain control and to keep the project's employment and economic benefits within tribal communities. However, because the federal government holds Native American land in trust, some lenders may fear that they would not be able to recoup their investment in case of financial failure. Moreover, some tribal projects may be perceived to lack stability because councils generally sit for only two years.

Financial Incentives. Because tribes do not pay federal taxes, they cannot claim the benefits of the PTC, which provides a guaranteed tax credit for 10 years after construction begins. The Renewable Energy Production Incentive (REPI) offers equivalent payments to tax-exempt entities, but its dependence on annual appropriations, which frequently fall short of demand, makes REPI less effective in attracting financing. Tribes must compete for REPI funds with the municipal utilities and other entities that have worked to establish this financial incentive and obtain the necessary appropriations.

Solutions

Jurisdiction. Tribal councils could turn their wind power development activities over to their business arms in order to stabilize and de-politicize the process. To further insulate wind power from political turnover, tribes could also consider chartering intertribal wind ventures.

[21] Deliberative polling in Texas gathered randomly-selected residential consumers and recorded their energy preferences before and after they spent a weekend hearing presentations from, and then questioning, a diverse panel of energy experts. The polls reveal that although most people do not understand how the electric system works in detail, most do support and express willingness to pay for clean energy after learning more about the issues. Texas policymakers have pointed to these deliberative polls as the key event that made clear to them broad public support for clean energy development.

REPI Modifications. Congress could lengthen the appropriation period for REPI, explicitly authorize payments to tribes and substantially increase the funding allocated to the program.

Partnerships. Tribes could consider innovative mechanisms to facilitate participation by outside entities in wind projects on tribal land. These may include limited waivers of sovereign immunity, the use of leasehold mortgages to create security interests on tribal land, and conducting business through entities that do not share in tribal immunity.

Power Purchase Contracts

Issues

Existing "Full Requirements" Contracts. Some municipal utilities and rural electric co-ops located near good wind power sites are bound to wholesale suppliers by "full requirements" contracts, which prevent them from purchasing or developing additional generation resources.

Financing. Financial institutions generally prefer to see long-term power-purchase contracts before lending money for wind development, but retail customers in the emerging competitive market generally sign short-term contracts.

Solutions

Studies. State legislatures, with assistance from the National Council of State Legislatures, can assess the potential for wind development by municipal utilities, especially the barrier to wind development represented by "full requirements" contracts. In states where this analysis reveals both reasonable wind development potential and a clear barrier, state legislatures could authorize a neutral mediator (e.g., a judge or conflict resolution commission) to oversee the negotiated modification of "full requirements" contracts to "partial requirements" contracts.

Federal Purchasing. In order to help facilitate financing, the federal government can aggregate electricity demand at its Midwestern facilities, and sign long-term power-purchase contracts with wind power developers. State governments also can make similar commitments.

Insurance. Federal and state governments could collaborate with the private insurance industry on the "Green Power Insurance Initiative" developed by the U.S. Department of Energy. This proposed initiative would offer "price insurance" to green power marketers, lowering the risk to them of falling prices. Its advocates estimate that this insurance approach would potentially result in 1,000 MW of new renewable energy development. As proposed, a joint federal-state investment of $5-10 million would establish the program, and an additional $40-45 million from federal and state sources would backstop private insurers' capital commitment to the program; any portion not paid out in claims would be refunded to the federal and state treasuries (Means 1999).

9.2 Biomass Co-Firing

Introduction

Biomass co-firing has strong technological and economic potential. The policies presented in Chapter 8 can advance biomass power development, but there are several specific barriers that should be addressed as well.

Including Biomass Energy in Renewable Energy Policies

Issues

Defining "Environmentally Acceptable." It is important to distinguish environmentally acceptable biomass co-firing from that which raises significant environmental concerns – e.g., including "energy crops" such as switchgrass and agricultural wastes, but excluding timber cutting and incineration of construction and demolition wastes. Many key legislators, other public officials and environmental organizations have carefully examined the eligibility of biomass energy for state renewable energy investment funds and other renewables policies because of concerns that:

1. Incinerators and other plants might co-fire potentially dirty fuels, especially construction and demolition waste, threatening to degrade local air quality.

2. Co-firing with biomass could increase the use of coal at older coal plants that are exempt from the most stringent portions of the Clean Air Act and even extend the operating life of the older coal plants.

3. Using wood biomass for co-firing could accelerate potentially destructive logging activities in public and

private forestlands, as well as encourage other unsustainable agricultural and forestry practices.

Price. Biomass fuels may not be available at a price acceptable to utilities. Most utilities report they would buy biomass if it cost the same as or less than coal on an energy basis. Biomass fuel suppliers may not enter the co-firing market at these prices, for two reasons. First, co-firing is sometimes a relatively low-value market for biomass. Second, the price offered by utilities often is lower than the cost of collecting, processing and transporting the biomass (including avoided waste disposal costs). Of course, the price and availability of biomass varies by location, and some coal plants may have access to large amounts of lowcost biomass just as coal supplies may be distant. In addition, the federal PTC includes only closed-loop biomass.

Solutions

Inclusion of Environmentally Acceptable Biomass in Renewable Energy Investment Funds. State legislatures can include carefully defined, environmentally acceptable biomass in legislation establishing investment funds for renewable energy. For example, the Illinois Renewable Energy Resources Trust Fund legislation provides funding for "dedicated crops grown for energy production and organic waste biomass," and it specifically excludes "energy from the incineration, burning or heating of waste wood, tires, garbage" and other types of potentially hazardous biomass. Minnesota legislation provides separate renewables development mandates for wind power and biomass energy, respectively. Any of these policies and incentives should only apply to the generation from the biomass portion of a co-fired power plant. This policy support is needed in light of the current price increment for biomass fuels.

Tax Credits. Congress could consider amending Section 45 of the Energy Policy Act of 1992 so that environmentally acceptable biomass co-firing qualifies to receive the PTC now available for wind and closed-loop biomass development. The credit would help plant owners offset any cost difference between biomass and coal. This credit should apply only to the generation from the biomass portion of the co-fired power plant.

Biomass Summit. A series of meetings can be convened among renewable energy advocates, environmental organizations, agricultural groups, federal and state energy and environmental officials, utilities and the biomass industry. These "summit meetings" could provide an opportunity to: (1) balance the positive and negative impacts of biomass development against the impacts of other energy sources; (2) consider the role of biomass in a coherent energy and economic development strategy; and (3) develop a consensus position on environmentally acceptable biomass fuels and practices. The scope of the summit could include various biomass energy applications, and, particularly, address the questions raised by co-firing. Moreover, the EPA could conduct a series of stakeholder meetings to assess how biomass co-firing interacts with New Source Review requirements for power plants. That might eventually lead to guidelines for how this important Clean Air Act protection applies to biomass co-firing.

Predominance of Pulverized Coal Boilers

Issue

Most Midwestern coal plants burn pulverized coal, as indicated in Figure 9.1. Co-firing pulverized coal (PC) boilers tends to be more difficult, and consequently more expensive, than co-firing in other boiler types. First, since PC boilers burn fuel crushed to a powder-like consistency, co-firing requires more elaborate measures for processing and handling biomass. Second, the high alkali content of some biomass fuels, particularly the potassium and sodium in herbaceous crops and agricultural residues, can cause problematic ash build-up and slagging. Retrofitting a PC facility to co-fire may cost $200/kW.

Cyclone boilers, the second most common Midwestern configuration, accept larger fuel particles than PC boilers. They also allow some ash slagging and, indeed, require it for proper operation, suiting them for high-alkali biomass fuels. Retrofitting a cyclone boiler to co-fire may cost $50/kW. Stoker and fluidized bed boilers, the least common Midwestern plant type, allow the largest fuel particles, due to the combustion process and fuel residence time. They are, however, susceptible to slagging problems.

While co-firing with PC boilers costs more than co-firing with cyclone boilers, they both represent a relatively low-cost opportunity for producing electricity from biomass. The co-firing capacity projected in the Clean Energy Development Plan incorporates the price differential between different boiler types.

FIGURE 9.1 COAL-FIRED BOILERS >25 MW AT MIDWESTERN UTILITIES BY TYPE

Boiler Type	Number (percent of total)	Particle size	Vulnerability to slagging
Pulverized Coal	278 (64)	Under ¼ inch	Yes
Cyclone	41 (9)	Under ½ inch	No
Fluidized Bed	0 (0)	Larger	Yes
Stoker	3 (1)	Larger	Yes
Unknown	112 (26)	n.a.	n.a.
Total	**434 (100)**	**n.a.**	**n.a.**

Note: "Unknown" boilers either were listed as "other," or no information was provided.

Solutions

Identifying High-Value Opportunities. The Department of Energy's Regional Biomass Energy Program and EPRI (formerly the Electric Power Research Institute) should identify all opportunities to co-fire biomass fuels in coal plants with cyclone, fluidized bed and stoker boilers.

Identifying High-Value Biomass Resources. The Regional Biomass Energy Program, state energy offices and appropriate federal laboratories should compile a database of low-cost, low-ash and low-alkali biomass fuels, and distribute it to owners of coal plants with PC boilers.

CONTAMINATION OF SELECTIVE CATALYTIC CONVERTERS

Issue

In the near future, many coal plants may use selective catalytic reduction (SCR) to comply with new, more stringent limits on NO_x emissions. Some analysts have expressed concerns that the alkali content of biomass fuels may contaminate the catalyst used in SCR technologies. Some types of coal, such as that from the Powder River Basin, also have a high alkali content that might cause contamination of the SCR catalyst.

Although there is some anecdotal evidence of this problem, it has not been firmly established. The National Energy Technology Laboratory is researching this issue. This may prove to be a problem in the short-term, but it is expected to be resolved five to 10 years from now. Regardless of whether this issue also proves to be a technical barrier to biomass co-firing, it may be a "perception" barrier. In the absence of further research and targeted education, coal plant owners may become wary of modifications to co-fire biomass if there is a perception that this will threaten SCR operation.

Solutions

Contamination Indicators. The National Energy Technology Laboratory, assisted by other appropriate federal laboratories, should develop "SCR contamination indicators" to classify biomass fuels by their reactive alkali content. These indicators will assist coal plant operators in identifying biomass fuels with low potential to contaminate SCR equipment. The labs should also investigate the impact of such factors on fuel availability and cost.

New Catalyst Development. The Department of Energy and the Environmental Protection Agency should encourage research and demonstration of SCR catalysts that are less susceptible to contamination by reactive alkalis in biomass and other fuels.

COAL FLY ASH DEFINITION

Issue

Coal plants sell fly ash to producers of cement and concrete for use as a raw material. These high-value transactions significantly reduce net operating costs. Many analysts believe (pending definitive tests) that co-firing biomass at rates up to five percent of heat content has minimal impact on ash characteristics due to biomass' comparatively low ash content. However, the American Society for Testing and Materials (ASTM), which sets standards for coal ash used in concrete, requires that ash be generated from unadulterated coal.

Some coal plant owners also may be concerned that even if ASTM were to accept co-fired ash, the cement and concrete industries might perceive it as inferior. This constitutes a further barrier to co-firing.

Solution

Stakeholder Group. A multi-stakeholder partnership should ensure that the concrete and cement industries have good, credible information on the effects of biomass ash in their products. The partnership might include: the American Coal Ash Association; federal and state agencies interested in biomass; national laboratories such as Sandia, the National Renewable Energy Laboratory and the National Energy Technology Laboratory; EPRI; and the University of North Dakota's Energy and Environmental Research Center. If this partnership deems current information insufficient, the Department of Energy should commission further research as necessary, through its fossil fuel and other programs. The goal would be to develop acceptable standards for coal ash that do not unnecessarily discriminate against biomass.

9.3 Biomass Combined Heat and Power

Introduction

Two types of biomass combined heat and power (CHP) co-generation systems have particularly high potential for the Midwest over the next decade.

Small Gasifiers

Small gasifiers are typically linked to generating equipment ranging from 10 kW to 5 MW. They are suitable for community, district energy, institutional, commercial and light industrial thermal loads, and power generators on both sides of the customer meter. The Department of Energy's Small Modular Biopower program is developing prototypes, and advanced testing is expected to begin soon. Worldwide, a number of developers are focused on small gasifiers, and the primary goal is to produce biogas clean enough to power internal combustion engines, diesel engines and gas turbines.

District Energy Systems (DES)

DES are the most fully mature biomass CHP technology (see the "District Energy St. Paul" project described in Chapter 5). District energy systems in the United States provide more than one quad of end-use energy, but renewable energy fuels only one percent of these systems. Thus, there is a huge opportunity for increased use of renewables in these systems.

The highest priority is to create financial incentives to counter the short financial time horizons for utility investments in biomass CHP.

Short Financial Time Horizons

Issue

Typically, utilities and other private entities look to a relatively short (two- to four-year) payback on investments in electricity, heating and cooling systems. For several reasons, biomass CHP systems require a greater capital investment than equivalent fossil fuel systems:

1. They include fuel storage and mechanical fuel handling facilities beyond the simple pipeline connection required by gas-fired systems.

2. The dust surrounding these facilities may necessitate more frequent maintenance.

3. Efficient biomass CHP projects typically require unique boilers.

4. Biomass CHP systems may be as much as 10 percent less efficient than equivalent fossil fuel systems (i.e., 35 percent for fossil fuels versus 25 percent for biomass).

For these reasons, biomass CHP systems generally present a longer payback horizon. Public agencies, universities and other not-for-profit institutions may tolerate longer time horizons for returns on their investments, and may be more inclined to invest in ways that benefit local communities and the environment. Campus heating systems relying on water or steam heat are ideal for biomass CHP.

Solutions

Financial Incentives for Biomass CHP Systems. Congress and state legislatures can create policies for accelerated depreciation for CHP systems to reduce tax burdens in the short-term, and therefore make the short-term economics more attractive to financiers. Policymakers might reasonably apply this measure to other clean energy technologies as well.

Congress and state legislatures could create an investment tax credit for biomass CHP systems. At least one of the proposed federal electricity restructuring bills included an eight percent investment tax credit for CHP systems with minimum total efficiencies between 60 percent and 70 percent, depending on the system's size. For biomass systems to qualify, the minimum efficiencies in the proposal would have to be lower, since they provide additional climate change and economic benefits. Again, policymakers might reasonably apply this measure to other clean energy technologies as well.

Municipal governments with existing CHP systems, or planning to build CHP systems, could identify opportunities to finance biomass CHP systems through the municipal bond market, and, for smaller projects, through municipal leasing companies.

Creation of Biomass CHP Systems in Universities. State energy offices could offer funding support to universities to develop preliminary feasibility studies. Managers of state renewable energy investment funds can target university biomass CHP as a prime project opportunity.

The International District Energy Association could hold its annual College and University Conference in the Midwest, and feature biomass CHP sessions on policy and technical issues for university officials.

Limited Experience with Biomass Fuels and Biomass CHP Systems

Issue

Important potential stakeholders in CHP systems lack experience with biomass fuels. Most notably, most farmers and other potential suppliers have no experience with growing, processing, storing and transporting crops suitable for combustion. In addition, power engineers have little real-world experience with burning biomass in gasifiers. (In fact, these obstacles have stymied a promising biomass gasifier project in Granite Falls, Minn.) Where biomass competes against natural gas for CHP applications, inconveniences based on inexperience are enough to discourage early adoption.

Furthermore, there is no well-established, well-distributed base of professional engineers, architects and planners who understand biomass CHP. Professional degree programs generally do not include information on biomass combustion, and fuel storage and handling for district energy systems. As a result, project initiators often rely on local professionals with limited knowledge, who inadvertently "reinvent the wheel," driving up costs or creating sub-optimal projects.

Solutions

Crop Development. U.S. Department of Agriculture (USDA) extension offices in the Midwest, in cooperation with farmer cooperatives, can help to develop dedicated energy crops, such switchgrass, that are geared to the Midwest applications.

Information. The DOE and the USDA can collect information on regional experience in handling, storing, and combusting a wide variety of agricultural crop residues. Regional outreach that expands the availability of that information should occur in cooperation with Midwestern biomass institutions.

Regional Center. Midwestern universities, community colleges and tribal institutions could form a regional consortium to build regional biomass expertise. The consortium could found a center to house—physically or on-line—the clearinghouse of information on Midwest biomass feedstock experience described above. In addition, it could coordinate the development of undergraduate programs to train engineers in biomass applications and develop professional training modules for farmers and others potentially interested in raising or handling energy crops. It can also expand to cover policy mechanisms and regulatory approaches to biomass projects.

Small Gasifiers

Issue

Small gasifiers are not yet market-ready, but they should be in five years and supportive policies are essential. As described above with regard to biomass co-firing, policy mechanisms such as renewable energy investment funds may not yet include thermal applications such as biomass CHP. Distributed energy policies – especially interconnection rules and net metering practices – can also have very significant impacts on small, modular biomass gasifiers.

Solutions

Identifying Sites. The Great Lakes Regional Biomass Program and the Department of Energy's Small Modular Biopower (SMB) Program can locate attractive sites for small biomass systems and identify ways to establish demonstration projects at these sites. Depending upon the site, host institutions such as municipal governments, universities, hospitals and industrial facilities could participate in developing project plans.

Easy Interconnection. For small biomass systems that can be sited on the customer side, state legislators and public utility commissions can adopt fairer and more accessible interconnection standards and net metering policies (see Chapter 8 policies above) for which biomass is eligible.

9.4 SOLAR PHOTOVOLTAICS

INTRODUCTION

Solar photovoltaic (PV) opportunities can be divided into off-grid and grid-tied markets. The former presents the most promising opportunity for PV in the short-term. The latter offers the most potential in terms of volume thereafter.

Off-Grid Markets

Water Pumping for Livestock. PV systems averaging 350 W can supply water to livestock, thereby preventing surface water pollution, protecting livestock from infestation by water parasites and supporting greater livestock growth. The total market in the Midwest ranges from 26 MW (at 100 W/farm) to 92 MW (350 W/farm) if all 264,000 farms with livestock installed a PV system. Nebraska holds the biggest prize—it harbors about 25 percent of all livestock in the Midwest and 11 percent of all farms. Iowa and Wisconsin each hold 15 percent of all livestock farms (USDA, 1999).

Cathodic Protection for Gas Pipelines. PV systems without batteries can be used to apply a voltage to metal gas pipelines to prevent corrosion. Systems range from 20 W to 10 kW, depending on site-specific factors including pipe diameter and soil type. Systems for transmission pipelines tend to be larger than those for distribution pipelines. The Midwest is the major hub of natural gas transmission in the United States. The Great Lakes region receives the largest volume of natural gas for any region in the United States (DOE 1999). Iowa, Nebraska and the Dakotas have important gas transmission pipelines, and Nebraska may soon have more transmission due to its proximity to the gas-rich Powder River Basin of Wyoming. The best markets involve new pipelines, although PV can replace diesel generators on existing lines.

Control Valves for Irrigation Systems. This application is not yet available commercially, but can become a sizable market for an early entrant. PV can power control valves that regulate the flow of irrigation water. PV systems for this application can range from 100 to 250 W. As an indication of market size, 35,432 farms covering 9.3 million acres in the Midwest used irrigation systems in 1992 (USDA 1994). Midwestern farms spent $125 million on energy for irrigation pumping in 1994. Nebraska has 74 percent of all irrigated acreage in the Midwest, and spent $105 million on energy for irrigation in 1994.

Rural Residential Off-Grid Use. The increasing amount of summer second-home development in outlying rural areas that are beyond the existing grid, as well as upgrades to existing more primitive cabins, can be an attractive market opportunity for solar PV.

Grid-Tied Markets

For grid-tied PV, both the Midwest/Great Lakes and Great Plains areas hold promise, albeit for different reasons.

Midwest/Great Lakes. In Illinois, Michigan, and northern Ohio, electricity prices are high, and interruptions in both the summer (through peak demand and transmission constraints) and winter (through ice storms and downed power lines) are common (DOE 1999). One study found that the price of a two-axis tracking PV system would be economical for businesses in northern Illinois, northern Ohio, and southern Michigan at approximately $3/Watt, given grid capacity needs. This does not include the substantial value of providing back-up power for several hours for local area networks and other critical systems (Perez, Wenger and Herig 1998).

Great Plains. Sparse populations and high distribution costs per customer may make PV attractive to rural electric cooperatives (RECs) in Nebraska, the Dakotas, and Iowa. One study estimates that the REC market for PV hybrids (which include PV, a generator and batteries) can grow to between 500 and 950 MW nationwide if the PV component of the hybrid system drops to $3/Watt, or half of the current low-bound cost cited in the study (Hoff and Cheney 1998). Since RECs serve many parts of the Midwest, they may represent the key rural prize for PV once PV has saturated closer to economic, off-grid markets.

The highest priorities among the issues and solutions discussed are the need for a Market Development Fund and for state media campaigns to raise awareness of PV.

Lack of Market Development

Issue

Despite the possibility of plentiful, economic applications for PV in the remote power market, there exists no significant PV industry presence able to (1) market PV to farmers and those who sell farming equipment (e.g., cooperatives and agricultural tool vendors); and (2) distribute and service PV systems before and after a purchase.

Two new PV manufacturing plants are underway—one in Chicago (Spire Solar) and one in Perrysburg, Ohio (First Solar)—and the regional marketing infrastructure may grow in response. The Chicago plant, however, is initially supported on pre-commitments from Commonwealth Edison and the City of Chicago to purchase PV. And while the demand for PV from the Perrysburg plant does not include early purchasing commitments, it is essential to note that 75 percent of all PV manufactured in the United States supplies the booming overseas market, particularly Europe and Japan. So it is not automatic that a local manufacturing presence will induce a vital local marketing presence.

This situation, particularly in the immediately attractive off-grid market, points to two factors:

1. ***Markets.*** Cost-effective markets appear to exist. Expanded PV markets will reduce PV costs and likely develop a strong regional industry presence.

2. ***Capital.*** The PV industry lacks the capital and, consequently, the risk-taking entrepreneurship to pursue "loss leaders" requiring up-front marketing. Instead, the industry prefers to channel resources to subsidized markets abroad (e.g., Germany); subsidized markets in the United States (e.g., government markets, green power markets and mandated markets, such as the new solar renewable portfolio standard in Arizona); and existing, economic markets (e.g., telecommunications).

This has significant implications for renewable energy policy in the region. In the case of PV, consumer incentives such as cheap financing or direct subsidies are undermined by a weak regional industry presence. Based on interviews with the PV industry, the most important government incentive to immediately attract industry to the region would be a solar renewable portfolio standard.

Without appropriate market conditioning, incentives short of a RPS or a generous subsidy will merely result in an under-subscribed incentives program. For example, the state of Nebraska has offered to purchase half of all bank loans to in-state buyers of renewable energy and energy efficiency technologies, including solar. Of the $51 million in state money lent under the program for 15,000 individual loans, none has gone to solar purchases. In Iowa, a similar program is also severely under-subscribed—the $300,000 program has helped to finance only three small residential PV systems. Again, the lack of suppliers, as well as difficult interconnection rules, has stymied potential consumers.

Solutions

Supply-Push. The gap between newly found applications and industry commitment to a region must be bridged with public investments based on public benefits. Specifically, state governments should offer cost-sharing support with the PV industry for a Market Development Fund (MDF). This could be one use of Renewable Energy Investment Funds (see Chapter 8). The appropriate Fund Administrator can select a solar industry association, an industry consortium or individual firms, based on transparent criteria such as their record of customer satisfaction, applicable standards for PV, competitive success and willingness to share some of the costs of the effort. The MDF could perform several essential market-building tasks:

1. The MDF could market PV products to relevant customer segments. In the case of livestock water pumping, national PV firms interested in establishing a Midwestern presence can work with water conservation districts interested in clean rivers and streams, agricultural extension agents interested in healthier livestock, and farmers interested in avoiding water pollution fines and in raising healthier cattle.

2. The MDF could market PV products to appropriate vendors. Once customers show an interest in a PV product, PV firms, in conjunction with interested rural parties, can approach vendors who already serve the relevant consumer segment. Encouraging existing vendors to include PVs in their sales offerings would give customers easy access to the technology from known and trusted sources. In the case of livestock water pumping, vendors may include rural electric cooperatives, farmer cooperatives that provide other farm inputs such

as fertilizer, distributors of agricultural tools and machinery (e.g., Country General in Nebraska), well drilling companies and home improvement stores.

3. The MDF could assure customers that PV products are reliable. These conditions can be imposed on participants from the PV industry. However, the public agent participating in this process can inform potential vendors of PV standards, as well as the performance of different balance-of-system components (e.g., motor, inverter for AC motor), and enable the vendors to make choices with customer satisfaction a prime driver.

Demand-Pull. Demand for PV can be developed through government procurement and economic incentives:

1. As states remove commercial and technical barriers to PV adoption, local and state governments can play an important role in jump-starting PV sales by committing to new installations for parks and buildings – off-grid applications for which PV is well suited, and applications which enhance power quality and reliability. Government commitments, such as the City of Chicago's to buy PVs over several years, can provide an incentive for industry involvement and, if publicized, demonstrate the feasibility of PV. It is important that these markets co-exist with genuine efforts targeting private markets offering the most promise for PV, so that regional sales are not limited to government procurement efforts, but instead truly spur private market sales as well.

2. As rural customers become more aware of solar products and have better access to them, and as grid-connected customers in states with higher electricity prices find it easier to use PV for summer peak use, economic incentives can accelerate the market penetration. Incentives can supply an effective "hook" in initial marketing efforts. And by funding only PV systems certified for safety and quality, incentives can reinforce quality-assurance provisions in other PV programs.

   Consumer incentives – preferably a combination of low-cost financing, writedowns and tax incentives – are essential to attract customer attention. Established financial institutions (e.g., Fannie Mae, Farmers Home Administration) can offer affordable financing packages, and state renewable energy investment and development programs can buy down interest costs. Producer incentives (e.g., tax incentives for unit sales) for the initial years of a buydown program could provide a clear way to attract industry attention.

   Relevant agencies and firms must publicize economic incentives and, preferably, plug them into marketing efforts to create a turnkey system for purchasing and financing PV.

Lack of Public Awareness

Issue

Many Americans have seen or heard about solar power, but very few know about solar products, let alone how to select, buy, finance and install them. Part of the responsibility in making solar purchases easy rests with the PV industry. To succeed, PV firms should offer a turnkey system including finance, installation and service. Unfortunately, much of the PV industry generally lacks the capacity to fund broad educational campaigns targeting consumers and professionals such as homebuilders, building inspectors and consumer finance institutions.

Solutions

State Media Campaigns. State energy offices, the renewable energy industry, renewable energy advocates and environmental advocates can sponsor media campaigns to promote public awareness about renewables. The campaign should be targeted to financiers, buildings professionals, commercial and residential customers and include the following information:

1. The environmental and economic benefits of PV and renewables.

2. The technical feasibility of PV and renewables.

3. Funds and incentives that are available to consumers.

4. Firms that sell PV and renewables.

Educate Financiers. The Department of Energy could fund the PV industry to develop PV education programs for real estate and finance-related fields who advise and provide financing for homebuyers.

Educate Building Professionals. The Department of Energy and state energy offices could provide cost-sharing support to the PV industry and environmental advocates to work with architect/design, construction and engineering professional societies and commercial real estate management firms to provide both broad and technical educational materials to these professionals on the smart and sensible deployment of PVs.

Poor Integration into Environmental Policy

Issue

Despite the environmental benefits of PV, environmental regulations offer little support to market development. Although some work has been done to explore ways to integrate renewables in pollution credit-trading programs, PV systems are unlikely to benefit because of their small size and distributed nature.

Solution

Diesel Replacement Program. PV, among other clean distributed energy resources, can be promoted as an alternative to diesel generators for small loads through replacement programs. PV "uninterruptible power supply" systems with batteries offer several hours of power for residences and small commercial establishments throughout the year. And in the summer, grid-connected PV offers reasonable security against power outages, while running as a small power plant from which the owner can sell excess power back to the grid. Vehicle trade-in programs, in which state environmental agencies offer to buy back old cars and retire them, offer a useful model. Midwestern states such as Illinois, which uses almost 28,000 diesel generators for stand-by power, can benefit from such programs.

The program can offer a capped amount of funding per customer who wants to buy PV, small wind, renewable energy hybrids, biodiesel or fuel cells fueled by renewables. The program can target areas that are in nonattainment with EPA criteria pollutant standards. The model for this program (though it does not include renewables) is the state of California's "Carl Moyer Program," which provides diesel engine owners with the added financing required to either upgrade or replace their equipment. The state has found that the program is a cost-effective tool to reduce nitrogen oxides and plans to continue the program as an important part of its state implementation plan for NO_X.

Interconnection Challenges

Issue

As discussed in Chapter 8, interconnection challenges for distributed renewable resources are significant. Currently, all Midwestern states except Michigan, Nebraska and South Dakota have net metering measures, although most net metering rules do not grant the generator retail rates (Spratley, 2000).

Solution

It is essential to adopt the net metering and distributed generation policies relating to interconnection standards and practices and transmission pricing and access as discussed in Chapter 8. Development efforts for grid-tied PV should focus on adequate implementation by individual distribution utilities, once these statewide policies are established. These efforts can be more effective if PV advocates develop alliances with other industries, including the fuel cell and microturbine industries.

9.5 Fuel Cells

Introduction

In its early stages, three major factors will drive fuel cell development: reliability, demand for distributed power and co-generation opportunities.

Reliability and Power Quality

Unfortunately, there have been a large number of major power outages in recent years in major cities, and one impact of the restructuring of the electric sector is the threat of the increased number and severity of power outages. At the same time, high-tech firms are proliferating in the American economy, as are firms dependent on computer systems; both groups require constant power free from fluctuations. Businesses and institutions that cannot readily tolerate outages (e.g., hospitals, credit card processors and hotels) or unstable voltage (e.g., semiconductor plants and database-dependent firms) may also turn to fuel cells for added reliability.

Distributed Power

Fuel cells form part of a larger trend toward small generating units installed directly where customers need power. EPRI suggests that there may be installation of 20 GW of distributed generation in the

United States, and a potential U.S. market of 25 million households over the next decade (EPRI 7/1999).

Co-generation Opportunities

Short-term market opportunities for fuel cells depend on exploiting their waste heat – for example in industrial processes, space heating or cooling. A recent Arthur D. Little, Inc. analysis suggests that while fuel cells will require prices of $1,500 to $1,300/kW to compete in distributed power applications, they will enter the market for commercial co-generation applications at $2,000 to $1,500/kW (ADL 1998).

The highest priorities for fuel cell development are the need for: (1) operating experience through demonstration projects to address lack of familiarity with the technology; and (2) innovative finance programs to address the higher front-end cost of fuel cells.

Lack of Familiarity Among Potential Users

Issue

Fuel cells are unfamiliar to most potential users and also to firms potentially able to distribute or service them, such as propane dealers and air conditioning service firms.

Solutions

Operating Experience. To accumulate field knowledge of fuel cells, and thereby raise the comfort level of potential users, the Department of Energy, EPA and state agencies can collaborate with industrial and municipal users to encourage fuel cell demonstrations at appropriate sites, especially those with a source of hydrogen-rich gas (e.g., landfills, breweries and wastewater treatment plants), or a need for heat (e.g., schools, hospitals and fast food restaurants) or high-quality power (e.g., airports, high-tech factories or computer data banks). Results from these demonstration projects should then be publicized to potential customers, investors and equipment vendors.

Professional Skills. To increase knowledge of fuel cells among small businesses potentially able to distribute and service them:

1. State and county governments could support the development of fuel cell training courses at community and technical colleges.
2. State energy offices could join with industry in supporting a fuel cell training initiative including the preparation of training videos and outreach to the propane, air conditioning and other appropriate industries.
3. State energy offices could work with RECs to identify cost-effective uses of fuel cells to avoid or defer constructing or upgrading high cost distribution systems.

Cost

Issue

Fuel cells cost too much for most customers. ONSI's PC25, the only commercial fuel cell now available on a large scale, generates power at a little over 12¢/kWh (ADL 1998). The unit costs about $4,000/kW, compared to microturbines at $1,000/kW (and projected to cost $300/kW in mass production) and to combined-cycle gas turbines at $550 to $650/kW.

Solutions

The fuel cell industry will lower costs by reducing the number of parts and streamlining manufacturing processes, reducing reliance on noble metal catalysts, and lowering unit costs by scaling up production. In the short term, public policy can play an auxiliary role in helping firms build markets by decreasing costs to the end-user elsewhere in the fuel cell industry.

Innovative finance programs. Renewable Energy Investment Funds (see Chapter 8) could support the following programs:

1. Funds could be provided as business development loans to small firms looking to sell or service fuel cells using renewable fuels.
2. Funds could be deployed to provide loan guarantees to reimburse financial institutions in full or in part if a business or homeowner defaults on a loan used to buy a fuel cell using renewable fuels. This would encourage financial institutions to lend at reasonable rates.

Favorable insurance treatment. In the aftermath of Hurricane Andrew, up to 30 percent of the insurance losses paid were for business interruptions due to power loss. State insurance regulators could encourage insurance firms to reward fuel cell owners through lower premiums for property and business interruption insurance.

Third-party ownership. This would effectively raise allowable costs by extending acceptable payback periods and leveraging O&M resources. Energy service companies will naturally tend to consider fuel cells as costs drop. In addition, state public utility commissions should consider the advantages and disadvantages of allowing distribution utilities to own fuel cells, particularly where such units would defer distribution upgrades or construction, or provide line support.

TECHNICAL BARRIERS

Issue

Fuel cells must become more robust to succeed on the basis of reliability. Fuel impurities can easily "poison" the stack, a particular problem for renewable biofuels. The PC25 can run eight years between overhauls, but other units may last only three years. There have been reports that smaller units require an overhaul after only 5,000 hours.

Solution

Performance Guarantees. As in the case of cost barriers, the fuel cell industry will resolve technical problems on its own. As firms improve their products, however, performance guarantees could lower perceived risk.

CODES, STANDARDS AND DEFINITIONS

Issue

Fuel cells suffer from many of the same obstacles facing photovoltaics, small wind turbines and other distributed generation resources discussed in Chapter 8.

Solutions

In addition to the policies described in Chapter 8, the following solutions would facilitate interconnection, raise consumer confidence and help create an integrated national market for fuel cells.

Codes and Standards. State policymakers can support existing industry efforts to develop consistent and easily understandable codes and standards for fuel cells.

Interconnection Protocols. The following policies would also help address the specific interconnection issues faced by fuel cells:

1. States could include fuel cells in net metering provisions. The provisions might allow higher buyback rates and size limits for fuel cells using renewable fuels.

2. State environmental agencies and zoning authorities could develop fast-track siting procedures for small fuel cells based on measured performance of given models in the field.

3. State utility commissions could exempt some or all fuel cells from paying all or part of the exit fees. Fuel cells qualifying for exemptions might include those using renewable fuels, those meeting high efficiency goals or those below a certain size. Commissioners also might set a cumulative system cap for exempt units at a level equivalent to expected new load growth.

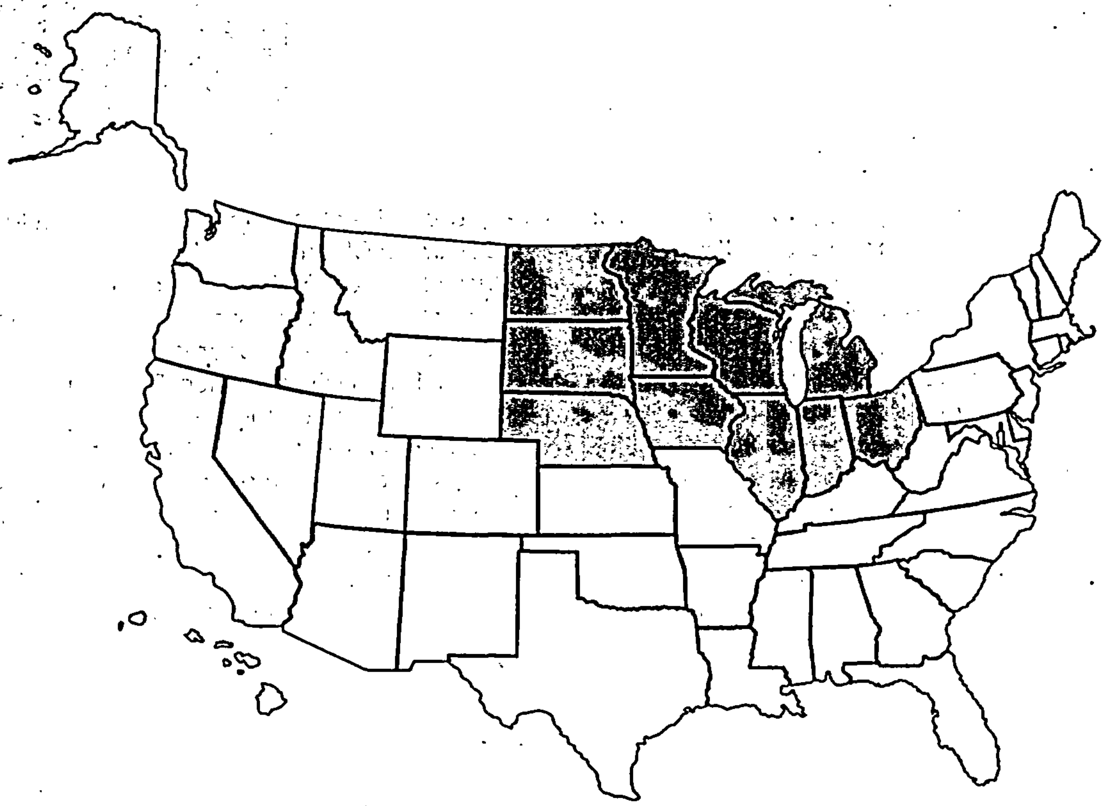
CONCLUSION

The Midwest Clean Energy Development Plan is visionary, and it is practical and achievable. It will require a dedicated and concerted effort by governors, legislators, regulators, the electric power industry, consumers and citizens to replace current, outdated power plants and practices with modern clean technologies and policy innovations. It will require specific steps to adopt and aggressively implement the recommended new strategies, policies, and practices. The Midwestern public is ready to seize the opportunities to robustly develop our clean energy efficiency and renewable energy resources that will lead to better environmental quality and public health, improved electric system reliability and regional economic development gains.

One or two states alone cannot achieve the full benefits of the Midwest Clean Energy Development Plan. The electricity services market is regional, and successful energy strategies and policies for the Midwest require regional solutions and cooperation across state lines. The Clean Energy Development Plan is a smart policy and technical strategy for the Midwest that can also serve as a model for the rest of the nation. As federal policymakers consider more aggressive clean energy development policies and practices to secure national environmental benefits, balanced fuel portfolios and economic growth, we can and should lead the way here in the Midwest – the nation's heartland.

Appendix 1. State Summaries

ON FOLLOWING PAGES



ILLINOIS

REPOWERING THE MIDWEST: THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Illinois needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying a power supply that has relied on old, highly polluting coal and nuclear plants, Illinois will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

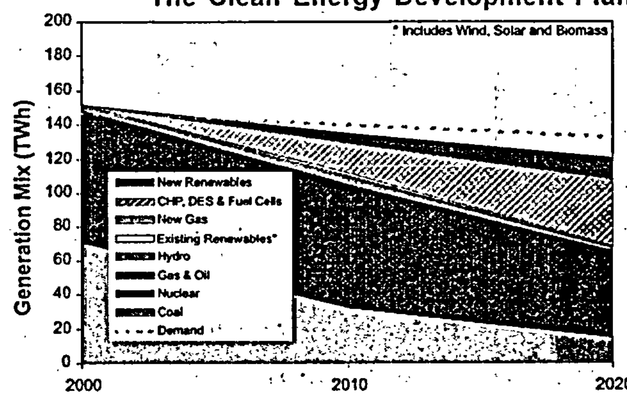
Illinois should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Illinois means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN ILLINOIS WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 87 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 82 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 71 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind and biomass power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

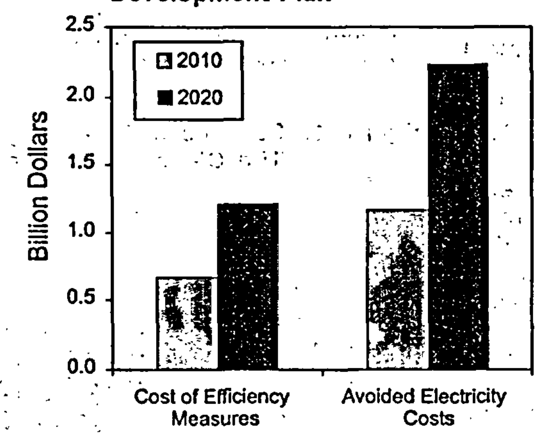
Harnessing clean energy improves the environment and spurs economic growth.

ILLINOIS

Reaping Energy Efficiency Opportunities

Illinois has tremendous opportunities to invest in energy efficiency technologies that will reduce pollution, save money and create jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $1 billion by 2020.
2. Saves 50,761 GWh of electricity – equal to about 18 large power plants – by 2020.
3. Reduces electricity demand by 16 percent in 2010 and 28 percent by 2020.
4. Costs less – at an average investment of 2.4¢/kWh – than generating, transmitting and distributing electricity from power plants.

Deploying Renewable Resources and Efficient Generation

Illinois has strong opportunities to develop wind, biomass and solar power, which provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Furthermore, Illinois can develop new efficient CHP using natural gas. Together, the opportunities shown in Figure 3 can provide 10 percent of Illinois' generation capacity by 2010 and 22 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In Illinois, it would increase overall electricity costs by about 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the market and regulatory barriers that energy efficiency and renewable resources face. Illinois has already adopted some policies to promote clean power options, but more must be done to succeed. The key policies for achieving the Clean Energy Development Plan are to:

1. Increase the Illinois Energy Efficiency Investment Fund by investing 0.3¢/kWh.
2. Evaluate and update Illinois' efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
3. Establish an Illinois Renewables Portfolio Standard that requires all retail electricity suppliers to provide eight percent of their power from renewable resources by 2010 and 20 percent by 2020.
4. Increase the Illinois Renewable Energy Investment Fund investment to 0.1¢/kWh.
5. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
6. Remove barriers to clean distributed generation by: (1) expanding Commonwealth Edison's net metering program to be offered statewide by all utilities; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	423	1,519
[illegible]	[illegible]	[illegible]
Biomass - Co-Firing	496	650
[illegible]	[illegible]	[illegible]
Biomass Gasification	0	0
[illegible]	[illegible]	[illegible]
Total	3,649	8,358
[illegible]	[illegible]	[illegible]

INDIANA

REPOWERING THE MIDWEST: THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Indiana needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying a power supply that has relied on old, highly polluting coal and nuclear plants, Indiana will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

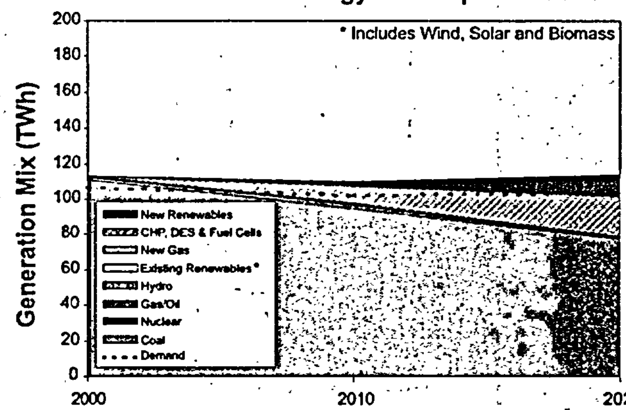
Indiana should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Indiana means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN INDIANA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 50 percent; nitrogen oxides (NO_x) pollution, which causes smog, by 69 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 39 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind and biomass power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

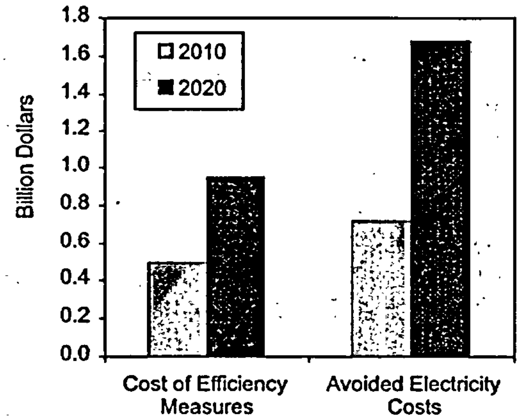
Harnessing clean energy improves the environment and spurs economic growth.

INDIANA

Reaping Energy Efficiency Opportunities

Indiana has tremendous opportunities to invest in energy efficiency technologies that will reduce pollution, save money and create jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $731 million by 2020.
2. Saves 41,752 GWh of electricity – equal to about 15 large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 29 percent by 2020.
4. Costs less – at an average cost of 2.4¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Indiana has the opportunity to develop wind, biomass and solar power, which provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Furthermore, Indiana can develop new efficient generators, such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could provide eight percent of Indiana's generation capacity by 2010 and 23 percent by 2020.

The Clean Energy Development Plan's benfits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In Indiana, it would increase overall electricity costs by about 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. To achieve the Clean Energy Development Plan in Indiana, the key policy actions are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Indiana Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update Indiana's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish an Indiana Renewables Portfolio Standard that requires all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies, with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
7. Remove barriers to clean distributed generation by: (1) expanding Indianapolis Power and Light's net metering policy to include wind and to be offered by utilities statewide; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	148	544
Biomass Co-Firing	139	1,255
Biomass Gasification	0	0
Total	1,683	5,078

ENVIRONMENTAL LAW AND POLICY CENTER OF THE MIDWEST

IOWA

REPOWERING THE MIDWEST: THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Iowa needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, Iowa will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

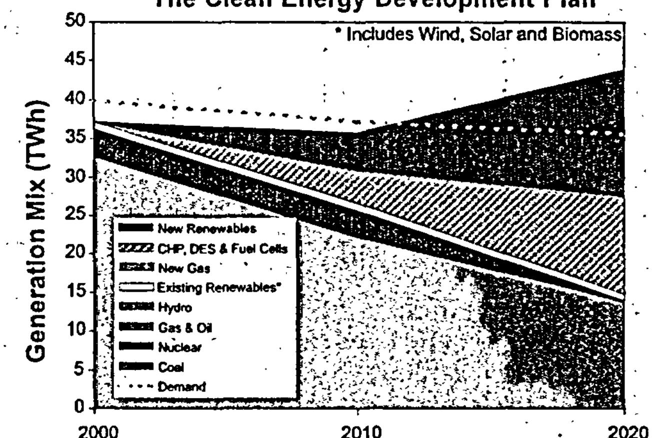
Iowa should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies, and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Iowa means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN IOWA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 61 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 65 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 56 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

Harnessing clean energy improves the environment and spurs economic growth.

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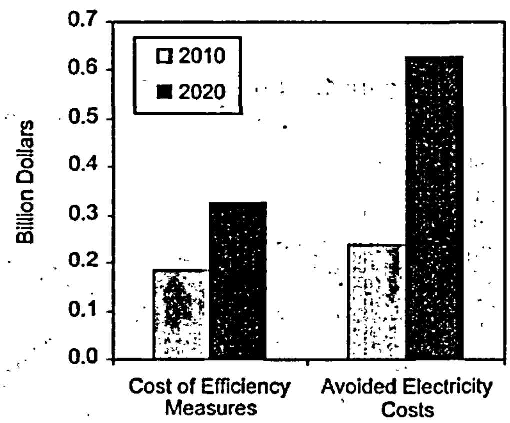
IOWA

Reaping Energy Efficiency Opportunities

Iowa has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $304 million by 2020.
2. Saves 13,895 GWh of electricity – equal to about five large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.5¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Iowa has a tremendous opportunity to harness abundant renewable resources – especially wind – that provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Iowa can also develop efficient generators, such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could supply 22 percent of Iowa's generation capacity by 2010 and 48 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In Iowa, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. Iowa has already adopted some policies to promote clean power options, but more must be done to succeed. The key policy actions for achieving the Clean Energy Development Plan are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update Iowa's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Increase Iowa's Renewables Portfolio Standard, so that the percentage requirement reaches eight percent by 2010 and 20 percent by 2020. Policymakers in Iowa may wish to adopt an RPS requirement that is higher than those in neighboring states, due to Iowa's abundance of wind resources. If the Iowa RPS requirement were to be set at 10 percent for new renewables by 2010 (instead of eight percent), the costs of the Clean Energy Development Plan in 2010 would increase from $40 million to $48 million.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly, and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) establishing standard business and interconnection terms; (2) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (3) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	1,021	3,817
[illegible]	[illegible]	[illegible]
Biomass - Co-Firing	325	325
[illegible]	[illegible]	[illegible]
Biomass Gasification	0	100
[illegible]	[illegible]	[illegible]
Total	1,984	16,071
[illegible]	[illegible]	[illegible]

MICHIGAN

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Michigan needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying a power supply that has relied on old, highly polluting coal and nuclear plants, Michigan will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

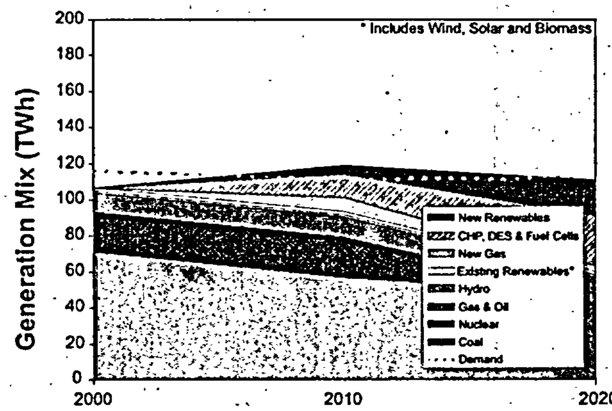
Michigan should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Michigan means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN MICHIGAN WILL ALSO PRODUCE:

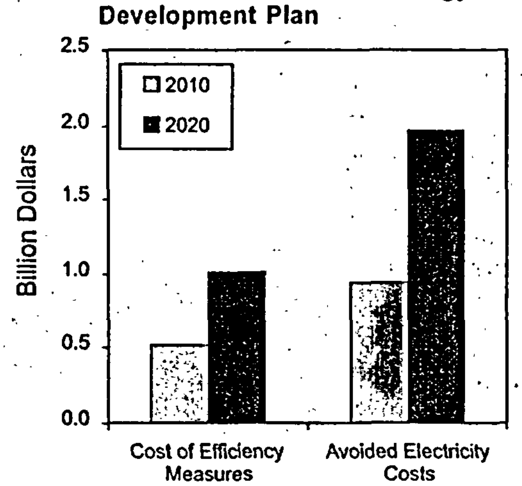
1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 41 percent; nitrogen oxides (NO_x) pollution, which causes smog, by 77 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 47 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind and biomass power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

MICHIGAN

Reaping Energy Efficiency Opportunities

Michigan has tremendous opportunities to invest in energy efficiency technologies that will reduce pollution, save money and create jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $968 million by 2020.
2. Saves 45,246 GWh of electricity – equal to about 16 large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 29 percent by 2020.
4. Costs less – at an average cost of 2.2¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Michigan has strong opportunities to develop wind, biomass and solar power, which provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Furthermore, Michigan can develop new efficient generation, such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could supply nine percent of Michigan's generation capacity by 2010 and 29 percent by 2020.

The Clean Energy Development Plan can be realized at a modest cost, as energy efficiency savings offset the cost of new generation. In Michigan, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. The most important policy actions for achieving the Clean Energy Development Plan in Michigan are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and modernize Michigan's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish a Michigan Renewables Portfolio Standard requiring all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies, with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) applying net metering policies to all wind and photovoltaics; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	304	2,552
Biomass - Co-Firing	94	521
Biomass Gasification	0	100
Total	2,255	7,437

ENVIRONMENTAL LAW AND POLICY CENTER OF THE MIDWEST

MINNESOTA

REPOWERING THE MIDWEST:
THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Minnesota needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, Minnesota will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

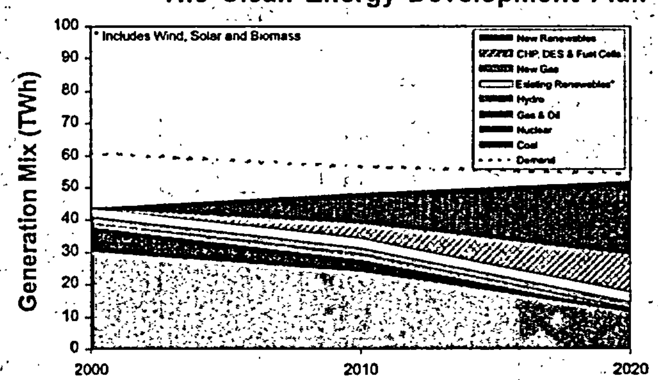
Minnesota should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Minnesota means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

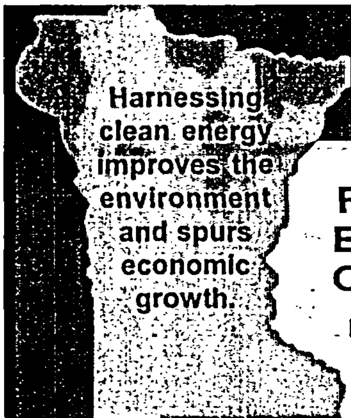
Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN MINNESOTA WILL ALSO PRODUCE:

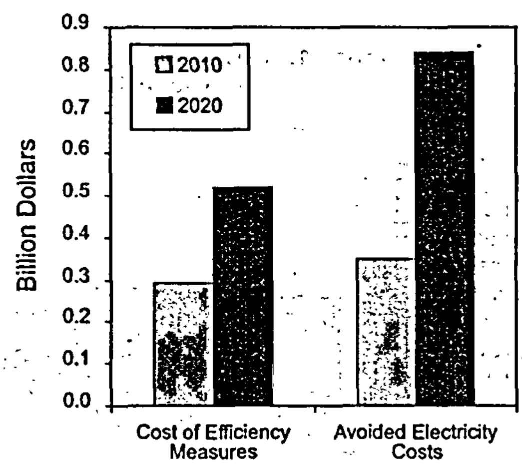
1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 71 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 71 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 67 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.



Reaping Energy Efficiency Opportunities

Minnesota has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $321 million by 2020.
2. Saves 21,152 GWh of electricity – equal to about seven large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.6¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Minnesota has the opportunity to harness abundant renewable resources – especially wind – that provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Minnesota can also develop efficient generators, such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could supply 24 percent of Minnesota's generation capacity by 2010 and 48 percent by 2020.

The Clean Energy Development Plan can be realized at a modest cost, as energy efficiency savings offset the cost of new generation. In Minnesota, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. Minnesota has already adopted some policies to promote clean power options, but more must be done to succeed. The key policies for achieving the Clean Energy Development Plan are to:

1. Increase Minnesota's Energy Efficiency Investment Fund by investing 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update Minnesota's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Increase Minnesota's Renewables Portfolio Standard, so that the percentage requirement reaches eight percent by 2010 and 20 percent by 2020. Policymakers in Minnesota may wish to adopt an RPS requirement that is higher than those in neighboring states, due to Minnesota's abundance of wind resources. If the Minnesota RPS requirement were to be set at 11.5 percent for new renewables by 2010 (instead of eight percent), the costs of the Clean Energy Development Plan in 2010 would increase from $61 million to roughly $83 million.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies, with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly, and account for their intermittent nature, remote locations, or smaller scale.
7. Remove barriers to clean distributed generation by: (1) establishing standard business and interconnection terms; (2) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (3) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	1,586	4,474
Biomass Co-Firing	15	282
Biomass Gasification	75	175
Total	2,699	7,160

NEBRASKA

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Nebraska needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, Nebraska will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

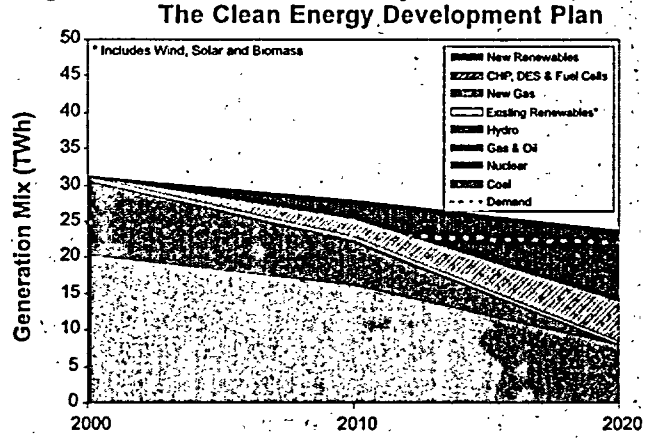
Nebraska should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Nebraska means:

1. Energy efficiency measures reduce electricity demand, and therefore generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN NEBRASKA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 63 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 60 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 61 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers and clean energy exports, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

Harnessing clean energy improves the environment and spurs economic growth.

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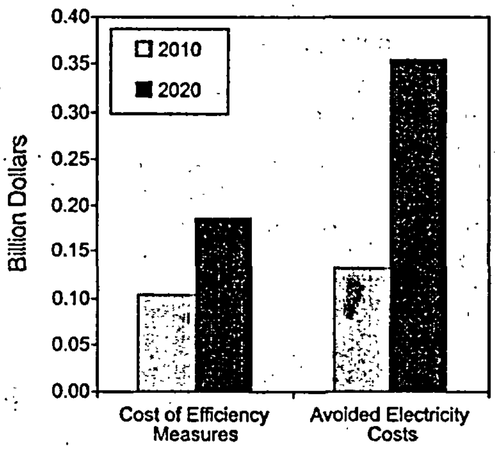
NEBRASKA

Reaping Energy Efficiency Opportunities

Nebraska has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $169 million by 2020.
2. Saves 8,628 GWh of electricity – equal to about three large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.2¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Nebraska has a tremendous opportunity to harness its abundant wind resources, which offer environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Nebraska can also develop efficient generators, such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could supply 21 percent of Nebraska's generation capacity by 2010 and 47 percent by 2020.

The Clean Energy Development Plan can be realized at a modest cost, as energy efficiency savings offset the cost of new generation. In Nebraska, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. The key policy actions for achieving the Clean Energy Development Plan in Nebraska are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update Nebraska's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish a Nebraska Renewables Portfolio Standard requiring all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly, and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) applying net metering policies to all wind and photovoltaics; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	850	2,446
Biomass - Co-Firing	72	208
Biomass Gasification	0	[illegible]
Total	1,248	3,424

NORTH DAKOTA

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

North Dakota needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, North Dakota will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

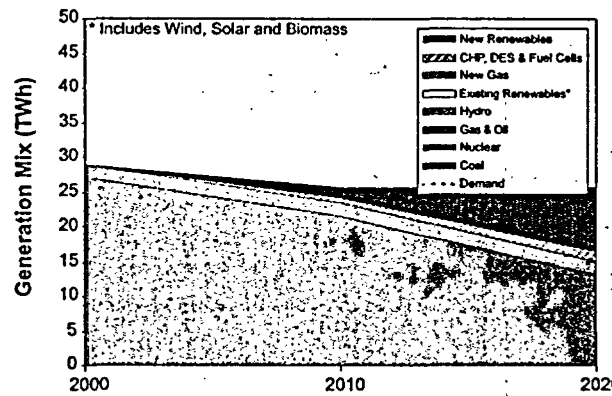
North Dakota should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in North Dakota means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN NORTH DAKOTA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 53 percent; nitrogen oxides (NO_x) pollution, which causes smog, by 53 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 48 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers and clean energy exports, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

REAPING ENERGY EFFICIENCY OPPORTUNITIES

North Dakota has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized on the following page.

Harnessing clean energy improves the environment and spurs economic growth.

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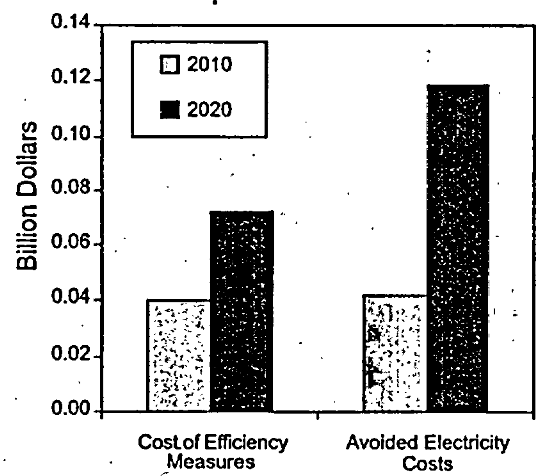
NORTH DAKOTA

1. Reduces net electricity costs by \$46 million by 2020.
2. Saves 3,064 GWh of electricity – equal to about one large power plant – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.4¢/kWh – than generating, transmitting and distributing electricity.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



Deploying Renewable Resources and Efficient Generation

North Dakota has a tremendous opportunity to harness its abundant wind resources, which offer environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. North Dakota can also develop efficient generators, such as CHP and district energy systems. Together, the opportunities shown in Figure 3 could supply 14 percent of North Dakota's generation capacity by 2010 and 35 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In North Dakota, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. The key policy actions for achieving the Clean Energy Development Plan in North Dakota are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update North Dakota's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish a North Dakota Renewables Portfolio Standard requiring all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) applying net metering policies to all wind and photovoltaics; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	750	2,550
Biomass - Co-Firing	0	0
Biomass Gasification	0	0
Total	830	2,738

OHIO

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Ohio needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment _and_ the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying a power supply that has relied on old, highly polluting coal and nuclear plants, Ohio will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

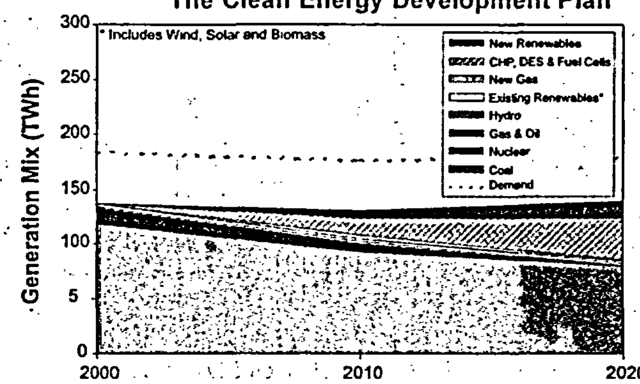
Ohio should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Ohio means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN OHIO WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 47 percent; nitrogen oxides (NO_X) pollution, which causes smog, by 69 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 43 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind and biomass power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

Harnessing clean energy improves the environment and spurs economic growth.

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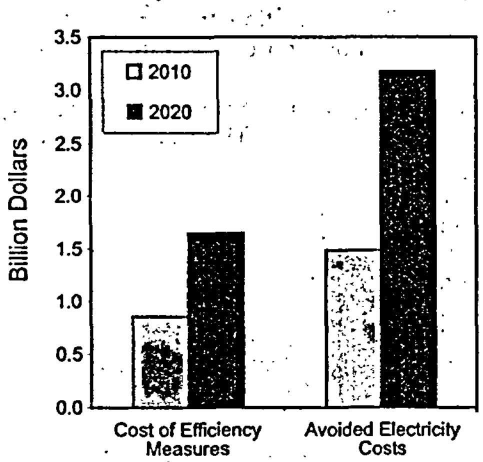
OHIO

Reaping Energy Efficiency Opportunities

Ohio has tremendous opportunities to invest in energy efficiency measures that will reduce pollution, save money and create jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $1,527 million by 2020.
2. Saves 72,417 GWh of electricity – equal to about 25 large power plants – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 29 percent by 2020.
4. Costs less – at an average cost of 2.4¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Ohio has strong opportunities to develop wind, biomass and solar power, which provide environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. Furthermore, Ohio can develop new efficient natural gas generation, such as CHP. Together, the opportunities shown in Figure 3 could supply 11 percent of Ohio's generation capacity by 2010 and 24 percent by 2020.

The Clean Energy Development Plan can be realized at a modest cost, as energy efficiency savings offset the cost of new generation. In Ohio, it would increase overall electricity costs by only about 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. Ohio has already adopted some important policies to promote clean power options, but more must be done to succeed. The key policy actions to achieve the Clean Energy Development Plan are to:

1. Increase Ohio's Energy Efficiency Investment Fund investment to 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by a third-party administrator overseen by an independent board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update Ohio's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish an Ohio Renewables Portfolio Standard that requires all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
6. Remove barriers to clean distributed generation by: (1) establishing standard business and interconnection terms; (2) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (3) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	264	920
[illegible]	[illegible]	[illegible]
Biomass - Co-Firing	443	1,179
[illegible]	[illegible]	[illegible]
Biomass Gasification	0	100
[illegible]	[illegible]	[illegible]
Total	3,172	7,967
[illegible]	[illegible]	[illegible]

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

South Dakota needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying its power supply, South Dakota will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

THE CLEAN ENERGY DEVELOPMENT PLAN

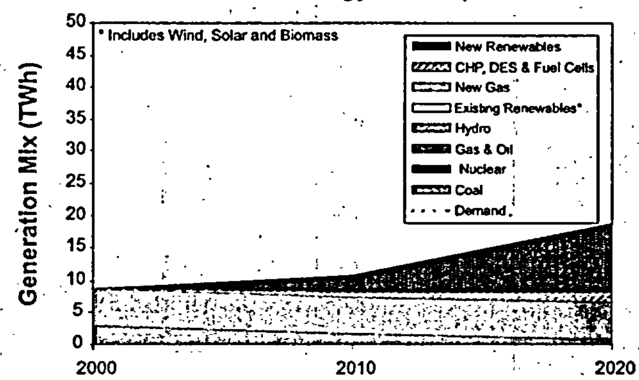
South Dakota should seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in South Dakota means:

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN SOUTH DAKOTA WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 50 percent; nitrogen oxides (NO_x) pollution, which causes smog, by 75 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 38 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind power "cash crops" for farmers and clean energy exports, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

Harnessing clean energy improves the environment and spurs economic growth.

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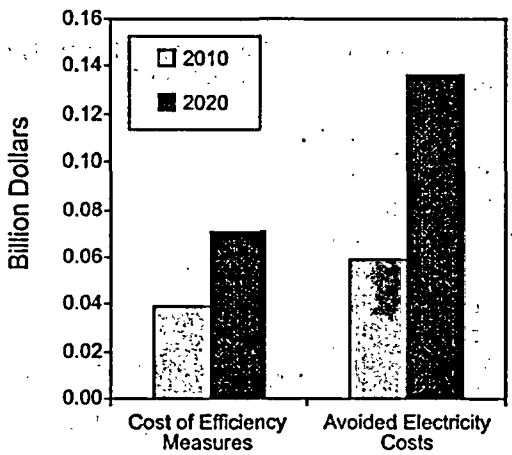
SOUTH DAKOTA

REAPING ENERGY EFFICIENCY OPPORTUNITIES

South Dakota has an opportunity to use energy in smarter, more efficient ways, thereby reducing pollution, saving money and creating jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $66 million by 2020.
2. Saves 2,917 GWh of electricity – equal to about one large power plant – by 2020.
3. Reduces electricity demand 17 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.5¢/kWh – than generating, transmitting and distributing electricity.

DEPLOYING RENEWABLE RESOURCES AND EFFICIENT GENERATION

South Dakota also has a tremendous opportunity to harness its abundant wind resources, which offer environmental benefits, improved reliability, and economic development in the growing renewable energy business sector. South Dakota can also develop efficient generators, such as CHP and district energy systems, using natural gas. Together, these opportunities, shown in Figure 3, could supply 28 percent of South Dakota's generation capacity by 2010 and 53 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In South Dakota, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21[ST] CENTURY POLICIES FOR MODERN TECHNOLOGIES

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. The key policy actions for achieving the Clean Energy Development Plan in South Dakota are to:

1. Establish an Energy Efficiency Investment Fund to support energy efficiency initiatives with a non-bypassable charge of 0.3¢/kWh.
2. Manage the Energy Efficiency Investment Fund by an independent third-party administrator overseen by a board composed of regulators, state energy offices, and consumer, efficiency and environmental advocates.
3. Evaluate and update South Dakota's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
4. Establish a South Dakota Renewables Portfolio Standard requiring all retail electricity sellers to provide eight percent of their electricity from renewable resources by 2010 and 20 percent by 2020.
5. Establish a Renewable Energy Investment Fund to support emerging renewable technologies with a non-bypassable charge of at least 0.1¢/kWh.
6. Ensure transmission pricing policies and power pooling practices that treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
7. Remove the barriers to clean distributed generation by: (1) applying net metering policies to all wind and photovoltaics; (2) establishing standard business and interconnection terms; (3) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (4) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	940	2,900
[illegible]	[illegible]	[illegible]
Biomass - Co-Firing	47	47
[illegible]	[illegible]	[illegible]
Biomass Gasification	0	0
[illegible]	[illegible]	[illegible]
Total	1,077	3,156

WISCONSIN

REPOWERING THE MIDWEST:

THE CLEAN ENERGY DEVELOPMENT PLAN FOR THE HEARTLAND

THE 21ST CENTURY OPPORTUNITIES FOR CLEAN ENERGY

Wisconsin needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health and economic development benefits. This sustainable development strategy is good for the environment and the economy. The Clean Energy Development Plan proposes policies to implement underutilized energy efficiency technologies and to aggressively develop renewable energy resources. By diversifying a power supply that has relied on old, highly polluting coal and nuclear plants, Wisconsin will reduce pollution, improve electricity reliability, create new "green" manufacturing and installation jobs, and provide renewable energy "cash crops" for farmers. The Clean Energy Development Plan provides the strategies to achieve these goals.

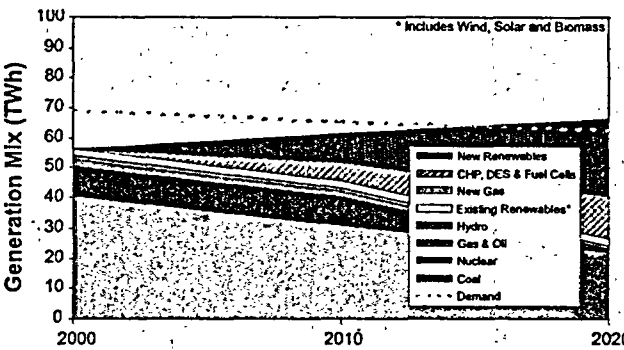
THE CLEAN ENERGY DEVELOPMENT PLAN

Wisconsin can seize the opportunity to develop its clean energy resources: modern energy efficiency technologies and wind, biomass and solar power. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits with only modest increases in cost. Moreover, investing in energy efficiency and renewable energy will diversify the region's electricity portfolio, thereby improving reliability. The Clean Energy Development Plan:

1. Aggressively implements the newest, as well as tried-and-true, energy efficiency technologies.
2. Develops and implements renewable energy technologies – wind, biomass and solar power – so that they provide eight percent of the region's electricity generation by 2010 and 22 percent by 2020.
3. Develops and implements efficient natural gas uses in appropriate locations, especially combined heat and power (CHP), district energy systems and fuel cells, so that they provide 10 percent of the region's electricity generation by 2010 and 25 percent by 2020.
4. Retires selected older, less efficient and highly polluting coal plants.
5. Applies sustainable development strategies to aggressively link environmental improvement policies to economic development.

As Figure 1 shows, implementing the Clean Energy Development Plan in Wisconsin means:

Figure 1. Sources of Electricity Generation: The Clean Energy Development Plan



The state's electricity demand is shown with a dashed line; when the dashed line is below generation, the state is a net exporter, and when above, the state is a net importer.

1. Energy efficiency measures reduce electricity demand, and therefore the need for generation.
2. Generation from renewable resources and efficient natural gas increases.
3. Generation from older, less efficient and highly polluting coal plants decreases.

IMPLEMENTING THE CLEAN ENERGY DEVELOPMENT PLAN IN WISCONSIN WILL ALSO PRODUCE:

1. Dramatic improvements in environmental quality by 2020, compared to business-as-usual practices, by reducing: sulfur dioxide (SO_2) pollution, which causes acid rain, by 55 percent; nitrogen oxides (NO_x) pollution, which causes smog, by 72 percent; and carbon dioxide (CO_2) pollution, which causes global warming, by 53 percent.
2. Improved electricity reliability thanks to a diversified power portfolio.
3. Economic development and job growth through wind and biomass power "cash crops" for farmers, increased business for energy efficiency and renewable energy manufacturers, and new skilled jobs in installation and maintenance of this equipment.

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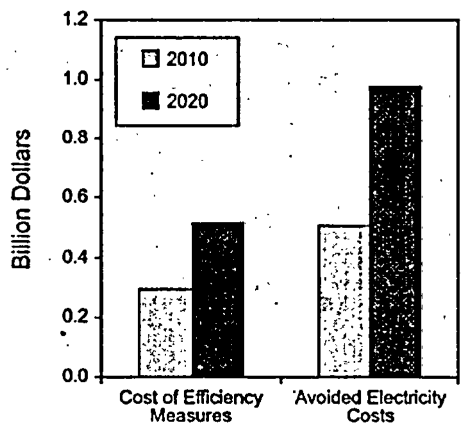
Harnessing clean energy improves the environment and spurs economic growth.

Reaping Energy Efficiency Opportunities

Wisconsin has tremendous opportunities to invest in energy efficiency technologies that will reduce pollution, save money and create jobs. This will produce the benefits summarized below.

Figure 2. Benefits from Energy Efficiency Investments: The Clean Energy Development Plan



1. Reduces net electricity costs by $468 million by 2020.
2. Saves 23,895 GWh of electricity – equal to about eight large power plants – by 2020.
3. Reduces electricity demand 16 percent by 2010 and 28 percent by 2020.
4. Costs less – at an average cost of 2.2¢/kWh – than generating, transmitting and distributing electricity.

Deploying Renewable Resources and Efficient Generation

Wisconsin has the opportunity to develop wind, solar and biomass power, which offer environmental benefits, improved reliability, and economic development in the growing renewable energy sector. Furthermore, Wisconsin has great potential to develop new efficient generators such as CHP, using natural gas. Together, the opportunities shown in Figure 3 could provide 17 percent of Wisconsin's generation capacity by 2010 and 41 percent by 2020.

The Clean Energy Development Plan's benefits can be achieved at a modest cost, as energy efficiency savings offset the cost of new generation. In Wisconsin, it would increase overall electricity costs by only 1.5 percent in 2010 and 3.4 percent in 2020.

21st Century Policies for Modern Technologies

Smart policies can overcome the many market and regulatory barriers that energy efficiency and renewable resources face. Wisconsin has already adopted some policies to promote clean power options, but more must be done to succeed. The key policy actions to achieve the Clean Power Plan are to:

1. Increase Wisconsin's Energy Efficiency Investment Fund investment to 0.3¢/kWh.
2. Evaluate and update Wisconsin's efficiency standards and building codes. Establish or reinforce monitoring and enforcement practices.
3. Modify Wisconsin's existing Renewables Portfolio Standard so that the percentage requirement reaches eight percent by 2010 and 20 percent by 2020.
4. Ensure that transmission pricing policies and power pooling practices treat renewable resources fairly and account for their intermittent nature, remote locations, or smaller scale.
5. Remove barriers to clean distributed generation by: (1) establishing uniform business and interconnection terms; and (2) establishing uniform safety and power quality standards to facilitate safe and economic interconnection to the electricity system; and (3) applying clean air standards to small distributed generation sources, thereby promoting clean power technologies and discouraging highly polluting diesel generators.

Figure 3: New Generation Resources in the Clean Energy Development Plan

Generator Type	2010 New Capacity (MW)	2020 Cumulative New Capacity (MW)
Wind Turbines	412	2,788
[illegible]	[illegible]	[illegible]
Biomass - Co-Firing	219	340
[illegible]	[illegible]	[illegible]
Biomass Gasification	0	100
[illegible]	[illegible]	[illegible]
Total	2,290	6,920
[illegible]	[illegible]	[illegible]

Appendix 2. Existing State Energy Efficiency and Renewable Programs

Illinois

Illinois Clean Energy Development Fund. The Illinois Clean Energy Community Foundation was created as a result of a settlement of contested issues between Commonwealth Edison and environmental organizations and was enacted by the Illinois General Assembly in 1999. The Foundation has $225 million of assets available to further its mission of improving energy efficiency and developing renewable energy resources, as well as certain other specified environmental measures.

City of Chicago Clean Energy Development Fund. The City of Chicago Environmental Fund was created as a result of the settlement of the city's claims against Commonwealth Edison relating to the franchise agreement. This Fund has $25 million per year for each of four years; about half of this is devoted to energy efficiency and half to renewables.

Energy Efficiency Investment Fund. The Illinois Energy Efficiency Trust Fund was enacted by the Illinois General Assembly and is supported by utility and energy supplier payments that provide $3 million per year for each of 10 years. The Illinois Department of Commerce and Community Affairs manages this Fund.

Renewable Energy Investment Fund. The Illinois Renewable Energy Resources Fund was enacted by the Illinois General Assembly. It has $5 million per year for each of 10 years for renewable energy development projects, and it is supported by: (1) residential and small commercial customers' payment of a flat fee of $0.50 per month; and (2) large commercial customers – that have a peak electric demand greater than 10 MW and used more than four million therms of gas in the previous calendar year – payment of a flat fee of $37.50 per month. The Illinois Department of Commerce and Community Affairs manages this Fund.

Commonwealth Edison Renewable Energy Fund. Commonwealth Edison's Renewables Program, also resulting from the settlement of the City of Chicago's claims against Edison relating to the franchise agreement, has $3 million per year for each of four years, principally for solar photovoltaics development.

Environmental Disclosure. Retail suppliers of electricity must disclose their fuel mix in the form of a multi-color pie chart and table and provide pollution information data on air emissions – carbon dioxide, nitrogen oxides and sulfur dioxide – and both high-level and low-level radioactive nuclear wastes. The environmental disclosure must be provided as a separate insert in customers' electricity bills each quarter.

Net Metering. Commonwealth Edison – wind and solar systems of less than 40 kW are eligible to a limit of 0.1 percent of total peak demand. Excess generation is purchased at the avoided cost.

State Grants. Grants of $60,000 to $1 million are available for capital projects of any renewable energy technology. Funding is not available for residential projects.

Tax Relief. Property tax assessment – solar energy systems are assessed at a value not greater than conventional energy systems.

Indiana

Energy Efficiency Programs Run by Utilities. Utilities are required to consider energy efficiency programs in the context of integrated resource planning. Some electric utilities implement demand-side management programs.

State Renewable Grants. Commercial/Industrial – 80 percent of renewable project costs up to $10,000. Industrial/Government/Utilities – $20,000 for biomass and alternative fuels. Commercial/Government/Nonprofit – small-scale grants for projects with high degrees of public visibility that demonstrate a novel technology or novel application of an available technology.

Net Metering. Indianapolis Power and Light offers a net metering program for PV systems, available for generators producing less than 1,000 kWh per month. No statewide limit exists on the amount of electricity that may be produced. Excess generation is granted to the utilities. For larger producers, two meters are installed.

Tax Relief. One hundred percent of residential renewable installations are exempt from property tax for the lifetime of the installation. Exemption is for therenewable device and related equipment.

Green Pricing. Indianapolis Power and Light offers customers a Green Power Option.

IOWA

Energy Efficiency Programs Run by Utilities. Regulated electric utilities are required to file energy efficiency plans with the Iowa Utilities Board. Programs must be available for all consumer classes. These programs are funded by a surcharge on all utilities, including municipal utilities and electric cooperatives.

Renewables Portfolio Standard. Investor-owned utilities in the state must purchase a combined total of 105 MW of electricity from renewable or small-scale hydro plants.

State Grants & Loans

1. The Iowa Energy Center sponsors a competitive grants program for renewables and energy efficiency.

2. Residential, commercial and industrial sectors are eligible for zero percent interest loans for up to half of the project cost, up to a maximum of $250,000. In 1996, $1.8 million per year was appropriated for the three-year period 1997-1999.

3. Renewable Fuel Fund – There is funding of up to $900,000. Approximately 20 percent of the money awarded to a project is in the form of a grant and the remaining 80 percent in the form of a low-interest loan.

Net Metering. All customer classes are eligible for net metering for renewable generation. Applicability is limited to 1,000 kWh/month. Excess generation is purchased at avoided cost.

Tax Relief. Property tax assessment – wind energy conversion equipment is to be assessed at zero percent of its cost for the first year. For the second through sixth years, value is increased by five percentage points per year. For the seventh and succeeding years the assessment is at 30 percent of its cost. Sales tax exemption – 100 percent of wind energy equipment is exempted.

MICHIGAN

Energy Efficiency Programs Run by Utilities (Discontinued). The Michigan Public Service Commission eliminated all requirements for utility energy efficiency programs in 1995 and 1996, in response to utility requests to abandon these programs in anticipation of electricity restructuring.

Green Pricing

1. Under the Green Rate offered by Traverse City Light and Power, customers who receive all of their power from a 600 kW wind turbine pay a premium of 1.58¢ per kilowatt hour. Residential customers must make a three-year commitment and commercial customers must make a 10-year commitment.

2. Detroit Edison's SolarCurrents program allows customers to purchase 100 Watt shares in the utility's two grid-connected photovoltaic systems. The monthly premium for a share is $6.70.

MINNESOTA

Energy Efficiency Programs Run by Utilities. Each public utility must spend 1.5 percent of its gross operating revenues from service provided in the state on energy conservation improvements. For a utility that furnishes electric service and operates a nuclear generating plant within the state, two percent of its gross operating revenues from in-state service must be spent.

Renewables Set Aside. XCel Energy (formerly Northern States Power) – was required to build or contract out 224 MW of wind power by December 31, 1998. An additional 200 MW are required by December 31, 2002. XCel Energy also was required to build or purchase 50 MW of farm grown closed-loop biomass by December 31, 1998 and an additional 75 MW by December 31, 2002.

State Grants & Loans

1. State Grants provide 1.5¢ per kilowatt hour payment for electricity generated from new wind projects less than 2 MW in capacity. Available up to a statewide ceiling of 7.5 MW. The ceiling will be raised to 100 MW by 2005. The credit is available for a period of 10 years after installation for all projects under the ceiling installed by Jan. 1, 2005.

2. The Rural Finance Authority will provide up to $100,000 (45 percent) of loan principal to farmers for improvements or additions to wind facilities. Rates on these loans average four percent. The loans are funded through a revolving account.

Construction Requirements. New state government building projects must incorporate active and passive solar energy and other alternative energy sources where feasible. Energy efficiency programs also are mandated in selected state buildings.

Net Metering. Renewable technologies and co-generators of less than 40 kW are eligible for net metering; there is no limit to statewide capacity. Excess generation is purchased at the average retail rate.

Tax Relief

1. Corporate Depreciation – follows the federal modified accelerated cost recovery schedule for renewables.

2. Property tax exemption – wind systems less than two MW are exempt; those larger than two MW have nine percent of their value subject to local taxes; and those larger than 12 MW will have 30 percent of their value subject to property taxes. PV systems also are eligible.

3. The total cost of solar and wind devices is exempt from sales tax.

Green Pricing

1. The Solar Advantage program, offered by XCel Energy (formerly Northern States Power) installs two-kW photovoltaic systems on participating customers' rooftops. Customers with the installations use power and sell excess generation to XCel Energy at the retail rate. Customers pay a monthly premium of $50 with a minimum commitment term of five years, after which customers have the option of purchasing the installation or continuing the agreement.

2. Wellspring, offered by Cooperative Power Association – Customers can purchase 100 kWh block of wind-generated electricity for a $2 monthly premium. Customers must commit to a term of 12 months.

Nebraska

Energy Efficiency Investment Funds

1. The Dollar and Energy Savings Loan Program provides low-interest loans to homeowners, businesses, government, and farmers and ranchers to make energy efficiency improvements.

2. The Energy Efficient Mortgages program provides mortgage discounts of up to one percent for newly constructed homes and .25 percent on existing homes.

3. Rebuild Nebraska assists communities and building owners with improving the energy efficiency of their commercial and multi-family residential buildings.

Loans. Loans are available at zero percent interest for up to half of a renewable energy project's cost. To date, more than 15,000 loans have been granted, totaling more than $100 million.

North Dakota

Net Metering. Net metering is available for renewables and co-generators of 100 kW or less. There is no statewide limit to net metered capacity. Utilities must purchase excess generation at their avoided cost.

Tax Relief. Tax payers can deduct five percent of the cost of equipment and installation of renewable energy installation from their personal taxes for a period of three years. Renewable energy devices are eligible for property tax exemption of 100 percent of the value for five years after installation.

Ohio

Energy Efficiency Investment Fund. Beginning in July, 2001, $100 million will be collected over 10 years to establish a revolving loan fund for energy efficiency and small-scale renewables.

Environmental Disclosure. Retail suppliers of electricity must disclose their fuel mix and environmental characteristics in a pie chart showing fuel mix of the competitive supplier and the region, bar graphs showing air emissions and a statement on radioactive waste. Generic descriptions of environmental characteristics (i.e. "air emissions and solid waste," "wildlife impacts," "radioactive waste," etc.) are included for each possible generation type.

Net Metering. Net metering is available for solar, wind, biomass, landfill gas, hydro, microturbines and fuel cells. There is no cap on system size, but the total capacity is limited to one percent of each utility's peak demand. Single meter trackingis used, and excess generation is purchased at the unbundled generation rate and credited to the following month's bill.

Green Pricing. Bowling Green's municipal utility program ranks seventh in the nation for customer participation and offers customers low-impact, "run of the river" hydropower from the Ohio River. Customers pay .0135¢/kWh for 100 percent renewable electricity; .0104¢/kWh for 75 percent; .0069¢/kWh for 50 percent; and, .0035¢/kWh for 25 percent. Green power offerings may be expanded to include wind and solar power.

SOUTH DAKOTA

Tax Relief. One hundred percent of residential installations and 50 percent of commercial installations are exempt from property tax. Exemption is available for three years after installation. Exemption is not available for installations producing energy for resale.

Green Pricing. The East River Electric Power Cooperative is making wind-generated electricity available to rate payers in 100 kWh blocks at a premium of $3.50. A one-MW installation will be constructed in early 2001. Customers will not be charged until the facility goes online.

WISCONSIN

Energy Efficiency and Renewable Energy Investment Funds. A transition plan is underway to transfer the management of energy efficiency and renewable energy initiatives from the utilities to state government. By 2003 the state government will administer and disburse, on an annual basis, between $70 and $80 million of ratepayer funding dedicated to clean energy programs.

Renewables Portfolio Standard. Beginning in 2001 and continuing for 10 years, electricity providers must increase the percentage contribution of renewable power sources relative to total electricity sales. The increase amounts to 1.7 percent of total electricity sales, which by 2011 translates to an increase in renewable electricity of nearly one billion kWh annually.

State Grants. Up to $15,000 in state grants is available for technical assistance. Funding for 10 to 20 percent of renewable installations is available up to $75,000. Half of the funding is withheld until project completion.

Net Metering. Net metering is available for all generator types less than 20 kW. Customers using renewables are paid the retail rate for their excess generation; customers using non-renewables are paid avoided costs.

Tax Relief. One hundred percent of renewable installations are exempt from property taxes.

Green Pricing Programs.

1. Energy for Tomorrow, offered by Wisconsin Electric, provides three levels of renewable fuel mix (currently hydro, wood waste and landfill gas; wind is planned). Customers can choose fuel mixes of 25 percent, 50 percent or 100 percent renewables and pay a monthly premium of $3, $6 or $12, respectively.

2. Under the SolarWise program, offered by Wisconsin Public Service, contributions from customers in amounts of $1, $2 and $4 support the installation of 12-kW grid-connected installations on school buildings. The SolarWise curriculum was developed, in part, through a grant from the Wisconsin Environmental Education Board

3. Wind Power Green Pricing, offered by Madison Gas & Electric, allows residential and business customers to purchase 100-kWh blocks for a monthly premium of $4 to $5 per block. MGE plans to construct and operate an 11.25 MW wind farm. The wind installation will consist of 15 – 750 kW turbines.

APPENDIX 3. MODELING ASSUMPTIONS

THE PROSYM MODEL

The electric power system in the Midwest was simulated using the PROSYM model. PROSYM is a chronological model that represents the operation of the roughly 2,000 individual generating units in the Midwest to serve customer electricity demand on an hourly basis. As a general matter, the units with lower operating costs have priority in the dispatch over higher cost units, so that the total cost of operating the system is minimized. The model also recognizes generator operating constraints such as minimum downtime and maximum ramp rates, as well as transmission constraints between each of the 10 individual "transmission areas" in the study region.

We selected the years 2010 and 2020 in which to perform simulations to provide a snapshot of the ways that the electric industry in the Midwest could evolve over time. We simulated 2010 and 2020 in both a business-as-usual case and a Clean Energy Development Plan. We also performed a simulation of 2000 as a benchmark of our assumptions.

The PROSYM model was used to analyze three NERC electricity regions: the East Central Area Reliability Coordination Agreement (ECAR), the Mid-American Interconnected Network (MAIN) and the Mid-Continent Area Power Pool (MAPP). These three regions include the 10 Midwestern states addressed in this study, as well as Kentucky, Missouri, Pennsylvania and West Virginia.

THE BUSINESS-AS-USUAL CASE

The business-as-usual case input assumptions were developed based primarily upon EIA's AEO 2000 in order to represent a "business-as-usual" future. For example, the business-as-usual case PROSYM inputs were set to match AEO 2000 projections of fossil fuel prices and electricity demand. The business-as-usual case, however, differs from AEO 2000 in several respects:

1. AEO 2000 does not include NO_x emission controls to comply with the EPA SIP Call. The business-as-usual case includes these controls, primarily SCR on newer plants (post-1960) and combustion controls on all plants, applied to individual generators in the portion of the study region east of the Mississippi River.

2. AEO 2000 assumes that the operating lives of some nuclear generating units in the region are extended beyond their current operating licenses. In the business-as-usual case we assume that these units – amounting to nearly 4,095 MW of capacity in 2010 and an additional 11,020 MW in 2020 – are retired at the expiration of their current operating licenses.

3. AEO 2000 has new renewable resources added, but apparently does not recognize certain recent state policies. In the business-as-usual case, additional renewable generation beyond that forecast in AEO 2000 was added to reflect the commitment in Minnesota to develop 400 MW of wind generation by 2012 and the funding for renewables in Illinois and Iowa.

It should be noted that under the business-as-usual case only a very small amount of existing coal generation is retired (1,700 MW by 2010). This is roughly consistent with AEO 2000, and appears to be consistent with the way coal plant owners will view the economics of retirement under business-as-usual conditions. That is, in the absence of explicit policies to the contrary (such as a carbon emissions cap or a targeted requirement for retirement/repowering), the existing fleet of coal plants will continue to operate (Synapse 6/1998). Indeed, consistent with AEO 2000, the coal units in the business-as-usual case operate at high-capacity factors over time, increasing from 63 percent in 2000 to 68 percent in 2010 and to 71 percent by 2020.

In the business-as-usual case, new generating resources must be added in order to meet growing demand and to replace retiring nuclear generation. In the business-as-usual case new gas-fired generators were added in order to meet a 12 percent reserve margin target in each "transmission area." It was assumed that 50 percent of this new capacity would be combustion turbine and 50 percent would be combined-cycle capacity. The resulting set of business-as-usual case capacity additions is broadly consistent with AEO 2000 and with the mix of new projects currently proposed and under construction in the Midwest, as indicated in Figure A.1.

FIGURE A.1 COMPARISON OF PROSYM AND AEO 2000 GENERATION FUEL MIX

	Percentage of Total Generation in 2000	
Fuel Type	PROSYM	AEO 2000
Coal	74	78
Natural Gas/Oil	2	3
Nuclear	20	17
Renewable	3	3

The Clean Energy Development Plan

The Clean Energy Development Plan includes four major changes from the business-as-usual case: (1) aggressive energy efficiency measures are implemented; (2) additional renewable and efficient generation resources are installed; (3) fewer new natural gas facilities are installed as a result of lower electricity demand and increased renewable resources; and (4) some older coal plants are retired early.

The energy efficiency measures, renewable technologies and efficient generators assumed in the Clean Energy Development Plan are described in Chapters 4, 5 and 6. The new natural gas units installed under the Clean Energy Development Plan to maintain a 12 percent reserve margin are consistent with the approach used in the business-as-usual case. However, in some control areas the reserve margins exceed 12 percent without installing any new natural gas facilities, because of the lower load and increased renewable resources. In these areas there will be some additional costs associated with having reserve margins higher than necessary, but there may also be additional benefits associated with higher reliability. We did not account for such benefits in our study. In the Clean Energy Development Plan we assumed that all new natural gas units are combustion turbine facilities because many of the new clean power options will meet the region's baseload needs.

The additional coal plant retirements were assumed to be the result of some form of CO_2 reduction policy. As described in Chapter 8, there are a variety of CO_2 reduction policies that could influence the retirement of older, less efficient, high-pollutant coal units. In the Clean Energy Development Plan we assumed that by 2010 all coal plants that were installed before 1960 (i.e., more than 50 years old) are retired. This represents roughly 19 percent of the existing coal fleet or 22 GW. There are no additional coal retirements between 2010 and 2020.

Our model calculated all of the going-forward costs associated with the production of electricity from 2000 through 2020. These going-forward costs include the costs to build new power plants; the fuel and O&M costs associated with running those plants; the costs of installing emission control costs and purchasing emission allowances; and the costs of any transmission and distribution upgrades that are necessary. The going-forward costs also include the costs of implementing efficiency initiatives, including administration costs, utility costs and customer costs. The difference in going-forward costs between the business-as-usual case and the Clean Energy Development Plan indicated the additional costs (or savings) associated with the Clean Energy Development Plan.

Going-forward costs do not represent the total cost of providing electricity. The total cost also includes "embedded" costs that are necessary to recover past expenditures. The price of electricity was based on total costs, in order to allow utilities to recover both embedded costs and going-forward costs.

We estimated the impact on total electricity system costs of the Clean Energy Development Plan by making a simplifying assumption about embedded costs. We began by estimating embedded costs in 2000 as the difference between 2000 total costs and 2000 going-forward costs. We then assumed that embedded costs will decline slightly from 2000 through 2020. Embedded costs were the same in the business-as-usual case and the Clean Power Case, by definition. Finally, we added the estimated embedded costs to the going forward costs from our model to determine total costs in 2010 and 2020. The percentage difference in total costs between the business-as-usual case and the Clean Energy Development Plan indicated the impact on total costs of the Clean Energy Development Plan.

The total costs included expenditures to reflect distribution system upgrades that will be necessary to meet load growth over the next 20 years. We assumed that distribution upgrades will cost $500/kW ($64/kW-yr) to cover the additional peak load over the study period. This is roughly half of the amount that U.S. electric utilities spent on transmission and distribution upgrades in the 10 years from 1979 through 1998.[22] These distribution upgrade costs were included in both the business-as-usual case and the Clean Energy Development Plan. In the Clean Energy Development Plan, however, we assumed that total distribution costs were reduced by 20 percent as a result of the energy efficiency investments. This is likely to be an underestimate of the distribution costs avoided by energy efficiency measures. Distributed generation technologies might result in additional avoided distribution costs.

[22] Distribution costs were roughly 75 percent of transmission and distribution costs over this period. We chose a lower distribution cost in order to be conservative.

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4

Scenarios

of

U.S. Carbon Reductions

Potential Impacts of Energy Technologies by 2010 and Beyond

Prepared by the

Interlaboratory Working Group
on Energy-Efficient and Low-Carbon Technologies

ornl
Oak Ridge National Laboratory*

Berkeley Lab
Lawrence Berkeley National Laboratory*

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Pacific Northwest National Laboratory

Argonne National Laboratory
University of Chicago

Argonne National Laboratory

NREL
National Renewable Energy Laboratory

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*Coordinating laboratories for this study

EXECUTIVE SUMMARY

This report presents the results of a study conducted by five U.S. Department of Energy national laboratories that quantifies the potential for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States.[1] The study documents in detail how four key sectors of the economy – buildings, transportation, industry, and electric utilities – could respond to directed programs and policies to expand adoption of energy-efficiency and low-carbon technologies, an increase in the relative price of carbon-based fuels by $25 or $50/tonne (e.g., as a result of a cap on domestic carbon emissions and a market for carbon "permits"), and an aggressive program of targeted research and development. Current projections suggest that a carbon emissions reduction of 390 million metric tons per year (MtC/year) is required to stabilize U.S. emissions in 2010 at 1990 levels.

The study, which has been peer-reviewed by industry and academic experts, uses a technology-by-technology assessment as well as an engineering-economic modeling approach. It draws upon a wide variety of technology cost and performance information to assess potential impacts. Analysis of the buildings, industry, and transportation sectors quantifies the impacts of end-use energy-efficiency improvements on carbon emissions. The utility sector analysis estimates the impacts of those improvements on utility carbon emissions, and quantifies additional emissions reductions through conversion of a number of coal power plants to natural gas, dispatching of the utility grid with $25 and $50/tonne carbon permit prices, the accelerated use of biomass cofiring and wind energy, and other low-carbon electricity supply options. Finally, a number of other promising low-carbon technologies are examined to determine their potential for reducing emissions in the end-use sectors, including advanced gas turbines in industry, transportation biofuels, and fuel cells in buildings.

Three overarching conclusions emerge from the analysis of alternative carbon scenarios. First, a vigorous national commitment to develop and deploy energy-efficient and low-carbon technologies has the potential to restrain the growth in U.S. energy consumption and carbon emissions such that levels in 2010 are close to those in 1997 (for energy) and 1990 (for carbon). We analyze a case in which energy efficiency can reduce carbon emissions by 120 MtC/year by 2010. We analyze a second case, with policies that promote adoption of energy-efficient and low carbon technologies and a $25/tonne carbon permit price, with emission reductions of 230 MtC/year in 2010. Under a $50/tonne carbon permit price and aggresive policies, 2010 emissions could be cut by about 390 MtC/year. The analysis also suggests that substantial additional savings are available if permit prices were to begin to rise above the $50/tonne level.

The second conclusion is that, if feasible ways are found to implement the carbon reductions as described above, all the cases (with reductions varying between 120 and 390 MtC/year by 2010) can produce energy savings that are roughly equal to or exceed costs.[2] The analysis includes only technologies estimated to be cost-effective under 2010 energy prices (with a $25/tonne and $50/tonne carbon permit price for the respective cases); it has not, however, analyzed specific policies to achieve the cases, identified the political feasibility of policies, or described a pathway to achieve the cases.

The third conclusion is that a next generation of energy-efficient and low-carbon technologies promises to enable the continuation of an aggressive pace of carbon reductions over the next quarter century. This report documents a wide array of advanced technology options that could be cost-competitive by the year 2020, assuming a vigorous and sustained program of energy R&D beginning now and extending beyond 2010.

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[1] The five national laboratories participating in the study were: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). LBNL and ORNL were the co-leaders of the effort.

[2] Here we count as benefits only the energy savings to the nation. We have not credited reduced CO_2 emissions or other external benefits. Costs include the increased technology cost plus an approximate estimate of the costs of program and policy implementation.

AUTHORSHIP

Marilyn A. Brown (Oak Ridge National Laboratory) and Mark D. Levine (Lawrence Berkeley National Laboratory) were responsible for the overall leadership of the project. They jointly authored the Executive Summary, Chapter 1 (Analysis Results), and Chapter 2 (Introduction and Background).

Chapter 3 (Buildings) authorship is best described in terms of the analysis for 2010 (Sections 3.2 and 3.3 and associated appendices) and R&D potential in 2020 (Section 3.4). Jonathan Koomey (Lawrence Berkeley National Laboratory) was the lead author for the 2010 analysis. Nathan Martin, Lynn Price, and Mark Levine (LBNL) were co-authors. Marilyn Brown was the lead author for the R&D section, with support from staff at Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory.

Gale Boyd (Argonne National Laboratory), Joseph M. Roop, and Madeline G. Woodruff (Pacific Northwest National Laboratory) were the lead authors of Chapter 4 (Industry) with the exception of Section 4.3 (Low-Carbon Technologies), which was prepared by Helena Chum and Ralph P. Overend (National Renewable Energy Laboratory), Tony Schaffhauser and Marilyn Brown (Oak Ridge National Laboratory), and Tina Kaarsberg (Vista Technologies).

David Greene (Oak Ridge National Laboratory) and Steve Plotkin (Argonne National Laboratory) were responsible for Chapter 5 (Transportation).

Stanton Hadley and Eric Hirst (Oak Ridge National Laboratory) were the authors of Chapter 6 (The Electricity Sector's Response to End-Use Efficiency Changes).

Chapter 7, Electricity Supply Technologies, consists of a variety of topics: Conversion of Coal-Based Power Plants to Natural Gas (Section 7.2) was prepared by David South and Jack Siegel (Energy Resources, Inc.); Renewable Electricity Technologies (Section 7.3) was written by Eldon Boes and Erik Ness with contributions from National Renewable Energy Laboratory staff; the section on Advanced Coal Technologies (Section 7.6) was written by Stanton Hadley (Oak Ridge National Laboratory); and the sections on Efficiency Improvements in Generation and T&D (Section 7.4) and Nuclear Plant Life Extension (Section 7.5) were written by Marilyn Brown (Oak Ridge National Laboratory). Other sections of this chapter are summaries of published materials.

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PREFACE

This report, *Scenarios for a Clean Energy Future,* was commissioned by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. It was produced by the Interlaboratory Working Group, composed of scientists from Argonne National Laboratory, Lawrence Berkeley National Laboratory, the National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory. The report seeks to develop a better understanding of the potential for R&D programs and public policies to foster clean energy technology solutions to the energy and environmental challenges facing the nation. These challenges include global climate change, air pollution, oil dependence, and inefficiencies in the production and use of energy.

The study uses a scenario-based approach to examine alternative portfolios of public policies and technologies. The policies were selected by the authors through a dialogue with numerous representatives from the private sector, non-profit organizations, universities, and government. These policies range from expansions of long-existing programs to new policies, some of which are clearly controversial.

This study does not make policy recommendations. Rather, the purpose of the study is to better understand the costs and benefits of alternative sets of policies to accelerate clean energy technology solutions. Some of these policies are not the policies of the current Administration. In addition, the policies do not address the complete range of policy options. For example, the scenarios do not include international emissions trading which could be important to meeting possible carbon emission targets.

This study identifies the potential for impressive advances in the development and deployment of clean energy technologies without significant net economic impacts. Widespread use of these technologies would do much to cut U.S. greenhouse gas emissions. In reviewing the study's results, however, it is important to remember the imprecision of policy analysis; uncertainties derive from such diverse issues as the likely pace of technology advancements and the response of consumers to market-based incentives.

We believe this study will make a substantial contribution to developing a deeper understanding of the potential for clean energy technologies and policies to meet future energy and environmental goals and challenges. This study provides a foundation of analysis that can help the nation identify smart, sustainable energy policies and technologies.

The contributions to this study by multiple national laboratories, and industry and university participants and reviewers, are another example of the effective partnerships that the Department of Energy is fostering to advance the nation's energy and environmental agenda.

Marilyn Brown | Mark D Levine | Walter D Short

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EXECUTIVE SUMMARY

As we move into the 21st century, a number of key energy-related challenges face the nation. U.S. dependence on imported oil is growing, increasing the nation's vulnerability to supply and price disruptions. Electricity outages, power disturbances, and price spikes threaten U.S. productivity especially in the rapidly growing information-based service industries. Despite ongoing improvements in air quality, air pollution from burning hydrocarbons continues to cause high levels of respiratory illnesses, acid rain, and photochemical smog. And global climate change threatens to impose significant long-term costs from increasing temperatures, rising sea levels, and more extreme weather. The prosperity and well-being of future generations will be strongly affected by the manner in which the nation responds to these challenges.

Following a 1997 study, *Scenarios of U.S. Carbon Reductions,* the U.S. Department of Energy (DOE) commissioned an Interlaboratory Working Group to examine the potential for public policies and programs to foster efficient and clean energy technology solutions to these energy-related challenges[1]. This document reflects the best efforts of the Interlaboratory Working Group to understand and present that potential. The three key conclusions of the CEF study are summarized below.

The Study's Key Conclusions

Smart public policies can significantly reduce not only carbon dioxide emissions, but also air pollution, petroleum dependence, and inefficiencies in energy production and use. A range of policies exists – including voluntary agreements; efficiency standards; increased research, development, and demonstration (RD&D); electric sector restructuring; and domestic carbon trading – that could move the United States a long way toward returning its carbon dioxide emissions to 1990 levels by 2010. Additional means would be needed to achieve further reductions, such as international carbon trading and stronger domestic policies.

The overall economic benefits of these policies appear to be comparable to their overall costs. The CEF policies could produce direct benefits, including energy savings, that exceed their direct costs (e.g., technology and policy investments). Indirect macroeconomic costs are in the same range as these net direct benefits. The CEF scenarios could produce important transition impacts and dislocations such as reduced coal and railroad employment; but at the same time, jobs in wind, biomass, energy efficiency, and other "green" industries could grow significantly.

Uncertainties in the CEF assessment are unlikely to alter the overall conclusions. The policy and technology opportunities identified in the CEF are so abundant that they compete with each other to reduce carbon emissions. We would expect enough of them to be successful to achieve the results we claim. Furthermore, a broad range of technology options, with sufficient research, could provide additional solutions in the long run.

In the end, the authors take advantage of the data available, use their best judgment informed by external expert review, and employ scenarios and sensitivity analysis to bound the uncertainties. The overall conclusion from this analysis is that the existence of a wide array of policy and technology options

[1] Members of the working group were drawn from Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL).

provides many low-cost pathways to a cleaner energy future. In reviewing the study's results, however, it is important to remember the imprecision of policy analysis; uncertainties derive from such diverse issues as the likely pace of technology advancements and the response of consumers to market-based incentives.

CEF SCENARIOS

This study does not make policy recommendations. Rather, the purpose of the study is to better understand the costs and benefits of alternative sets of policies to accelerate clean energy technology solutions. Some of these policies are not the policies of the current Administration. In addition, the policies do not address the complete range of policy options. For example, the scenarios do not include international emissions trading which could be important to meeting possible carbon emission targets.

The structured development of energy scenarios allows a way to examine a range of public policies and to consider alternative possibilities. The CEF study develops three scenarios: Business-as-Usual (BAU), Moderate, and Advanced. The BAU scenario assumes a continuation of current energy policies and a steady, but modest pace of technological progress. In contrast, the Moderate and Advanced scenarios are defined by policies that are consistent with increasing levels of public commitment and political resolve to solving the nation's energy-related challenges. Some of the public policies and programs that define the scenarios are cross-cutting; others are designed individually for each sector (buildings, industry, transportation, and electric generation) and assessed for impacts to 2020.

The CEF scenarios address U.S. energy and environmental issues for the next 20 years. They are not long-term, global, integrated assessments. As such, the CEF scenarios are not necessarily responsive to energy needs, environmental conditions, and technology opportunities that emerge after 2020 or elsewhere in the world. The scope of this quantitative analysis is limited to near-term domestic issues to illustrate specific clean energy technology and policy opportunities for the United States today. "Clean energy technologies" include:

- measures that reduce the energy intensity of the economy (e.g., more efficient lighting, cars, and industrial processes),
- measures that reduce the carbon intensity of the energy used (e.g., renewable energy resources, nuclear power, natural gas, and more efficient fossil-fueled electricity plants), and
- measures that integrate carbon sequestration into the energy production and delivery system (e.g., integrated gasification combined cycle plants with carbon separation and storage).

To place the CEF scenarios within an expanded context that considers the post 2020 period, we qualitatively describe energy technology breakthroughs that could occur by mid-century. With successful research and supportive policies, such breakthroughs could provide additional solutions to long-term and global energy problems. These technologies include carbon sequestration from coal, a new generation of nuclear power plants, advanced gas and chemical separation technologies, hybrid electric systems deploying wind power and gas turbines in combination with low-cost storage and advanced power electronics, and a host of highly efficient and advanced renewable energy technologies.

Following a detailed assessment of market failures and institutional barriers to the market penetration of clean energy technologies, numerous policies were chosen for examination in the CEF study. These policies include fiscal incentives, voluntary programs, regulations, and research and development. Many of the policies were selected on the basis of their potential to reduce carbon dioxide emissions. Others were designed specifically for air quality (e.g., reducing SO_2 emissions in the electric sector), oil security (e.g., alternative fuels research), and economic efficiency (e.g., restructuring of the electric sector).

Regardless of the driving force behind them, almost all reduce carbon dioxide emissions and improve air quality. Policies are generally stronger in the Advanced than in the Moderate scenario, with larger expenditures on public-private RD&D partnerships, stricter standards, higher tax incentives, and greater government investment in programs that promote efficient and clean energy technologies. Some policies are assumed to begin in 2000; others are assumed to begin in subsequent years. Their impacts tend to be gradual, as stock turnover and other factors dampen initial responses. Delays in implementation would miss immediate capital replacement opportunities.

The policies identified as most important in the Advanced scenario are summarized in Table 1. A key policy mechanism for the Advanced scenario across all of the sectors is the addition of a domestic carbon trading system. In this system, which is assumed to be announced in 2002 and implemented in 2005, permits are sold annually in a competitive auction run by the federal government. The carbon emissions annual limit is set so that the permit price equilibrates at \$50/tC (in 1997\$) throughout the period. A \$25/tC case is also analyzed. The second key policy mechanism in the Advanced scenario for all of the sectors is the doubling of federal government appropriations for cost-shared RD&D in efficient and clean energy technologies. As these resources are spent in public/private RD&D partnerships, they are matched by private-sector funds, resulting in an assumed increase of \$1.4 billion per year by 2005, bringing the total to \$2.8 billion (in 1997 \$) in 2005 and each year after that. Half of these expenditures are federal appropriations and half are from private-sector cost sharing.

Table 1 Key Policies in the Advanced Scenario*

Buildings	Industry
–Efficiency standards for equipment –Voluntary labeling and deployment programs	–Voluntary programs –Voluntary agreements with individual industries and trade associations
Transportation	**Electric Generators**
–Voluntary fuel economy agreements with auto manufacturers[a] –"Pay-at-the-pump" auto insurance	–Renewable energy portfolio standards and production tax credits –Electric industry restructuring
Cross-Sector Policies	
– Doubled federal research and development	–Domestic carbon trading system

*The scenarios are defined by approximately 50 policies. The 10 in this table are the most important ones in the Advanced scenario. Each policy is specified in terms of magnitude and timing. For instance, "Efficiency standards for equipment" comprise 16 new equipment standards introduced in various years with specific levels of minimum efficiencies.
[a] These voluntary agreements, because they are met in the Advanced scenario, would have the same effect as a corporate average fuel economy (CAFE) standard of the same level.

Several of the policies in the CEF scenarios are coupled to produce significant positive synergies. For instance, research prepares clean energy technologies to respond to opportunities created by incentives and to meet subsequent codes and standards. Efficiency gains from policies directed at the buildings and industrial sectors prevent or temper price increases from rising natural gas demand in the power sector, which results from policies such as the domestic carbon trading system. At the same time, some policies compete with one another. For example, policies that strengthen the performance of energy-efficient technologies foreclose the rapid penetration of many clean energy supply options in the 2020 timeframe, despite the inclusion of policies intended to promote them, since less energy supply is needed.

The CEF scenarios are based on a limited set of policies, many of which are relatively non-intrusive policies. Inclusion of stronger, more intrusive policies would result in more rapid progress toward meeting the nation's energy and environmental goals, though probably at higher cost. Many of these additional policies are explored in other studies, which could be consulted if the nation requires acceleration beyond the transitions described here. Further, the CEF scenarios omit policies that some policymakers might consider attractive. Some policies are omitted because their impacts are redundant. Others are left out because of modeling difficulties. Additional policies are excluded because the authors concluded that the required levels of public commitment or costs exceed CEF scenario guidelines.

METHODOLOGY

A scenario-based approach is used to allow examination of alternative portfolios of public policies. A scenario is a story – not a prediction – of how the future might unfold. Scenarios are useful for organizing scientific insight, gauging emerging trends, and considering alternatives.

We have used various assessment methods, analytic tools, and expert judgments to analyze the impacts of individual policies. The CEF-NEMS model – based on the Energy Information Administration's (EIA) National Energy Modeling System (NEMS) – is then employed to quantitatively integrate the impacts of each scenario's policies. The integration step of CEF-NEMS allows the estimated effects of changes in energy use in each sector to be considered in the resultant energy use patterns of the other sectors. The CEF-NEMS also assesses additional changes in energy demand where new policies or technologies affect energy prices. Macroeconomic impacts and feedback are separately assessed through an analysis of previous published modeling results.

The EIA's Reference case from the *Annual Energy Outlook 1999* is used as the starting point for the CEF BAU forecast (the most recent available from the EIA at the time of this analysis). Thus the EIA's Reference case assumptions on fossil fuel supplies, world oil prices, energy transport, end-use service demands, and macroeconomic growth underlie the three CEF scenarios[2].

The CEF BAU forecast and the EIA Reference case forecast differ only slightly. The BAU forecast uses different base year values and stock turnover rates for several industries, which result in a lower rate of growth of energy use. This is the principal cause of the CEF BAU forecast having ~0.5% lower total energy use in 2010 and 2020 than the EIA Reference case. Carbon emissions in the BAU forecast are almost 1% less in 2010 and are 3% less in 2020 than in the EIA Reference case, primarily because the BAU assumes lower nuclear power relicensing costs.

To capture the policies of the Moderate and Advanced scenarios, CEF-NEMS inputs (such as technology and process characterizations, stock turnover rates, consumer discount rates, and fuel prices) are changed from the BAU scenario (and therefore from the EIA's Reference case). Translation of these policies into the inputs required by CEF-NEMS was conducted through off-line analysis, reference to past studies, expert judgment, and outside review. This process enabled quantitative estimates of the impacts of key voluntary policies such as appliance labeling and energy audit programs.
As an engineering-economic study, the analysis is unable to incorporate the full impact of market-wide behavioral responses to the CEF policies. Therefore, the final estimates of costs and benefits should be considered the costs and benefits of the technology and policy implementation, not of the comprehensive impacts of these policies. For example, although the technical analysis was based on comparing products with similar characteristics (e.g., automobiles of the same expected size), technology improvements can change the mix of products and features demanded by consumers. These potential changes are not

[2] While these Reference case assumptions differ slightly from those used in the *Annual Energy Outlook 2000*, the overall conclusions of the CEF study would be similar if these more recent assumptions were used.

reflected in this study. Likewise, potential feedbacks from any technology or policy-induced shifts in sector output on energy use are not reflected in this analysis.

RESULTS

Key findings of this study are presented in Table 2 for the BAU forecast and for the Moderate and Advanced scenarios. Results are also shown for one of the numerous alternative policy sets that are examined – in this case, the Advanced scenario with a domestic carbon trading system that equilibrates at a carbon allowance price of $25/tC. Dozens of alternative policies were analyzed to reflect the unpredictable nature of political and consumer views and to highlight the diversity of policy options. The presentation of results with three or more significant figures here and throughout this report is not intended to imply high precision, but rather is designed to facilitate comparison among the scenarios and

Table 2 Selected Results for 2010 and 2020*

			2010 Scenarios			
	1990	1997	BAU Forecast	Moderate	Advanced ($25/tC)[a]	Advanced ($50/tC)[b]
U.S. Primary Energy Use in Quadrillion Btu (Percent Change from BAU)	84.2 –	94.0 –	110.4 –	106.2 - 106.5 (-4%)	101.0 (-9%)	98.2 - 99.3 (-11% to -10%)
U. S. Energy Bill in Billion 1997$ (Percent Change from BAU)	516 –	552 –	651 –	595 (-9%)	598 (-8%)	634[c] (-3%)
U.S. Carbon Emissions in Million Metric Tons (Percent Change from BAU)	1,346 –	1,480 –	1,769 –	1,679 - 1,684 (-5%)	1,539 (-13%)	1,437 - 1,463 (-19 to -17%)
			2020 Scenarios			
	1990	1997	BAU Forecast	Moderate	Advanced ($25/tC)[a]	Advanced ($50/tC)[b]
U.S. Primary Energy Use in Quadrillion Btu (Percent Change from BAU)	84.2 –	94.0 –	119.8 –	109.6 - 110.1 (-9% to -8%)	98.8 (-18%)	94.4 - 96.8 (-21% to -19%)
U. S. Energy Bill in Billion 1997$ (Percent Change from BAU)	516 –	552 –	694 –	594 (-14%)	541 (-22%)	572[c] (-18%)
U.S. Carbon Emissions in Million Metric Tons (Percent Change from BAU)	1,346 –	1,480 –	1,922 –	1,730 - 1,740 (-10% to -9%)	1,472 (-23%)	1,307 - 1,347 (-32% to -30%)

*A number of key technologies were not modeled within the CEF-NEMS framework, including combined heat and power (CHP), solar domestic hot water heaters, and fossil fueled on-site generation in buildings. An off-line analysis of policies to tackle barriers to CHP in industry was completed. It produced estimates of energy and carbon impacts for the Moderate and Advanced scenarios. These estimates are included in the lower numbers in the ranges shown in this table. Estimates of impacts of CHP policies on the U.S. energy bill are not available.

[a] This variation of the Advanced scenario has a domestic carbon trading system that equilibrates at a carbon permit value of $25/tC.

[b] The Advanced scenario includes a domestic carbon trading system that equilibrates at a carbon permit value of $50/tC.

[c] The energy prices used to calculate this energy bill include the cost of the carbon permit.

to allow the reader to better track the results. An uncertainty range for each value would be preferred to our single-point estimates, but the analysis required to prepare such ranges was not possible given the available resources and the process described above.

Energy Use. The Moderate and Advanced scenarios produce reductions in energy use as a result of the many CEF policies that are directed at the adoption of energy-efficient technologies. Efficiency standards play a major role in reducing energy demand in the buildings sector. Voluntary agreements with industries and voluntary labeling and deployment programs are also key to the substantial demand reductions of these scenarios. Such efficiency improvements are generally most economic when it is time to replace existing equipment; they therefore take time to materialize.

In the Advanced scenario, the nation consumes 20% less energy in 2020 than it is predicted to require in the BAU forecast. These savings of 23 quadrillion Btu (quads) are equal to almost one-quarter of the nation's current energy use. They are enough to meet the current energy needs of all the citizens, businesses, and industries located in the top three energy consuming states (Texas, California, and Ohio) or the combined current energy needs of the 30 lowest consuming states.

Accelerated technology improvements from expanded RD&D contribute significantly to energy savings in every sector of the economy. For example, in the transportation sector, RD&D is estimated to drive down the cost of a hydrogen fuel cell system from $4,400 more than a comparable gasoline vehicle in 2005 to an increment of only $1,540 in 2020. In the electric sector, capital costs for wind power drop to $611/kW in 2016 as a result of RD&D. Even reductions in primary energy use in all sectors can be expected after 2020 as technology improves further and utilization expands.

Energy use reductions in the Advanced scenario are more than twice those of the Moderate scenario because of two types of policy changes. First, the policies of the Moderate scenario have been strengthened in the Advanced scenario. For example, RD&D has been further expanded and performance standards in the buildings sector have been applied to more end uses. Secondly, additional policies are applied in the Advanced scenario, including domestic carbon trading, voluntary agreements to improve the fuel economy of light-duty vehicles, and pay-at-the-pump automobile insurance. An off-line analysis of combined heat and power in industry suggests that policies tackling barriers to this technology could increase energy savings by an additional quad in 2010 and by an additional 2.4 quads in 2020.

Carbon Emissions[3]. By 2020, carbon emissions in the Advanced scenario are 30 to 32% lower than in the BAU forecast. These emission reductions are nearly three times those of the Moderate scenario (Figures 1 and 2). This much stronger performance of the Advanced scenario results from the focus of many of its policies on the use of low-carbon energy resources.

The electric sector in particular experiences a strong shift to low-carbon fuels. The policies that drive this conversion include domestic carbon trading, expansion of the production tax credit for renewables, restrictions on emissions of particulate matter, and restructuring of the electricity industry that allows cost-effective options to be introduced more quickly. These Advanced scenario policies produce a 47% reduction in carbon emissions in the electric sector by 2020. The largest portion of these electric sector reductions comes from the repowering or replacement of coal-fired power plants by natural gas-fired power generation as well as wind, biomass, and geothermal power. The off-line analysis of combined heat

[3] Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and a host of engineered chemicals such as sulfur hexafluoride (SF_6), hydro-fluorocarbons (HFCs), and perflorocarbons (PFCs). It is convenient to refer to greenhouse gas emissions in terms of their carbon equivalent and the reduction of greenhouse gases as a reduction in carbon emissions. We will follow this convention here.

and power in industry suggests the potential to reduce carbon dioxide emissions by an additional 40 MtC in 2020.

Fig. 1 Carbon Emission Reductions, by Sector, in the Moderate Scenario

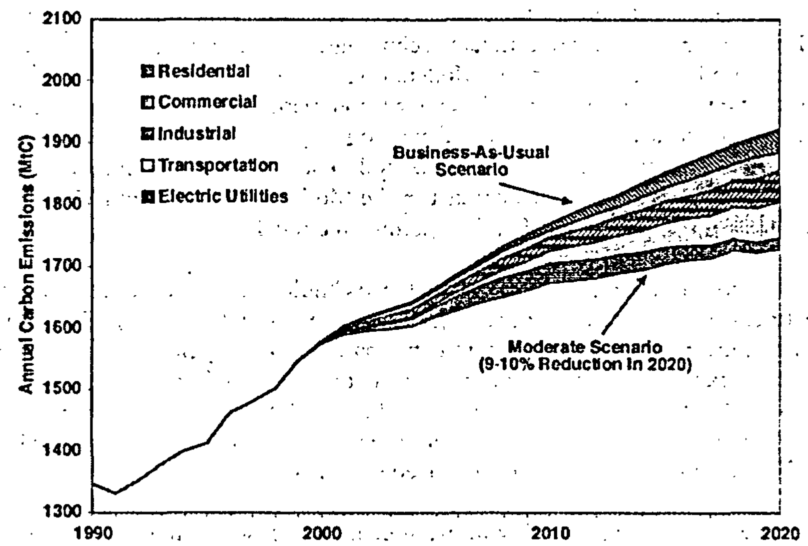
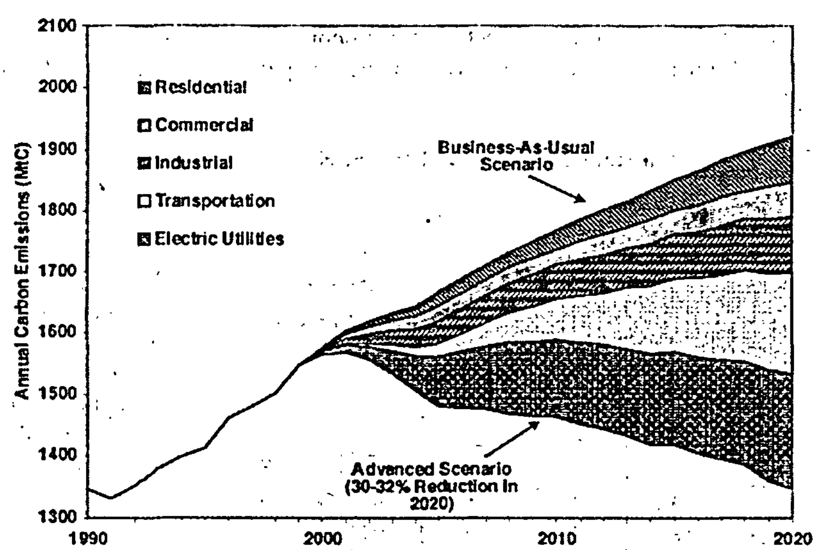


Fig. 2 Carbon Emission Reductions, by Sector, in the Advanced Scenario



Overall, the Moderate scenario brings CO_2 emissions 20% of the way back to 1990 levels by 2010; the Advanced scenario with a carbon permit value of \$25/tC brings them 54% of the way down; and the Advanced scenario at \$50/tC closes 72% of the gap. In the context of the U.S. Kyoto Protocol goal of reducing greenhouse gas emissions to 7% below 1990 levels by 2010, the CEF policies would need to be supplemented by other means such as international carbon trading, reductions in other greenhouse gases, and/or stronger domestic policies. In the Advanced scenario, carbon emissions drop fully to 1990 levels by the year 2020.

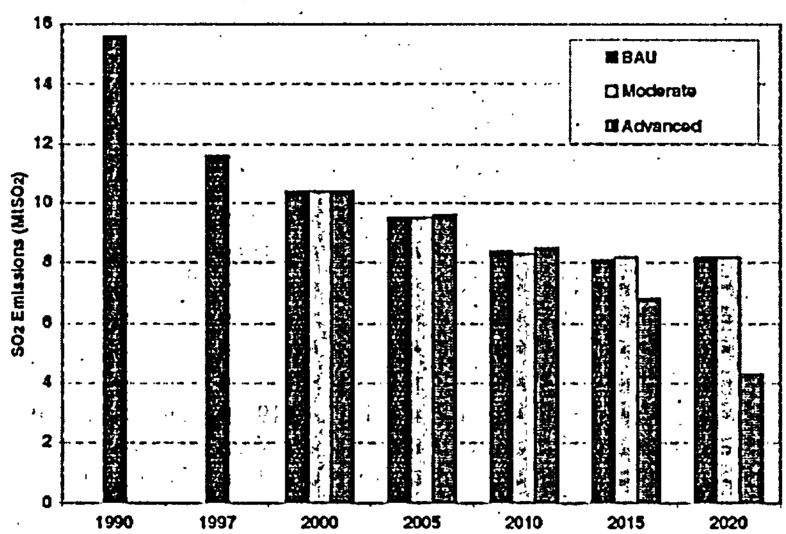
Costs and Benefits. In both the Moderate and Advanced scenarios and in both timeframes (2010 and 2020), the nation pays less for its energy than in the BAU forecast. This is largely due to the accelerated development and deployment of energy-efficient technologies that reduce primary energy use. In 2010, the Advanced scenario bill is higher than the Moderate scenario bill because energy producers increase energy prices to recover their cost of purchasing carbon permits. The increased use and improved performance of efficient and low-carbon energy technologies in the Advanced scenario place downward pressure on energy prices throughout the 20-year period. The net effect is that by 2020 the Advanced scenario's energy bill is $23 billion lower than that in the Moderate scenario and $124 billion lower than in the BAU forecast, even with the costs of carbon permits included.

While consumers benefit from lower energy bills, the technologies that produce these savings require incremental investment. In addition, there are costs to implement and operate policies and programs. In both policy scenarios, the energy bill savings, in combination with recycled revenues from the domestic carbon trading system, exceed the annualized direct costs of the technologies and policies. The Moderate scenario produces direct benefits of approximately $40 billion compared to the Advanced scenario of $48 billion in 2010. By 2020, these benefits grow to more than $60 billion per year in the Moderate scenario and to more than $100 billion per year in the Advanced scenario.

Against these direct benefits is the possibility of macroeconomic costs arising from distortions induced by domestic carbon trading. An integrated macroeconomic analysis was not undertaken for this study. However, an assessment of these costs, based on a review of the quantitative modeling of other researchers, shows them to range from a $4 billion to a $66 billion loss in Gross Domestic Product (GDP) in 2010. These costs are the same order of magnitude as the direct benefits described above.

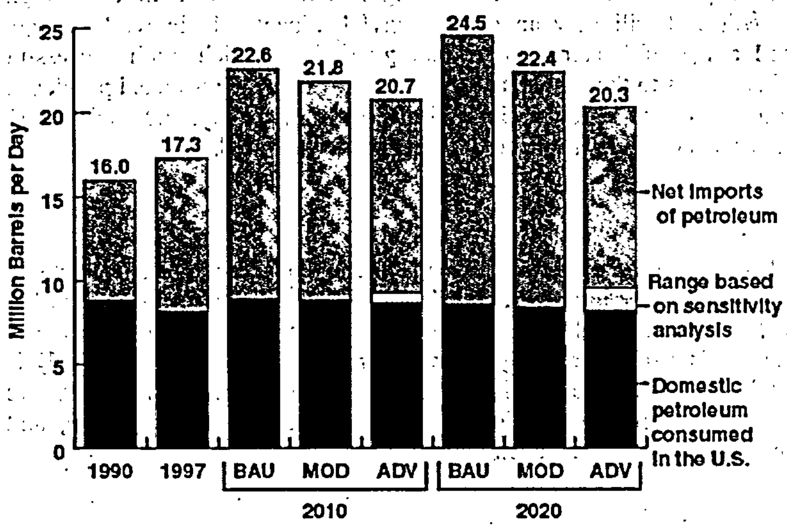
The impacts summarized above do not reflect several important other benefits: reduced vulnerability to oil supply disruptions, cleaner air, and improved balance of payments. For example, in the Advanced scenario, in 2020:

Fig. 3 SO_2 Emission Reductions in the Electric Sector



- SO_2 emissions from the electric sector decline from 8.2 million metric tons in the BAU forecast to 4.1 million metric tons in the Advanced scenario, resulting in substantial environmental and health benefits (see Fig. 3).

Fig. 4 U.S. Consumption of Domestic and Imported Crude Oil and Petroleum Products



- Petroleum consumption decreases 23% below the BAU forecast, thereby strengthening oil security. In addition, the nation benefits from significant reductions in annual wealth transfers from U.S. oil consumers to world oil exporters (see Fig. 4).

In spite of the overall net economic and environmental benefits of the scenarios, implementation of the CEF policies could produce important transition impacts and dislocations, and some regions are likely to be disproportionately impacted[4]. The impact of the Advanced scenario on the coal and coal transport industry is of particular note. Overall coal production in the United States decreases by 2020 to 50% of the BAU forecast, causing significant adverse impacts on that industry. On the other hand, the growth of strong domestic wind, bioenergy, energy efficiency, and other "green" industries envisioned in this scenario would bring new employment opportunities to many regions and could contribute to a revitalization of the economies of rural America. Efficiency technologies could boost output over a range of industries located throughout the United States, such as agriculture and bioprocessing, lightweight materials fabrication, sensor and control systems, and energy service companies.

As is true of any study that estimates future impacts of technology and policy, these scenarios have many uncertainties. The first concerns RD&D. On one hand, the Advanced scenario depends on technologies not currently available or cost-effective. For instance, substantial progress toward more efficient vehicles is assumed, as well as important evolutionary improvements in renewable and fossil-fueled electricity technologies. The degree of success for RD&D is inherently uncertain, however, and it is not possible to be sure that the results would turn out as estimated. On the other hand, the broad portfolio of technologies adds to the robustness of the results and, conceivably, the Advanced policies could lead to greater technical progress than assumed. The second major uncertainty is in the effectiveness, benefits, and costs of policies. This is closely tied to the success of RD&D. If efficient and clean energy technologies become increasingly cost-effective, then the policies driving them to market in the Advanced scenario are much easier to pursue and much more likely to generate net economic gains.

LONG-TERM AND GLOBAL CONTEXT

The CEF scenarios cover a near-term timeframe – the next two decades – and focus primarily upon domestic energy challenges and issues. This scope is not meant to minimize the importance of longer-term and global energy issues such as the severe air pollution problems in many countries throughout the world, access to electricity for the third of the world's population that is currently unserved, and long-term fossil fuel resource limitations.

[4] Policies to mitigate these regional impacts are not explored in this report.

A consideration of the longer term makes clear the tremendous variety of possible energy futures. In spite of this diversity, two observations appear likely. First, developing nations will account for a high percentage of energy demand growth and will play an increasingly dominant role in world energy markets. Second, there is a broad range of longer-term technology options which, with successful research, would provide additional solutions to the nation's – and the world's – energy-related problems. Given uncertainties in global economic trends, demographics and lifestyles, air quality, and climates, an expanded R&D effort in most energy technology arenas would appear to be warranted.

SUMMARY

This study makes a strong case that a vigorous program of energy technology research, development, demonstration and deployment coupled with an array of public policies and programs to overcome market failures and organizational barriers hindering technology utilization can be an effective public response to the nation's energy-related challenges. This study helps move the nation toward developing the analysis and public process needed to identify smart, sustainable energy policies and programs. This study shows that policies exist that could significantly reduce inefficiencies, oil dependence, air pollution, and greenhouse gas emissions at essentially no net cost to the U.S. economy.

6

SMART ENERGY POLICIES: SAVING MONEY AND REDUCING POLLUTANT EMISSIONS THROUGH GREATER ENERGY EFFICIENCY

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CONTENTS

Executive Summary

Multiple Energy Problems Confront the United States

There are a variety of serious energy challenges confronting the United States. California has experienced power shortages and severe electricity price spikes. Power reliability problems could spread to other regions such as the Pacific Northwest or New York. Even if the lights stay on, electricity prices will continue to climb in many regions of the country—utilities in several states have increased electric rates by 40–50% this year. Natural gas prices have also significantly increased in many parts of the country, causing skyrocketing home energy bills this past winter. Furthermore, our reliance on imported oil has grown—oil imports more than doubled during the past 15 years and oil imports now exceed domestic oil production. Rising demand for oil and tight supplies have also caused gasoline prices to rise; the average price of gas in the United States topped $1.70 per gallon earlier this year and while prices have since abated, price spikes are likely to be a periodic phenomenon in the future.

In addition, emissions of the gases that contribute to global climate change continue to rise. In 2000, U.S. greenhouse gas emissions were up 16% relative to levels in 1990. However, under the Global Framework Convention agreed to in Rio de Janeiro in 1992 by then-President Bush and subsequently ratified by the Senate, the United States voluntarily committed to reducing our emissions to 1990 levels by 2000.

Energy Efficiency—A Critical Foundation for U.S. Energy Policy

Most of these problems—reliability, high prices, and reliance on imports—are all fundamentally due to imbalances between energy demand and energy supply. As demand approaches available supply, prices rise and reliability deteriorates. Rising demand for oil (driven primarily by growing transportation sector energy use) combined with declining domestic production feeds the need for more imported oil. Statements by the current Bush Administration suggest that these problems can largely be solved by increasing energy supplies—more oil wells, coal mines, pipelines, refineries, power plants, and transmission lines. However, a supply-only strategy will be expensive (e.g., energy prices will need to be high to sustain private-sector investments in supply), time-consuming (it takes years to develop new energy sources), and harmful to our environment (e.g, adverse impacts on our land and air). Furthermore, available domestic supplies are not adequate to fully support the domestic economy. The United States accounts for one-quarter of global energy demand but has only 8% of known worldwide oil and natural gas reserves, placing limits on how much expanding energy supply can contribute to our energy needs. Instead of a supply-focused energy strategy, a far more rationale approach would be to first reduce energy demand to the extent that it is cost-effective to do so, and then meet the remaining demand with increased energy supplies (domestic or imported).

Energy efficiency improvement has contributed a great deal to our nation's economic growth and increased standard of living over the past 25 years. Total primary energy use per capita in the United States in 2000 was almost identical to that of 1973. Over the same 27-year period, economic output (GDP) per capita increased 74%. In 2000, consumers and businesses spent over $600 billion for total energy use in the United States. Had the nation not dramatically reduced its energy intensity over the previous 27 years, they would have spent at least $430 billion more on energy purchases in 2000.

Even though the United States is much more energy-efficient today than it was 25 years ago, there is still enormous potential for additional cost-effective energy savings. Some newer energy efficiency measures such as hybrid vehicles and sealing home heating ducts have barely begun to be adopted. With proper support, other efficiency measures could be developed and commercialized in coming years. The U.S. Department of Energy (DOE) estimates that increasing energy efficiency throughout the economy could cut national energy use by 10% or more in 2010 and approximately 20% in 2020, with net economic benefits for consumers and businesses. A 1999 ACEEE study estimates that adopting a comprehensive set of policies for advancing energy efficiency could lower national energy use by as much as 18% in 2010 and 33% in 2020, and do so cost-effectively.

Whether the energy savings potential is 20% or 30%, increasing the efficiency of our homes, appliances, vehicles, businesses, and industries should be the cornerstone of national energy policy since it provides a host of benefits. Furthermore, increasing energy efficiency does not present a trade-off between enhancing national security and energy reliability on the one hand and protecting the environment on the other, as do a number of energy supply options. Increasing energy efficiency is a "win-win" strategy from the perspective of economic growth, national security, reliability, and environmental protection.

Energy Efficiency Policy Recommendations

We have identified nine specific policy recommendations that could have a substantial impact on the demand for energy in the United States while also providing positive economic returns to American consumers and businesses. We list these policies in approximate order of energy savings, starting with the policies that yield the largest savings.

1. Increase Corporate Average Fuel Economy

The average fuel economy of new passenger vehicles (cars and light trucks) has declined from about 26 miles per gallon (mpg) in 1988 to 24 mpg in 2000 due to increasing vehicle size and power, the rising market share of light trucks, and the lack of tougher Corporate Average Fuel Economy (CAFE) standards. The original CAFE standards for cars were adopted in 1975 and reached their maximum level in 1985. We recommend increasing the CAFE standards for cars and light trucks by 5% per year for 10 years so that they reach 44 mpg for cars and 33 mpg for light trucks in 2012, with further improvements beyond 2012. Alternatively, the standards for cars and light trucks could be combined into one value for all new passenger vehicles, specifically 38 mpg by 2012. This level of fuel economy improvement is technically feasible, cost-effective for consumers, and can be achieved without compromising vehicle safety.

Higher fuel economy standards should be complemented by (1) implementing tax credits for purchasers of innovative, highly efficient vehicles, (2) expanding taxes on gas-guzzling vehicles, (3) increasing labeling and consumer education efforts, and (4) continuing vigorous research and development (R&D) on fuel-efficient, low-emissions vehicles. This combination of policies would facilitate compliance with the tougher standards.

2. Adopt a National System Benefit Trust Fund

Electric utilities historically have funded programs to encourage more efficient energy use, assist low-income families with home weatherization and energy bill payment, promote the development of renewable energy sources, and undertake R&D. Experience with utility energy efficiency programs in the Northeast, Northwest and Great Lakes region shows that these programs have been highly effective. The value of energy bill savings for households and businesses is about double the costs to produce these savings. Unfortunately, increasing competition and restructuring have led utilities to cut these discretionary "system benefit" expenditures over the past 5 years. Total utility spending on all demand-side management programs (i.e., energy efficiency and peak load reduction) fell by more than 50% from a high of $3.1 billion in 1993 to $1.4 billion in 1999 (1999$).

In order to ensure that energy efficiency programs and other public benefits activities continue following restructuring, 15 states have established system benefits funds through a small charge on all kilowatt-hours flowing through the transmission and distribution grid. We recommend creation of a national systems benefits trust fund that would provide matching funds to states for eligible public benefits expenditures. Specifically, we recommend a non-bypassable wires charge of two-tenths of a cent per kilowatt-hour. This policy would give states and utilities a strong incentive to expand their energy efficiency programs and other public benefits activities.

3. Enact New Equipment Efficiency Standards and Strengthen Existing Standards

Federal appliance and equipment efficiency standards were signed into law by President Reagan in 1987 and expanded under President Bush in 1992. Minimum-efficiency standards were adopted because many market barriers (such as lack of awareness, rush purchases when an existing appliance breaks down, and purchases by builders and landlords) inhibit the purchase of efficient appliances in the unregulated market. Standards remove inefficient products from the market but still leave consumers with a full range of products and features to choose among. Appliance and equipment standards are clearly one of the federal government's most effective energy-saving programs. In 2000, federal appliance and equipment efficiency standards reduced consumer energy bills by approximately $9 billion, with energy bill savings far exceeding any increase in product cost. By 2020, standards already adopted will reduce peak electrical demand by an amount equal to the output of more than 400 power plants of 300 MW each.

In order to provide additional cost-effective savings under this program, we recommend that Congress adopt new efficiency standards for products now or soon to be covered by state efficiency standards. Among the products that should be included are distribution transformers, exit signs, traffic lights, and torchiere lighting fixtures. California is now adopting standards on these products and Massachusetts and Minnesota already have standards on distribution transformers. None of these standards have been controversial and all yield highly cost-effective energy savings. Congress should also adopt standards on commercial refrigeration equipment, commercial unit heaters, and standby power consumption for household appliances and electronic products (such as televisions, VCRs, cable boxes, and audio equipment). In addition, DOE, with adequate funding and encouragement from Congress, should complete equipment standard rulemakings in a timely manner. Finally, the Bush Administration should drop its efforts to roll-back the recently set SEER 13 efficiency standard for residential central air conditioners and heat pumps.

4. Enact Tax Incentives for Highly Energy-Efficient Vehicles, Homes, Commercial Buildings, and Other Products

Many new energy-efficient technologies have been commercialized in recent years or are nearing commercialization. But these technologies may never get manufactured on a large scale or widely used due to barriers such as their initial high cost, market uncertainty, and lack of consumer awareness. Tax incentives would help manufacturers justify mass marketing for innovative energy-efficient technologies. Tax credits also could help buyers (or manufacturers) offset the relatively high first cost premium for the new technologies, thereby helping to build sales and market share. Once the new technologies become widely available and produced on a significant scale, costs should decline and the tax credits could be phased out.

We recommend tax incentives for advanced, high-efficiency appliances, new homes, new commercial buildings, hybrid and fuel cell vehicles, combined heat and power (CHP)systems, and other building equipment such as air conditioners and heat pump water heaters. The total cost to the Treasury would be on the order of $10 billion. These credits would save energy directly due to purchases of equipment eligible for the credits, but even more importantly, if the credits helped to establish these innovative products in the marketplace and reduced the first cost premium so that the products would be viable after the credits were phased out, the indirect impacts would be many times greater than the direct impacts.

5. Expand Federal Energy Efficiency R&D and Deployment Programs

DOE has made many valuable contributions towards increasing the energy efficiency of U.S. buildings, appliances, vehicles, and industries. Consequently, the President's Committee of Advisors on Science and Technology (PCAST) stated in 1997 that "R&D investments in energy efficiency are the most cost-effective way to simultaneously reduce the risks of climate change, oil import interruption, and local air pollution, and to improve the productivity of the economy." A July 2001 National Academy of Sciences review of some of DOE's R&D programs found that a sample of energy efficiency R&D programs resulted in net realized economic benefits of approximately $30 billion (1999$), substantially exceeding the roughly $7 billion (1999$) in total energy efficiency RD&D investment over the 22-year life of the programs. Similarly, the ENERGY STAR deployment programs operated by EPA and DOE have also been very successful.

Based on specific budget recommendations in the PCAST report, we recommend that instead of cutting funding for DOE's R&D programs as proposed this spring by the Bush Administration, funding should instead be increased by about 17% per year for the next 3 years. Funding for EPA's programs should also be expanded at a similar level.

6. Promote Clean, High-Efficiency Combined Heat and Power Systems

CHP systems produce multiple usable energy forms (e.g., electricity and steam) from a single fuel input. These combined systems achieve much greater efficiency than the usual separate systems for producing steam and electricity because the CHP systems recover heat that would otherwise be wasted in separate power production, and use this heat to displace the fuel that otherwise would be used to produce heat in a separate boiler.

Several inequities in government and utility regulations hinder development of CHP resources. These include environmental standards that do not recognize the efficiency gains of CHP systems, utility rules that make it difficult for many CHP systems to connect to the utility grid, and tax depreciation rules that vary the depreciation period for CHP systems from 5–39 years depending on plant ownership. Each of these problems need to be addressed, including: (1) reforming regulations to regulate emissions per unit of energy output rather than per unit of energy input; (2) developing uniform standards for CHP facilities to be interconnected with the local distribution facilities; and (3) standardizing depreciation periods for CHP systems based on the technical and market life of current systems.

7. Voluntary Agreements and Incentives to Reduce Industrial Energy Use

There is substantial potential for cost-effective efficiency improvement in industry. For example, in-depth analyses of specific energy efficiency technologies for the iron and steel, paper and pulp, and cement industries found a total cost-effective energy savings potential of 11–22%. In order to stimulate widespread energy efficiency improvements in the industrial sector, we propose that the U.S. government establish voluntary agreements with individual companies or entire sectors. Companies or sector trade associations would pledge to reduce their overall energy and carbon emissions intensities (energy and carbon per unit of output) by a significant amount, for example, at least 1% per year over 10 years. Companies that make a more substantial commitment (for example, at least 2% per year) could be given ENERGY STAR or similar recognition. The government could encourage participation and support implementation by: (1) providing technical assistance to participating companies that request assistance; (2) offering to postpone consideration of mandatory emissions reductions or tax measures if a large percentage of industries participate and achieve their goals; and (3) expanding federal R&D and demonstration programs for sectors with high participation.

A number of major companies have already made voluntary energy efficiency commitments on their own. For example, Johnson and Johnson set a goal in 1995 of reducing energy costs by10% by 2000 through adoption of "best practices" in its 96 U.S. facilities. As of April 1999, they were 95% of the way towards this goal, with the vast majority of projects providing a payback of 3 years or less. Voluntary agreements between government and industry along the lines proposed here have resulted in substantial energy intensity reductions in some European nations such as Germany, the Netherlands, and Denmark. The United States should build on this experience.

8. Improve the Efficiency and Reduce the Emissions of the Existing Power Plant Fleet

Many old, highly polluting power plants are "grandfathered" under the Clean Air Act. This means that they do not need to meet the same emissions standards for nitrogen oxides (NOx), sulfur dioxide (SO_2), and particulates as plants built after the Clean Air Act of 1970 was enacted. Currently, 850 plants built before 1970 are still operating, with a combined power output of 145,400 MW. In 1999, these plants produced about 21% of our nation's electric generation. These older, dirty power plants emit 3–5 times as much pollution per unit of power generated as newer, coal-fired power plants and 15–50 times as much NOx and particulates as a new combined-cycle natural gas power plant. These older plants also are less efficient than most new plants; the pre-1970 plants have an average heat rate of 11,025 Btus of fuel per kWh generated, compared to modern combined-cycle plants with heat rates of 7,000 or less. When the Clean Air Act was adopted, it was expected that these dirty power plants would eventually be retired. However, many utilities are continuing to operate these plants beyond their "design life" due to their low capital and operating cost.

If old, grandfathered plants were required to meet the same emissions standards as new plants, some plants would be modernized and cleaned up, but many would be shut down and replaced with much more efficient and cleaner generating sources such as combined-cycle natural gas power plants. We recommend that a policy to end "grandfathering" be enacted soon but not take effect until 2010 or thereabouts. This phase-in period would allow owners of these old plants to make plant upgrade vs. replacement decisions and then have sufficient time to implement these decisions without unduly disrupting power markets. Alternatively, the same general objectives would be achieved by adopting new emissions standards as part of a Clean

Air Act "four pollutant" strategy that has been proposed in order to address SOx, NOx, mercury, and carbon dioxide (CO_2) emissions in an integrated fashion. Such a strategy would include tradeable emissions permits, with the number of emissions allowances based on the phase-out of old, dirty, inefficient power plants.

9. Greater Adoption of Current Model Building Energy Codes and Development and Implementation of More Advanced Codes

Building energy codes require all new residential, commercial, and industrial buildings to be built to a minimum level of energy efficiency that is cost-effective and technically feasible. "Good practice" residential and commercial energy codes have been adopted by just over half the states. However, some major states (such as Arizona, Illinois, Michigan, New Jersey, and Texas) have not adopted these "good practice" energy codes. Furthermore, building codes can and should be upgraded. In the case of residential codes, codes can be further improved by including several measures to reduce use of air conditioning in hot climates and by reducing energy losses due to air infiltration and duct leakage. In the case of commercial codes, a new national model standard was published in 1999 that reduces energy use approximately 6% compared to the old "good practice" code. Here too, substantial additional improvements are possible as measures with 10–20% additional savings were included in early drafts but dropped as part of a political process to gain "consensus."

In order to capture the available savings, states should be directed to review their codes and encouraged to revise them. DOE should continue to provide technical assistance for these efforts, with preference given to states that adopt statewide mandatory codes at or above the model codes. The model code organizations (International Energy Conservation Code [IECC] and American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE]) should also be encouraged to regularly update their codes to incorporate the latest in cost-effective energy-saving measures. IECC has been doing well in this regard, but ASHRAE's 1999 standard revision achieves far less savings than ASHRAE had targeted. Given ASHRAE's conservatism, DOE should broaden its funding activities to include organizations and consortiums of states that are interested in achieving higher levels of energy savings than ASHRAE is able to deliver.

Integrated Analysis

In order to estimate the energy and emissions savings of these nine policies as well as their costs and benefits, we conducted an integrated analysis using the DOE/EIA National Energy Modeling System, known as NEMS. Most of our assumptions for the base case were taken from the NEMS model, specifically as it was applied to produce the *Annual Energy Outlook 2001*. We then modeled each of our policies individually and together to estimate the overall impacts of our policy set and the contribution of each policy towards these combined impacts.

Energy Impacts

Key results of the analysis are summarized in Table ES-1. Overall in the base case, total U.S. primary energy consumption grows 1.3% per year on average. Relative to the base case, the nine policies reduce primary energy consumption by 11% by 2010 and by 26% by 2020. Primary energy use rises slightly during the next decade but falls significantly during 2010-2020 (see Figure ES-1).

Table ES-1. Summary of Overall Results for the Base and Policy Cases

	1990	1999	2010 Base Case	2010 Policy Case	2020 Base Case	2020 Policy Case
End Use Energy (Quads)	63.9	71.6	86.5	79.4	98.3	78.9
Primary Energy (Quads)	84.6	96.1	114.6	102.2	128.1	94.2
Energy Use by Fuel (Quads)						
Coal	19.1	21.4	25.2	18.1	26.2	9.5
Oil	33.5	38	44.9	41.9	51.7	42.1
Natural gas	19.3	22	28.7	26	35.5	27.5
Nuclear	6.2	7.8	7.7	7.8	6.1	6.3
Hydro	3	3.2	3.1	3.1	3.1	3.1
Other renewables	3.5	3.4	4.8	5.1	5.2	5.5
Carbon Emissions (Million Metric Tons)	1,338	1,505	1,817	1,540	2,063	1,338
Other Emissions (Million Metric Tons)						
Sulfur dioxide	19.3	20.5	16.5	14.9	16.9	13.1
Nitrogen oxides	21.9	15.8	12.8	11.6	12.7	6.6
Particulate matter (PM-10)	1.7	1.5	1.5	1.4	1.6	1.4
Cumulative Net Savings ($ billions)			-	152	-	591

In the base case, oil consumption would increase by about one-third by 2020, and oil imports would increase by more than 60% over that period. Thus, the oil import fraction is projected to rise from a little over 50% today to about 70% of total U.S. oil use by 2020. The policies evaluated here would significantly reduce overall oil imports. Relative to the base case, annual oil use would be reduced by about 19% and imports by about 40% by 2020. With implementation of the nine policies, U.S. total energy use in 2020 would be about 2% lower than energy use in 1999. Within this overall trend, use of some fuels would increase and use of other fuels would decrease. For example, use of coal would decline 56% over this period, primarily due to substantial retirements of old coal-fired power plants and replacement with natural gas. Due to increased use of natural gas for electricity generation, natural gas use would grow 25% under the policy case relative to 1999 consumption, indicating that increased natural gas supplies would be needed. This growth in natural gas use in the policy case would be substantially less than the 62% increase in natural gas use in the base case. As for petroleum, even with substantial efficiency improvements, petroleum use in the policy case would be 11% higher than use in

1999. With domestic production at best stagnant, this would mean that oil imports would grow modestly, even with a full array of efficiency policies. (By way of comparison, petroleum use would grow 36% in the base case.) Finally, electricity use in 2020 would be about the same as 1999 use, although growth in CHP systems would decrease the need for centrally generated power relative to 1999. In total, while our nine policies would dramatically reduce the need for new energy supplies, even with these policies, there would be some need for new supplies, particularly natural gas.

Figure ES-1. U.S. Energy Consumption Over Time in the Base and Policy Cases

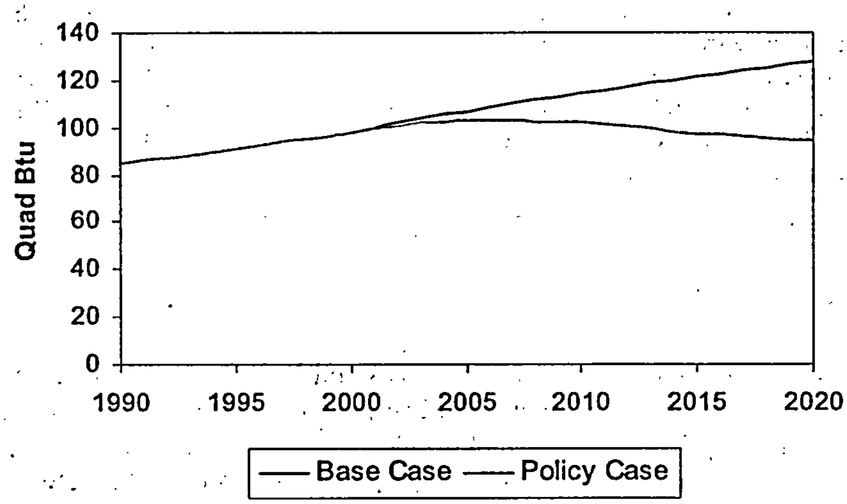


Table ES-2 summarizes savings from the different policies. Each of the policies would have a substantial impact on U.S. energy use, with all saving at least 1.5 quad by 2020 (although tax credits are listed with lower savings since a substantial portion of their savings would be subsumed under the CAFE standards, CHP, appliance standards and building code policies). The largest savings would be achieved by CAFE standards and related policies to improve the fuel economy of light duty vehicles. Public benefit funds and industrial voluntary programs would have the next largest savings. These three policies together would account for about 60% of the savings in our policy case. However, for these policies to achieve such savings, they would need to be stringent along the lines discussed above, with the equivalent of a 38 mpg CAFE standard, a two-tenths of a cent per kilowatt-hour matching public benefit fund, and an industrial targets program backed by significant "carrots and sticks." Scaled-back versions of these policies would result in significantly lower savings.

Intermediate levels of energy savings would be achieved by updated and expanded appliance and equipment efficiency standards, expanded federal R&D and deployment efforts, increased use of CHP systems, and tax credits. Finally, more moderate, albeit still substantial, savings would be achieved by building codes and retirement of old, inefficient power plants. Savings from this latter policy are somewhat limited by our analytical approach, whereby demand-side measures are applied before supply-side measures. With this convention, efficiency programs would lead to substantial power plant retirements, leaving only about half of the old "grandfathered" plants to be affected by the power plant policy. If we had instead considered supply-side policies first, power plant retirements would be included among the policies with intermediate energy savings.

Table ES-2. Energy Use Reductions by Policy

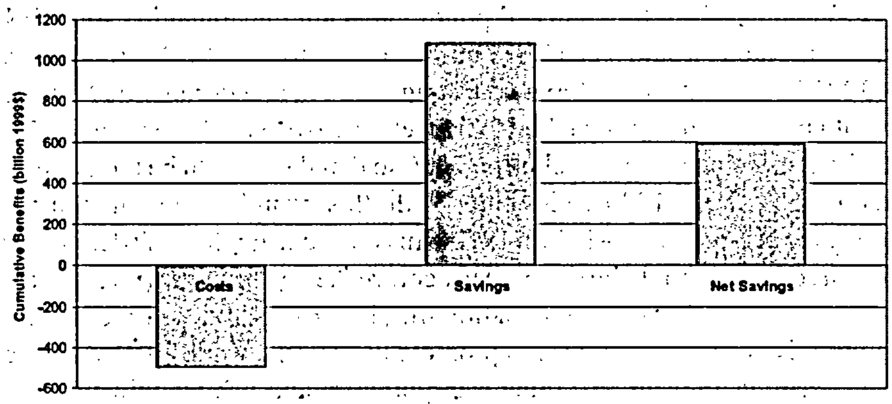
	2010	2020
Total Policy Case Consumption	102.2	94.2
Reduction from industrial policies	4.5	9.5
Reduction from commercial policies	2.7	7.9
Reduction from transport policies	2.1	7.7
Reduction from residential policies	2.5	7.2
Reduction from electric supply policies	0.6	1.5
Total Base Case Consumption	114.6	128.1

Economic Impacts

Figure ES-2 summarizes the direct economic costs and benefits in the policy case. The policies would induce incremental investments in advanced industrial processes; more efficient buildings, lighting, and appliances; more fuel-efficient cars and trucks; cleaner and more efficient power plants; and so on. We estimate a total investment of $127 billion through 2010 and $495 billion through 2020, expressed in 1999 dollars using a 5% real discount rate. To place these figures in context, total U.S. energy expenditures (excluding on-site renewables) equaled a little over $600 billion in 2000. Overall, we estimate that end-users would save over $1,100 billion through 2020 as a result of these policies. The energy bill and operating savings would more than offset the investments costs, with net savings of about $170 billion through 2010 and over $600 billion through 2020. The net savings would grow over time since energy efficiency measures would have more time to pay back their initial cost.

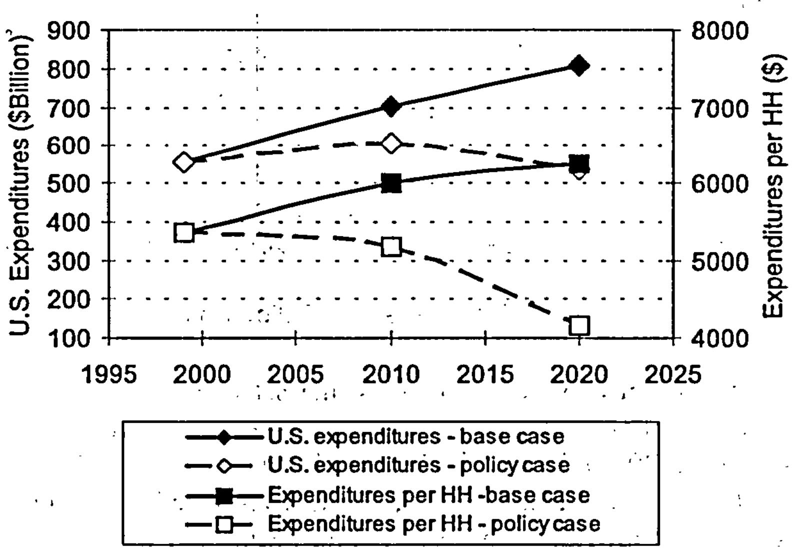
The nine policies would also have a positive impact on the economy by weakening demand for different energy sources, which would result in lower energy prices. In the base case, NEMS projects that domestic electricity and coal prices will decline somewhat in real terms over the 1999–2020 period (e.g., declines of 8% and 25%, respectively), while natural gas prices will increase by 49%. Under the policy case, electricity and coal prices are projected to drop by an additional 7% and 1%, respectively. More dramatically, natural gas prices are projected to decline to below 1999 levels (e.g., to $1.9 per million Btus in 2020), a *37%* decline from the base case.

Figure ES-2. Costs, Savings, and Net Savings for the Policies by 2020



These price declines would have a substantial and positive impact on the U.S. economy and would benefit all consumers and businesses. These indirect benefits are in addition to the direct benefits discussed above. Figure ES-3 summarizes our model results for energy expenditures in the base and policy cases, incorporating both the direct and indirect effects. Viewed on a per household basis, in the base case, energy expenditures per household would gradually climb from $5,355 in 1999 to $6,249 in 2020 (1999$). In the policy case, expenditures per household would be only $4,156, an annual savings of $2,093 per household (a savings of one-third).

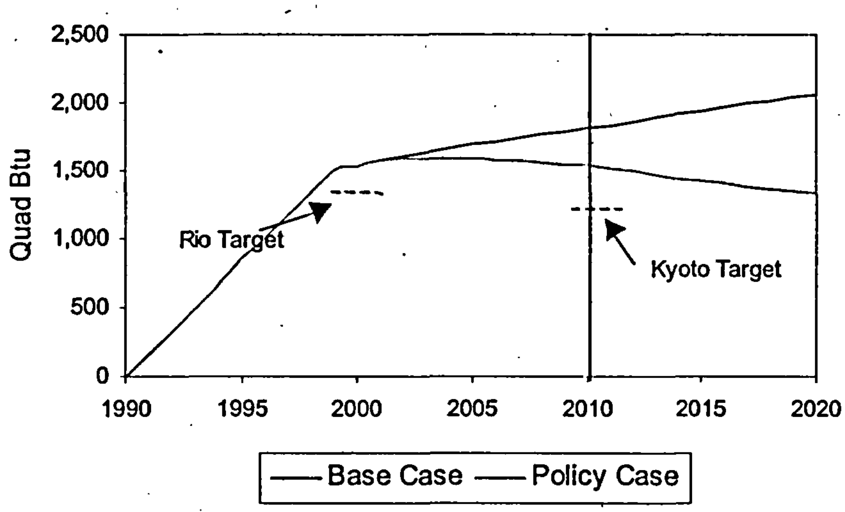
Figure ES-3. Energy Expenditures in the Base and Policy Cases



Emission Impacts

U.S. carbon emission trends in the base and policy cases are illustrated in Figure ES-4. In the base case, carbon emissions would reach 1,817 million metric tons (MMT) carbon equivalent by 2010 and 2,063 MMT by 2020, a 1.5% annual average growth rate during 2000–2020. Base case emissions would be 36% greater than the 1990 level by 2010 and 54% greater by 2020. In the policy case, carbon emissions would decline by 2010 so that they would be the same as 2000 emissions and about 15% above 1990 emissions. While this would not be enough to reach America's Kyoto Protocol target of 7% below 1990 emissions during 2008–2012, it would be strong steps in that direction. It should be possible to achieve the Kyoto target (i.e., a further 290 MMT annual reduction) through some combination of: (1) further domestic reductions from additional policy initiatives, such as policies to promote use of renewable energy sources and policies to reduce energy use for air and truck transportation and vehicle miles traveled for passenger cars; (2) reductions in emissions of other greenhouse gases; (3) purchase of emissions reductions from other Annex 1 countries; and (4) reductions in developing countries from Clean Development Mechanism projects.

Figure ES-4. U.S. Carbon Emissions Over Time in the Base and Policy Cases



In addition to carbon emission reductions, the set of nine policies would also reduce emissions of criteria air pollutants. Implementing the nine policies would reduce SO_2 emissions the most— 48% by 2020. Emissions of NOx would be cut 19% by 2020 and fine particulate emissions would drop 13% by 2020. Clearly, taking action to reduce energy use as proposed in the policy case would provide significant public health and local/regional environmental benefits.

Discussion and Conclusion

Energy efficiency should be a cornerstone for America's energy policy. Taken together, the nine policies recommended here could reduce U.S. energy use by more than 20% in 2020. These efficiency policies alone would not solve all of our energy problems—energy use would continue to grow for a decade or more while these energy-saving policies would gradually take effect. Furthermore, sustaining current rates of energy use into the long-term future would require new sources of energy supply and distribution. However, these efficiency policies would substantially reduce our energy problems, making it easier to find reasonably priced and environmentally acceptable energy supplies to meet U.S. energy demand. In other words, relative to a supply-focused energy strategy, a balanced energy strategy that complements efforts to expand supplies with a major focus on improving efficiency, would have a greater chance of success in terms of ensuring the reliability of the U.S. energy system, reducing economic costs (since all the efficiency strategies incorporated here save consumers and businesses money at projected future energy costs), and protecting the environment.

The general public voices strong support for increasing energy efficiency and a balanced energy strategy. For example, a recent nationwide poll conducted for the *Los Angeles Times* found that when people were read a list of 11 actions to deal with the energy situation, the top four actions (supported by 85–91% of respondents) were "invest in new sources of energy," "mandate more energy-efficient appliances," "mandate more energy-efficient new buildings," and "mandate more energy-efficient cars." Options for increasing the supply and delivery of traditional energy sources received significantly less support.

Ten years ago the previous Bush Administration issued its National Energy Strategy. It gave considerable priority to greater energy efficiency and called for expansion of energy efficiency R&D and technology deployment programs, new policies to stimulate utility energy efficiency programs, establishing new appliance and equipment energy efficiency standards, and new federal incentives to increase energy efficiency. Many of these proposals were incorporated in the Energy Policy Act of 1992, and the budget for and impacts of DOE's energy efficiency programs rose throughout the previous Bush Administration.

In May 2001 the current Bush Administration released its *National Energy Policy*. This policy calls for "advanc[ing] new, environmentally friendly technologies to increase energy supplies and encourage cleaner, more efficient energy use." Unfortunately the policy details do not bear this rhetoric out. Instead, the plan proposes many specific policies for increasing energy supplies, but the major specific efficiency policy is a call for tax incentives for efficient vehicles and CHP systems (a subset of the tax credits we propose). In addition, the plan calls for "reviewing" CAFE and "tak[ing] steps" to set new appliance efficiency standards. These latter suggestions fall well short of our specific policy prescriptions.

Congress is now beginning to consider energy legislation, and these efforts so far go farther than the Bush Administration proposes, but are still well short of what is needed. As of this writing, legislation passed by the House of Representatives includes many of the tax incentives we call for, some of the appliance standards we call for, and an extremely modest increase in CAFE standards. At the same time, both houses of Congress have passed appropriations bills that reverse the budget cuts proposed by the Bush Administration, but do not provide the growth in funding that is needed. All of our other policies are not included in the House legislation. Congress is so far doing much less than what polls show the American people want. Congress needs to redouble its efforts in order to properly value and support energy efficiency in new energy legislation and in appropriations for energy programs.

This report shows that energy efficiency policies would make a very large contribution towards meeting U.S. needs for new energy sources, while reducing emissions and saving consumers and businesses billions of dollars. However, without aggressive policy intervention, many of these benefits will be lost, costing the United States dearly in terms of economics, public health, dependence on imported energy, and adverse impacts on our environment.

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CURRENT ENERGY PROBLEMS

There are a variety of serious energy challenges confronting the United States. California has experienced power shortages and severe electricity price spikes. Power reliability problems could spread to other regions such as the Pacific Northwest or New York. Even if the lights stay on, electricity prices will continue to skyrocket in many regions of the country. In Washington state, retail electric rates have risen by up to 40%; in Montana, new power supply contracts will lead to retail rate increases of as much as 50%; and in New York City, electricity prices climbed 40% for part of last summer and the Chairman of the local utility says that prices this summer are expected to jump "about the same" (Smith and Emshwiller 2001).

Natural gas prices have also significantly increased in many parts of the country, causing skyrocketing home energy bills this past winter. Earlier this year, residential natural gas prices passed $1 per therm[1] in many states, and while prices are now down somewhat, they still substantially exceed the approximately $0.60–0.70 per therm price that prevailed for most of the past decade (EIA 2001a, 2001b).

Our reliance on imported oil has grown—oil imports more than doubled during the past 15 years and oil imports now exceed domestic oil production.[2] Rising demand for oil and tight supplies have also caused gasoline prices to rise; the average price of gas in the United States topped $1.70 per gallon earlier this year and the average price is still above this level in California (EIA 2001c; Macintyre 2001).

Also, our emissions of the gases that contribute to global climate change continue to rise. In 2000, U.S. greenhouse gas emissions were up 16% relative to levels in 1990 (EIA 2001d). However, under the Global Framework Convention agreed to in Rio de Janeiro in 1992 by then-President Bush and subsequently ratified by the Senate, the United States voluntarily committed to reducing our emissions to 1990 levels by 2000.[3]

Most of these problems—reliability, high prices, and reliance on imports—are all fundamentally due to imbalances between energy demand and energy supply. As demand approaches available supply, prices rise and reliability deteriorates. Rising demand for oil (driven primarily by growing transportation sector energy use) combined with declining domestic production feeds the need for more imported oil. Statements by the current Bush Administration suggest that these problems can largely be solved by increasing energy

[1] A therm is the unit of natural gas sales. It's 100,00 Btus of energy and approximately equal to 100 ft^3 of gas.

[2] In 2000, oil imports averaged 11,093 barrels per day, up from 5,067 in 1985. In 2000, imports exceeded total domestic petroleum consumption by 36% (EIA 2001b).

[3] This commitment is a voluntary one—there are no penalties for non-compliance. Also, the United States is not the only country to fall short of its Rio targets.

supplies—more oil wells, coal mines, pipelines, refineries, power plants, and transmission lines. However, a supply-only strategy will be expensive (e.g., energy prices will need to be high to sustain private-sector investments in supply), time-consuming (it takes years to develop new energy sources), and harmful to our environment (e.g, adverse impacts on our land and air). Furthermore, available domestic supplies are not adequate to fully support the domestic economy. The United States accounts for one-quarter of global energy demand (EIA 2000a) but has only 8% of known worldwide oil and natural gas reserves (USGS 1996, 1998), placing limits on how much expanding energy supply can contribute to our energy needs. Instead of a supply-focused energy strategy, a far more rationale approach would be to first reduce energy demand to the extent that it is cost-effective to do so, and then meet the remaining demand with increased energy supplies (domestic or imported).

THE HISTORIC AND POTENTIAL FUTURE ROLE OF ENERGY EFFICIENCY

Energy efficiency improvement has contributed a great deal to our nation's economic growth and increased standard of living over the past 25 years. Consider the following facts (EIA 2000c, 2001b; 2001e):

- Total primary energy use per capita in the United States in 2000 was almost identical to that of 1973. Over the same 27-year period, economic output (GDP) per capita increased 74%.

- National energy intensity (energy use per unit of GDP) fell 42% between 1973 and 2000. About 60% of this decline is attributable to real energy efficiency improvements and about 40% is due to structural changes in the economy and fuel switching (Murtishaw and Schipper 2001).

- In 2000, consumers and businesses spent over $600 billion for total energy use in the United States. Had the nation not dramatically reduced its energy intensity over the previous 27 years, they would have spent at least $430 billion more on energy purchases in 2000.

- Between 1996 and 2000, GDP increased 19% while primary energy use increased just 5%. Imagine how much worse our energy problems would be today if energy use had increased 10 or 15% during 1996–2000!

Even though the United States is much more energy-efficient today than it was 25 years ago, there is still enormous potential for additional cost-effective energy savings. Some newer energy efficiency measures, such as hybrid vehicles and sealing residential heating ducts to prevent leakage, have barely begun to be adopted. With proper support, other efficiency measures could be developed and commercialized in coming years. DOE estimates that increasing energy efficiency throughout the economy could cut national energy use by 10% or more in 2010 and approximately 20% in 2020, with net economic benefits for consumers and businesses (EERE

2000a). A 1999 ACEEE study estimates that adopting a comprehensive set of policies for advancing energy efficiency could lower national energy use by as much as 18% in 2010 and 33% in 2020, and do so cost-effectively (Geller, Bernow, and Dougherty 1999).

Whether the energy savings potential is 20% or 30%, increasing the efficiency of our homes, appliances, vehicles, businesses, and industries should be the cornerstone of national energy policy since it provides a host of benefits. Increasing energy efficiency would:

- reduce energy waste and increase productivity without forcing consumers or businesses to cut back on energy services or amenities;
- reduce the risk of energy shortages and improve the reliability of overtaxed electric systems;
- save consumers and businesses money since the energy savings more than pay for any increase in first cost;
- reduce energy imports;
- reduce air pollution of all types since burning fossil fuels is the main source of most types of air pollution; and
- lower U.S. greenhouse gas emissions and thereby help to slow the rate of global warming.

Furthermore, increasing energy efficiency does not present a trade-off between enhancing national security and energy reliability on the

Energy Efficiency vs. Energy Conservation

Energy efficiency means improving equipment and systems to get the same or increased output (e.g., miles traveled or widgets produced) but with less energy input. Essentially everybody is in favor of energy efficiency. For example, in a speech to the Associated Press, Vice President Cheney (while maligning "conservation") did say that the United States needs "to make better use, through the latest technology, of what we take from the earth [including] efficient use..." (Cheney 2001). And in a radio address to the nation, President Bush stated: "Over the long term, the most effective way to conserve energy is by using energy more efficiently." (Bush 2001).

Energy conservation means reducing energy use, and at times may mean reducing the services received. Examples of energy conservation include changing thermostat settings, reducing lighting levels, and driving less. To the extent energy conservation eliminates waste, it is generally desirable. For example, quite a few commercial buildings are overlit (lighting systems provide more lumens of light output than called for in current lighting design guidelines) and energy can be saved by reducing lighting levels to conform to current guidelines. Similarly, energy is wasted when thermostats are set so low that sweaters are needed in the middle of the summer.

But in those instances where conservation results in discomfort (e.g, "freezing in the dark"), conservation is much less desirable. During energy emergencies, such as the oil shortages of the 1970s and the electricity shortages in California today), some discomfort may be necessary. However, by pursuing a balanced and comprehensive energy policy (including energy efficiency and waste-reducing conservation), we can reduce the number of energy emergencies and the need for cutbacks that cause discomfort.

one hand and protecting the environment on the other, as do a number of energy supply options. Increasing energy efficiency is a "win-win" strategy from the perspective of economic growth, national security, reliability, and environmental protection.

ENERGY EFFICIENCY POLICY RECOMMENDATIONS

We have identified nine specific policy recommendations that could have a substantial impact on the demand for energy in the United States while also providing positive economic returns to American consumers and businesses. These policies involve new incentives, funding for R&D and technology deployment, and new or updated regulations. The policies would significantly increase the efficiency of energy use in our homes, commercial buildings, factories, and vehicles. The policies would not entirely solve our nation's energy problems but they would make a major contribution towards addressing the energy and environmental challenges our nation is facing. We list these policies in approximate order of energy savings, starting with the policies that yield the largest savings.

1. Increase Passenger Vehicle Fuel Economy

The average fuel economy of new passenger vehicles (cars and light trucks) has declined from about 26 mpg in 1988 to 24 mpg in 2000 due to increasing vehicle size and power, the rising market share of light trucks, and the lack of tougher Corporate Average Fuel Economy (CAFE) standards. The original CAFE standards for cars were adopted in 1975 and reached their maximum level in 1985.

We recommend increasing the CAFE standards for cars and light trucks by 5% per year for 10 years so that they reach 44 mpg for cars and 33 mpg for light trucks in 2012, with further improvements of 3% per year beyond 2012. Alternatively, the standards for cars and light trucks could be combined into one value for all new passenger vehicles, specifically 38 mpg by 2012. This level of fuel economy improvement is technically feasible, cost-effective for consumers, and can be achieved without compromising vehicle safety (DeCicco, An, and Ross 2001; Friedman et al. 2001; Ross and Wenzel 2001). The 5% annual fuel economy improvement is the rate of improvement that Ford has indicated it will achieve voluntarily with its sport utility vehicles (SUVs) over the next 5 years. If this rate can be achieved with SUVs, it can be achieved in all new vehicles made by Ford and other manufacturers.[4]

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[4] The rate of 5% annual improvement in fuel economy is higher than that included in the "breakeven" scenario in the National Academy of Sciences' report (National Academy of Sciences 2001b). The range of fuel economy improvement technologies considered in ACEEE's analysis (DeCicco, An, and Ross 2001) is similar to what the NAS report considers and, while percentage improvement and cost estimates do not track measure-for-measure, they are generally comparable in the two analyses. ACEEE's estimates of the potential for overall fuel economy improvements are somewhat higher than those in the NAS report, however. This is largely attributable to the NAS panel's exclusion of vehicle mass reduction as a fuel-savings strategy, due to safety concerns. The ACEEE analysis,

(continued...)

Car manufacturers will protest and say that this improvement in fuel economy will " lead to unsafe cars" or "cost U.S. jobs." However, these arguments ignore the facts: safe, fuel-efficient cars could be built, and fuel efficiency improvements to large SUVs could actually help improve overall on-road safety, as many vehicle-related deaths would be avoided if the weight of these behemoths were reduced (Friedman et al. 2001; Ross and Wenzel 2001). Even the National Academy of Sciences report finds that significant fuel economy improvements could be made without compromising safety, provided manufacturers have enough time to prepare (National Academy of Sciences 2001b). As for the impact on jobs, analyses indicate that improved fuel economy would actually increase jobs in the United States, including employment in the auto industry. Jobs would tend to increase due to the retooling needed to provide the more efficient vehicles, the increased costs and therefore larger sales revenues associated with light vehicles, and the significant respending effect resulting from the gasoline bill savings, which enables greater purchase of non-energy goods, including cars and light trucks. These effects are likely to be larger than any adverse impacts improved fuel efficiency would have on domestic automobile production directly (Geller, DeCicco, and Laitner 1992).

The initial CAFE standards were enacted by Congress and signed into law by President Ford in 1975 in the face of industry opposition, and the car companies complied with these standards at reasonable cost. Higher performance standards are now long overdue and should be adopted before we face another oil price shock or crisis, considering "technological feasibility, economic practicability, and the need of the nation to conserve energy," as stated in the Energy Production and Conservation Act of 1975.

Higher fuel economy standards should be complemented by (1) implementing tax credits for purchasers of innovative, highly efficient vehicles—see Policy 4 below, (2) expanding taxes on gas-guzzling vehicles, (3) increasing labeling and consumer education efforts, and (4) continuing vigorous R&D on fuel-efficient, low-emissions vehicles (see text box on next page). This combination of policies would facilitate compliance with the tougher standards. An alternative approach would be to establish a cap on the use of petroleum products by passenger vehicles and then come up with the policy mechanisms (including but not limited to stronger CAFE standards) that would enable the cap to be met. This approach was included in recent Senate legislation (S. 597), which sets the cap at 105% of fuel consumption in 2000 starting in 2008.

The CAFE standards proposed here would save about 1.1 million barrels of petroleum per day by 2010 and 4.0 million barrels per day by 2020, equivalent to 3 and 10 quadrillion Btus[5]

[4] (...continued)
by contrast, exploits the potential of light-weighting not only to increase efficiency, but also to improve safety, by targeting the heavier vehicles for greater weight loss, thereby reducing the average weight differential in two-vehicle crashes.

[5] A *quad*—by way of reference, the United States used 98.5 quads in 2000.

of energy on an annual basis in 2010 and 2020, respectively.[6] Over 40 years, increasing vehicle efficiency as suggested above would save 10–20 times more oil than the projected supply from the Arctic National Wildlife Refuge (ANWR) and more than three times today's total proven oil reserves (Geller 2001). Under business-as-usual policies and trends, net imports of crude oil and finished petroleum products are projected to rise 67% from 1999 to 2020 (EIA 2000c). Energy savings from fuel economy improvements would reduce this increase from 67% to 19%, which would be a major cut in the growth of petroleum imports.

Complementary Policies to Improve Passenger Vehicle Fuel Economy

- Inefficient cars are already subject to a "gas guzzler" tax ranging from $1,000 to $7,700. But millions of inefficient light trucks (including SUVs) are used as passenger vehicles, yet are not subject to the tax, creating a loophole that encourages their production and sale. Applying the tax to new gas-guzzling passenger vehicles of all classes would "pull up" the bottom end of the vehicle fleet and generate billions of dollars in new tax revenue, which could be used for incentives for buyers of high-efficiency vehicles (see Policy 4).
- The federal government should also extend ENERGY STAR® labeling to high-efficiency and low-emitting vehicles. This would make it easier for consumers to identify "greener vehicles" and for manufacturers to promote them. Government agencies should also continue their participation in information campaigns to raise public awareness of greener vehicles, and programs to facilitate fleet purchases of these vehicles.
- Given the importance of dramatically improving new vehicle economy in the coming decades, federal participation in R&D on highly efficient vehicles and technologies (such as fuel cells, hybrid-electric drivetrains, and lightweight materials) should be expanded. Such efforts should focus simultaneously on developing cleaner and more efficient vehicles by adopting aggressive emissions goals to complement fuel economy goals.

Standards along these lines could save consumers $196 billion net (discounted gasoline savings minus discounted vehicle cost) through 2020.[7] Additional money would be saved because reductions in gasoline demand also tend to reduce gasoline prices. The avoided CO_2 emissions would reach about 40 MMT of carbon equivalent by 2010 and 142 MMT by 2020. The fuel consumption cap proposed in S. 597 would result in a similar level of energy savings, economic savings, and avoided CO_2 emissions in the near term (i.e., by 2010).

2. Adopt a National System Benefit Trust Fund

Electric utilities historically have funded programs to encourage more efficient energy use, assist low-income families with home weatherization and energy bill payment, promote the development of renewable energy sources, and undertake R&D. Experience with utility energy

[6] The figures cited here come from the "Integrated Analysis" section later in this report.

[7] The figures here are also from the "Integrated Analysis" section.

efficiency programs in New England, New York, and California shows that these programs have been highly effective. The value of energy bill savings for households and businesses is about double the costs to produce these savings (Nadel and Kushler 2000). Unfortunately, increasing competition and restructuring have led utilities to cut these discretionary "system benefit" expenditures over the past 5 years. Total utility spending on all demand-side management programs (i.e., energy efficiency and peak load reduction) fell by more than 50% from a high of $3.1 billion in 1993 to $1.4 billion in 1999 (1999$) (EIA 2000b; Nadel and Kushler 2000).

In order to ensure that energy efficiency programs and other public benefits activities continue following restructuring, 15 states have established system benefits funds through a small charge on all kilowatt-hours flowing through the transmission and distribution grid. We recommend creation of a national systems benefits trust fund that would provide matching funds to states for eligible public benefits expenditures. Specifically, we recommend a non-bypassable wires charge of two-tenths of a cent per kilowatt-hour. This concept and specific amount were included in utility restructuring bills sponsored by Senator Jeffords (S. 1369) and Rep. Pallone (H.R. 2569) in the last Congress. These bills provide one federal dollar for each state dollar but other matching ratios could also be considered, such as a 2:1 federal:state match, or a baseline funding amount with no matching requirement plus an additional supplemental amount subject to a match.

This policy would give states and utilities a strong incentive to expand their energy efficiency programs and other public benefits activities. All states and utilities would pay into the fund, but they would only get money back out if they establish or continue energy efficiency programs and other public benefit activities. However, individual states, not the federal government, would decide how the money gets spent.

Our analysis indicates that this policy would lead to widespread energy efficiency improvements in lighting, appliances, air conditioning, motors systems, and other electricity end-uses. We estimate it could save nearly 300 TWh in 2010 (7% of projected use), equal to about 2.5 quads of primary energy savings. By 2020, annual savings would exceed 800 TWh (6.5 quads). The impacts estimated here are for a federal systems benefit program and do not include savings from existing state programs. Savings from the federal program include direct national expenditures as well as incremental state expenditures induced by the federal matching program. Net lifetime economic benefits (i.e., net present value lifetime benefits minus program and measure costs) from measures installed under this program through 2020 would be about $100 billion (i.e., nearly $1,000 per household). With these levels of electricity savings, the risk of power shortages in the future would diminish, there would be fewer price spikes caused by periods of tight supply and demand, and there would be less need to build often contentious new power plants. In addition, pollutant emissions from power plants would fall (including carbon emission reductions of about 46 and 127 MMT in 2010 and 2020, respectively), thereby improving public health and helping cities and states meet the ambient air quality standards.[8]

3. Enact New Equipment Efficiency Standards and Strengthen Existing Standards

Federal appliance and equipment efficiency standards were signed into law by President Reagan in 1987 and expanded under President Bush in 1992. Minimum-efficiency standards were adopted because many market barriers (such as lack of awareness, rush purchases when an existing appliance breaks down, and purchases by builders and landlords) inhibit the purchase of efficient appliances in the unregulated market. Standards remove inefficient products from the market but still leave consumers with a full range of products and features to choose among.

Appliance and equipment standards are clearly one of the federal government's most effective energy-saving programs. Analyses by DOE and others indicate that in 2000, appliance and equipment efficiency standards saved 1.2 quads of energy (1.3% of U.S. electric use) and reduced consumer energy bills by approximately $9 billion, with energy bill savings far exceeding any increase in product cost. By 2020, standards already enacted will save 4.3 quads per year (3.5% of projected U.S. energy use) and reduce peak electric demand by 120,000 MW (more than a 10% reduction) (Geller, Kubo, and Nadel 2001).

In order to provide additional cost-effective savings under this program, we recommend three actions:

- Congress should adopt new efficiency standards for products now or soon to be covered by state efficiency standards. Among the products that should be included are distribution transformers, commercial refrigerators, exit signs, traffic lights, and torchiere lighting fixtures. California is now adopting standards on these products and Massachusetts and Minnesota already have standards on distribution transformers. None of these standards have been controversial and all involve highly cost-effective energy savings. In addition, Congress should adopt standards for commercial unit heaters, ice makers, and standby power consumption for household appliances and electronic products (such as televisions, VCRs, cable boxes, and audio equipment). Commercial furnaces are covered by existing federal standards; the same standard should be extended to unit heaters that are widely used to heat open spaces such as warehouses, garages, and factories. Ice makers are covered by an existing federal purchase specification, which should be enacted as a standard. Regarding standby power, many household electronic products use electricity even when they are switched "off." In a recent speech, President Bush pointed out these "vampires" and directed the federal government to purchase products with a standby power use of 1 Watt or less. This 1 Watt requirement should be adopted as an across-the-board standard (Nadel 2001).

[8] The figures cited here are from the "Integrated Analysis" section later in this report.

- DOE, with adequate funding and encouragement from Congress, should complete equipment standard rulemakings in a timely manner. Current rulemakings include updated standards for commercial air conditioning systems and residential heating systems. DOE should begin proceedings over the next few years to update standards for residential dishwashers and refrigerators, and then should consider updates to some of the standards that were set in the past few years.

- The Bush Administration should permit implementation of a SEER 13 efficiency standard for residential central air conditioners and heat pumps. The Administration recently proposed rolling back the standard issued in January from SEER 13 to SEER 12. This change would increase peak electricity demand by 18,000 MW once the standard is fully phased in and would increase consumer electricity bills by over $18 billion over the next 30 years. This rollback is now being challenged in court under a provision in the law that prevents DOE from weakening standards once they have been set. In addition, California and other states are developing new state standard and code requirements at SEER 13 and are planning to petition DOE for exemption from a SEER 12 standard. DOE can avoid many of these battles, and capture substantial energy and economic savings, by restoring the standard to SEER 13 (Nadel 2001).

Analysis by ACEEE indicates that these three steps would save approximately 95 billion kWh of electricity in 2010 and 265 billion kWh in 2020. The savings in 2020 amount to about 8% of projected residential and commercial electricity use in that year, and reduce projected peak electrical demand by the equivalent of nearly 300 power plants (300 MW each). In addition, the unit heater standard by itself would reduce commercial building gas consumption by about 3% in 2020, a remarkable achievement for a product with annual sales of only about one-quarter million units. These standards would also result in substantial economic savings for consumers and businesses. Our analysis indicates that for products purchased through 2020, discounted net benefits (benefits minus costs) would total about $80 billion, with a benefit-cost ratio of more than 4:1. Furthermore, we estimate that these standards would reduce carbon emissions by more than 70 MMT in 2020, which could be a useful component of U.S. efforts to reduce greenhouse gas emissions.[9]

4. Enact Tax Incentives for Highly Energy-Efficient Vehicles, Homes, Commercial Buildings, and Other Products

Many new energy-efficient technologies (including fuel cell power systems; hybrid and fuel cell vehicles; gas-fired heat pumps; and super-efficient refrigerators, clothes washers, and new buildings) have been commercialized in recent years or are nearing commercialization. But these technologies may never get manufactured on a large scale or widely used due to barriers such as their initial high cost, market uncertainty, and lack of consumer awareness.

[9] The figures are from the "Integrated Analysis" section later in this report.

Tax incentives could help manufacturers justify mass marketing for innovative energy-efficient technologies. Tax credits also could help buyers (or manufacturers) offset the relatively high first cost premium for the new technologies, thereby helping to build sales and market share. Once the new technologies become widely available and produced on a significant scale, costs should decline and the tax credits could be phased out.

We recommend providing tax incentives for a variety of very energy-efficient vehicles, buildings, and other products. A key element in designing the credits should be that only highly efficient products would be eligible. If the eligibility level is set too low, then the cost to the Treasury will be high and incremental energy savings will be low because incentives will be paid for sales that would have happened anyway (so-called "free riders"). Also, tax credits should be of limited duration (e.g., approximately 5 years) and possibly reduced in value over time so that the credits would help innovative technologies get established in the marketplace rather than become a permanent subsidy. We recommend tax incentives for the following products:

- **Appliances.** A tax credit of $50–100 for manufacturers of highly efficient clothes washers and refrigerators (with a cap on the total credit per manufacturer) would help save energy and water. This proposal is included in the energy bill that recently passed the House of Representatives and has been introduced in the Senate by Senators Grassley and Allard. It is strongly supported by the appliance industry.

- **New Homes.** A tax credit of up to $2,500 for highly efficient new homes (with 50% reductions in space heating and cooling costs compared to homes meeting the current Model Energy Code) would stimulate efficiency and help lower housing costs for American families. The House energy bill includes tax credits for homes with 30% energy savings. We recommend providing moderate tax credits for 30% savings and substantially higher tax credits for 50%. Bills with provisions along these lines have been introduced by Senators Bob Smith and Bingaman (S. 207 and S. 596, respectively), and Representatives Cunningham and Inslee (H.R. 778 and H.R. 2392, respectively).

- **Other Building Equipment.** We recommend a 20% investment tax credit (with caps) for innovative building technologies (including air conditioners, electric and gas-fired heat pumps, electric heat pump water heaters, stationary fuel cell power systems, and very efficient furnaces). This proposal is included in the Bingaman bill and also in a bill by Rep. Inslee (H.R. 2392). The fuel cell provision was included in the House energy bill.

- **Hybrid Electric and Fuel Cell Vehicles.** Tax credits of up to $5,000 for hybrid electric vehicles and $8,000 for fuel cell vehicles would help jump-start introduction and purchase of these innovative, fuel-efficient technologies. The incentives should be based primarily on energy performance and also require emissions reductions, as is the case in the CLEAR Act introduced by Sen. Hatch and others (S.760). The House energy bill includes tax credits along these lines but does not include any emissions requirements, and includes extra incentives for vehicles with only modest fuel economy improvements. We strongly prefer the original CLEAR Act as it would provide much better energy and environmental returns for taxpayer dollars.

- **Commercial Buildings.** We recommend a tax deduction of $2.25 per square foot for investments in commercial buildings and multifamily residences that achieve 50% or greater reductions in heating and cooling costs compared to buildings meeting the current ASHRAE model energy standards. This proposal is included in the House energy bill and in legislation sponsored by Sen. Bob Smith (S. 207).

- **Combined Heat and Power (CHP).** We recommend either a 10% investment tax credit or a shortened depreciation period (7 years for industrial systems and 10 for building systems) for CHP systems with overall efficiencies of at least 60–70%, depending on system size. This proposal has strong industry support and is included in both the Bingaman and Murkowski (S. 389) bills, as well as bills targeted at promoting CHP that were introduced by Representatives Wilson and Quinn (H.R. 1045 and H.R. 1945, respectively) in the House. The House energy bill includes a 10% investment tax credit but excludes small systems and takes back much of the benefits by *lengthening* depreciation periods for many systems. The depreciation change is a step in the wrong direction and there is no rationale that we are aware of for excluding small systems. We recommend that these deficiencies be corrected.

Regarding potential costs and impacts, it is likely that there would be millions of qualifying products, buildings, and CHP systems sold during the 2002–2006 time period. The total cost to the Treasury would be on the order of $10 billion, with vehicles and commercial buildings likely being the most costly components of the package. Participation on this scale would have a relatively modest direct impact on energy use and CO_2 emissions, saving on the order of 0.5 quads of energy and 5 MMT of carbon emissions per year by the end of the eligibility period. However, if the credits help to establish these innovative products in the marketplace and reduce the first cost premium so that the products would be viable after the credits are phased out, the indirect impacts would be many times greater than the direct impacts. We estimate that the total energy savings would reach 1.1 quads by 2010 and 3.6 quads by 2020 if the credits are successful. Under this scenario, avoided carbon emissions would reach around 20 MMT by 2010 and 75 MMT by 2020 (Geller and Quinlan 2001).

5. Expand Federal Energy Efficiency R&D and Deployment Programs

DOE has made many valuable contributions towards increasing the energy efficiency of U.S. buildings, appliances, vehicles, and industries. Consequently, the President's Committee of Advisors on Science and Technology (PCAST) stated in 1997 that "R&D investments in energy efficiency are the most cost-effective way to simultaneously reduce the risks of climate change, oil import interruption, and local air pollution, and to improve the productivity of the economy." (PCAST 1997).

Similarly, a July 2001 National Academy of Sciences review of DOE's energy efficiency and fossil energy R&D programs found that "the total net realized economic benefits associated with [DOE's] energy efficiency programs that [we] reviewed were approximately $30 billion (valued in 1999$), substantially exceeding the roughly $7 billion (1999$) in total energy efficiency RD&D investment over the 22-year life of the programs." The NAS review went on to recommend an R&D portfolio in energy efficiency that "focus[es on] national public good goals... [and has] (1) a mix of exploratory, applied, development and demonstration research and related activities, (2) different time horizons for the deployment of any resulting technologies, (3) an array of different technologies for any programmatic goals, and (4) a mix of economic, environmental and security objectives." (National Academy of Science 2001a).

In a similar vein, DOE recently documented that 20 of its most successful energy efficiency projects have already saved the nation 5.5 quadrillion Btus of energy, worth about $30 billion in avoided energy costs, mostly over the past decade (EERE 2000b). The cost to taxpayers for these 20 activities was $712 million, less than 3% of the energy bill savings so far. In fact, the energy bill savings from these 20 projects alone is over three times the amount of money appropriated by Congress for all DOE energy efficiency and renewable energy programs during the 1990s, demonstrating that spending taxpayers' money on energy efficiency R&D and deployment is a very sound investment. There are many other indicators of success and effectiveness besides the 20 projects reviewed in this report.

The ENERGY STAR deployment programs operated by EPA and DOE have also been very successful. Since starting the Green Lights program in 1991, EPA has shown great creativity in developing cost-effective, practical programs that have a substantial impact. For example, 16% of the commercial and public sector building space in the country has now signed up for the ENERGY STAR Buildings™ program. Program participants saved more than 27 billion kWh of energy in 2000 alone, according to data compiled by EPA. This is more than twice the level of savings as of 1998. In other words, the impacts are growing rapidly as new participants join and all participants move forward with their energy efficiency upgrades. Similarly, the ENERGY STAR New Homes program is growing rapidly with over 1,600 builders now participating and more than 25,000 ENERGY STAR homes built. These homes use 35% less energy for heating and cooling on average compared to the 1993 Model Energy Code (Brown, Webber, and Koomey 2000; EPA 2001).

The ENERGY STAR labeling program has transformed the market for personal computers, photocopiers, printers, and facsimile machines. Prior to ENERGY STAR, most of this equipment consumed energy whether the machine was in use or not. Through the ENERGY STAR program, EPA stimulated use of power management that allows equipment to go into a low-power "sleep mode" when equipment is not in use. Power management can reduce the energy use of office equipment by up to 50%. Around 80% of new personal computers, 95% of monitors, 99% of printers, and 65% of copiers now have the ENERGY STAR label. In total, consumers bought more than 120 million ENERGY STAR products in 2000. As a result of cumulative purchases, consumers saved more than 49 billion kWh in 2000—worth about $3.9 billion (Brown, Webber, and Koomey 2000; EPA 2001).

The Bush Administration has proposed cutting DOE's energy efficiency R&D and technology deployment programs (apart from grants to low-income households for home weatherization) by $180 million (29%) in FY2002. Some programs would be cut by 50% or more. Proposed funding for EPA's ENERGY STAR program is approximately level with last year. Cutting funding for DOE's energy efficiency programs would increase consumers' energy bills, hurt U.S. economic growth, increase the likelihood of power shortages, put upward pressure on energy prices, increase oil imports, and increase air pollution. Deep cuts in DOE's energy efficiency programs also would harm both the public-private partnerships that have been built up over many years and the energy efficiency R&D and deployment "infrastructure" that exists at national laboratories, state energy offices, and elsewhere. In light of the serious energy problems our nation is facing, we should expand, not cut, energy efficiency R&D and deployment programs.

Based on the PCAST recommendations of long-term funding of $880 million annually, we suggest increasing funding for DOE 's energy efficiency programs by about 17% per year for the next three years.[10] PCAST estimated that if these recommendations were adopted, energy bills would be reduced by $30–45 billion in 2010 and $75–95 billion in 2020, and carbon emissions reduced by 60–150 MMT in 2010 and 90–200 MMT by 2020 (PCAST 1997). These savings would overlap to some extent with savings from many other deployment policies recommended in this report.

Funding for the EPA programs should also be expanded. We recommend that EPA ENERGY STAR funding be increased 20% per year for the next 2 years and then funding should be sustained, in real terms, at those levels. EPA has projected that with continued funding at current levels, energy and emissions savings in 2010 will be more than double savings in 2000, including carbon emissions reductions of about 90 MMT (EPA 2000) (these savings overlap to some extent with other policies.) With increased funding, savings would be even greater. EPA and DOE should expand the scope and level of promotion associated with the ENERGY STAR program. ENERGY STAR labeling should be extended to additional types of electronic products, commercial refrigeration equipment, motors, and other mass-produced products not currently covered. The commercial building benchmarking and rating program should be expanded to include retail buildings, healthcare, lodging, groceries, and warehouses. Also, more funding is needed to expand promotion and training activities in the ENERGY STAR new homes and small

[10] Funding in FY2001 was $556, so 17% increases for three years would bring the program to the PCAST target.

business programs, and to develop and implement a major program to encourage home energy retrofits, as well as to increase consumer awareness and market penetration of energy-efficient ENERGY STAR products of all types.

Overall, we estimate that expanding DOE and EPA R&D and deployment programs would reduce U.S. energy use by about 1 quad in 2010 and 3 quads in 2020. These estimates are based on EPA calculations of savings from the current ENERGY STAR programs plus extrapolations based on a few successful DOE R&D programs over the past decade (EERE 2000b; EPA 2000). Additional energy would be saved from likely program expansions, and other R&D projects besides a few of the biggest "winners," but in order to prevent double-counting of savings with other policies, we use these very conservative savings estimates. These energy savings in turn would result in carbon emissions reductions of about 20 and 65 MMT in 2010 and 2020, respectively. We estimate that these savings could be achieved with an average simple payback period of 4–5 years.

6. Promote Clean, High-Efficiency Combined Heat and Power Systems

Combined heat and power (CHP) technology is a system that produces multiple usable energy forms (e.g., electricity and steam) from a single fuel input. These combined systems can achieve much greater efficiency than the usual separate systems for producing steam and electricity because the CHP systems recover heat that would otherwise be wasted in separate power production, and use this heat to displace the fuel that otherwise would be used to produce heat in a separate boiler. Because of the greater efficiency achieved, the total emissions from CHP systems are usually lower than the combined emissions required to produce the same output from separate systems.

Several inequities in government and utility regulations hinder development of CHP resources. These include environmental standards that do not recognize the efficiency gains of CHP systems, utility rules that make it difficult for many CHP systems to connect to the utility grid, and tax depreciation rules that vary the depreciation period for CHP systems from 5–39 years depending on plant ownership. Each of these problems need to be addressed.

Most stationary-source air quality regulations are based on either the emissions per unit of fuel burned or the concentration of a pollutant in the smokestack. This smokestack approach makes no adjustment in allowable emissions based on the efficiency of energy production. Thus, a CHP system receives no credit for net total emissions reductions achieved when compared to separate systems for providing heat and power. To address this problem, the permitting of CHP systems should be shifted from an input-based to an output-based approach (i.e., maximum emissions per unit of useful energy output). Output-based levels equivalent to current input-based levels for separate heat and power should be designated by EPA. Output based standards clearly are within the scope of the Clean Air Act. In fact, they are applied to all mobile sources (e.g., grams per mile traveled for passenger cars) and stationary reciprocating engines (grams per horsepower-hour). Since these regulations would be implemented at the state level, EPA should also educate state environmental officials and assist them in implementing this change.

CHP and other distributed generation technologies have encountered hurdles in interconnecting with the electric utility system, which has lead to a hostile environment for CHP in many utility service territories. These hurdles include: (1) a lack of standard technical specifications, which results in each utility developing its own specification with unreasonable requirements in some cases (e.g., expensive equipment or project analyses); and (2) discriminatory pricing and contractual practices by some utilities (e.g., "exit fees" and onerous terms and conditions of service).

While some states have begun to address these issues, many have not. And states are starting to take somewhat different approaches. Federal legislation is needed to address these issues in a consistent manner across states. The legislation should require the development of standards for CHP facilities to be interconnected with the local distribution facilities. CHP facilities should have a right to back-up power sold at rates, terms, and conditions that are reasonable and not discriminatory, as determined by the appropriate state regulatory authority. In addition, states should be mandated to exempt CHP facilities from exit fees that are not directly related to service to the customer.

Under current IRS rules, CHP assets are depreciated over varying time periods depending on system configuration and owner (i.e., the same equipment can be depreciated over as little as 5 years to as much as 39 years). For example, equipment at a data center is depreciated over 5 years while the same system installed in an owner-occupied commercial building is depreciated over 39 years. This treatment is a result of policies that did not envision the changes in technology and markets that have occurred in recent years. A common depreciation period is needed for CHP equipment. Based on the technical and market life of current systems, we recommend a depreciation period of 7 years for CHP systems used in industrial facilities and 10 years for CHP systems used in residential and commercial buildings.[11] More reasonable depreciation periods would increase the amount of capital cost that is treated as a tax deduction, thereby improving CHP economics. Alternatively, depreciation periods could be standardized at somewhat higher levels and an investment tax credit enacted to encourage CHP development.

DOE and EPA have set a goal of adding 50,000 MW of new CHP capacity by 2010. If the barriers described here were removed, we believe that this target would be achievable, and further growth could add an additional 95,000 MW over the 2011–2020 period. Relative to the conventional power plants these systems would displace, this new CHP capacity would result in net energy savings of approximately 1.1 quads in 2010 and 2.9 quads in 2020. Much of this

[11] CHP systems in industry tend to be operated for more hours than those used in buildings. This shortens the system life and by extension the recommended depreciation period.

capacity would likely be fired with natural gas, although some would use coal, waste heat, waste gas, and industrial process byproducts. Due to the higher efficiency of CHP systems and their common use of natural gas, CO_2 emissions would be cut by approximately 29 MMT of carbon equivalent in 2010 and 78 MMT in 2020.[12] Owners of CHP systems (businesses and industries) would realize net cost savings that pay back the first cost in 4–5 years on average, based on projected energy prices (Geller et al. 1998).

7. Voluntary Agreements and Incentives to Reduce Industrial Energy Use

The industrial sector accounts for about 39% of total U.S. energy consumption. Manufacturing represents about two-thirds of industrial energy use, with six energy-intensive sectors dominating (petroleum refining, chemicals, primary metals, paper and pulp, food and kindred products, and stone, clay, and glass products). There is substantial potential for cost-effective efficiency improvement in both energy-intensive and non-energy-intensive industries. For example, an in-depth analysis of 49 specific energy efficiency technologies for the iron and steel industry found a total cost-effective energy savings potential of 18% (Worrell, Martin, and Price 1999). Similar analyses for the paper/pulp and cement industries found cost-effective available savings of 16–22% and 11%, respectively (Martin, Anglani, et al. 2000; Martin, Worrell, and Price 1999). Furthermore, new energy-saving technologies and practices continue to be developed. For example, a recent study on *Emerging Energy-Efficient Industrial Technologies* identified 32 new technologies with substantial energy savings and a medium or high likelihood of commercial success (Martin, Worrell, et al. 2000).

In order to stimulate widespread energy efficiency improvements in the industrial sector, we propose that the U.S. government (White House or DOE) establish voluntary agreements with individual companies or entire sectors. Companies or entire sectors would pledge to reduce their overall energy and carbon emissions intensities (energy and carbon per unit of output) by a significant amount, for example, at least 1% per year over 10 years. Companies that make a more substantial commitment (for example, at least 2% per year) could be given ENERGY STAR or similar recognition. The government could encourage participation and support implementation by: (1) providing technical assistance to participating companies that request assistance; (2) offering to postpone consideration of mandatory emissions reductions or tax measures if a large percentage of industries participate and achieve their goals; and (3) expanding federal R&D and demonstration programs for sectors with high participation.

In order to get a large fraction of industries to make serious commitments and enter into voluntary agreements with the federal government, it may be necessary for the government to threaten to take more drastic action. For example, the government could indicate that it was going to issue carbon emissions standards or energy efficiency standards on major types of

[12] The figures are from the "Integrated Analysis" section later in this report.

industrial processes (e.g., steelmaking, aluminum production, paper and pulp making, petroleum refining, etc.) and/or adopt carbon emissions taxes if industries did not enter into meaningful voluntary agreements. And if participation in the voluntary agreements is limited or participants do not meet the agreed-upon targets, then the government should proceed with adopting mandatory energy intensity or carbon emissions reduction requirements for energy-intensive industries.

A number of major companies are demonstrating that it is possible to significantly reduce energy and carbon intensity while enhancing productivity and profitability, and have set voluntary goals for doing so. For example, Johnson and Johnson set a goal in 1995 of reducing energy costs by10% by 2000 through adoption of "best practices" in its 96 U.S. facilities. As of April 1999, they were 95% of the way towards this goal, with the vast majority of projects providing a payback of 3 years or less (Kauffman 1999). In 1998, British Petroleum announced it would voluntarily reduce its carbon emissions to 10% below 1990 levels by 2010, representing an almost 40% reduction from projected emissions levels in 2010 given "business-as-usual" emissions growth (Romm 1999). And DuPont announced it would reduce its greenhouse gas (GHG) emissions worldwide by 65% relative to 1990 levels while holding total energy use flat and increasing renewable energy resources to 10% of total energy inputs by 2010. DuPont is on track for achieving earlier commitments to reduce energy intensity by 15% and total GHG emissions by 50% by 2000, relative to 1990 levels (Romm 1999). If J&J, BP, and DuPont can make and deliver on these voluntary commitments, so can other companies.

Voluntary agreements between government and industry along the lines proposed here have resulted in substantial energy intensity reductions in some European nations such as Germany, the Netherlands, and Denmark. In the Netherlands, for example, the energy intensity of a wide range of industries improved by 20% on average during 1989–99, and thus industries achieved the targeted improvement of 20% by 2000 (CADDET 2000; Nuijen 1998; van Luyt 2001). A key factor in the success of these programs was the threat of new taxes or regulations (e.g.,the threat of additional taxes in the Denmark) if voluntary programs were not successful, and/or substantial financial incentives (e.g., in the Netherlands and Germany). Without these "carrots" and "sticks," according to expert observers of these programs, savings would have been far less (Price and Worrell. 2000; Worrell and Price 2001).

In order to estimate the impacts of this policy, we rely on a detailed analysis of voluntary agreements carried out by a team from the national laboratories (Murtishaw and Schipper 2001). Based on this analysis, we estimate that widespread adoption of voluntary agreements and supporting activities would reduce primary energy use in the industrial sector by about 3.3 quads (8.5%) in 2010 and 6.7 quads (16%) in 2020, relative to energy consumption levels otherwise forecast by the Energy Information Administration. The corresponding reductions in CO_2 emissions are 67 MMT of carbon by 2010 and 132 MMT by 2020. In order to realize these energy savings, a cumulative investment in efficiency measures of about $50 billion through

2020 is needed. But the energy bill savings during this period would equal around $160 billion, leading to net economic benefits of about $110 billion, with further savings due to reduced energy use after 2020 (all values are in discounted 1999$).

8. Improve the Efficiency and Reduce the Emissions of the Existing Power Plant Fleet

Many old, highly polluting power plants are "grandfathered" under the Clean Air Act. This means that they do not need to meet the same emissions standards for NOx, SO_2, and particulates as plants built after the Clean Air Act of 1970 was enacted. There are now 850 plants in operation, with a combined power output of 145,400 MW, that were constructed prior to 1970. In 1999, these plants produced approximately 760 billion kWh, about 21% of our nation's electric generation (Shoengold 2001). These older, dirty power plants emit 3–5 times as much pollution per unit of power generated as newer, coal-fired power plants and 15–50 times as much NOx and particulates as a new combined-cycle natural gas power plant (Cavanagh 1999). These older plants also are less efficient than most new plants; the pre-1970 plants have an average heat rate of 11,025 Btus of fuel per kWh generated, compared to modern combined-cycle plants with heat rates of 7,000 or less (Shoengold 2001). When the Clean Air Act was adopted, it was expected that these dirty power plants would eventually be retired. However, many utilities are continuing to operate these plants beyond their "design life" due to their low capital and operating costs. In fact, electricity generation from older coal-fired power plants increased about 16% during 1992–98 due in part to restructuring of wholesale power markets, which enabled utilities to sell low-cost, "dirty" kilowatt-hours outside their region (Coequyt and Stanfield 1999)

If old, grandfathered plants were required to meet the same emissions standards as new plants, some plants would be modernized and cleaned up, but many would be shut down and replaced with much more efficient and cleaner generating sources such as combined-cycle natural gas power plants. We recommend that a policy to end "grandfathering" be enacted soon but not take effect until 2010 or thereabouts. This phase-in period would allow owners of these old plants to make plant upgrade vs. replacement decisions and then have sufficient time to implement these decisions without unduly disrupting power markets.

Alternatively, the same general objectives would be achieved by adopting CO_2 emissions standards as part of a Clean Air Act "four pollutant" strategy that has been proposed in order to address SOx, NOx, mercury, and CO_2 emissions in an integrated fashion. Such a strategy would include tradeable carbon emissions permits, with the number of emissions allowances based on the phase-out of old, dirty, inefficient power plants. Bills along these lines have been introduced by Senators Jeffords and Lieberman (S.556) and Representatives Boehlert and Waxman (H.R.1256).

Yet another strategy that could achieve similar results would be "CAFE-like" power plant heat rate standards that would require generators to achieve a specified average heat rate (Btus of fuel per kWh generated) from their plants or else buy allowances from other generators with an average heat rate below the specified average. The allowable average heat rate would be based on some percentage reduction from the current national average heat rate. A single target could be set (e.g., a 10–20% reduction) or the allowable average heat rate could gradually ramp down each year (e.g., a 2% reduction each year). This would result in the retirement of some older, less efficient coal-fired plants.

Applying new emissions standards to old, grandfathered power plants has been done or is being considered by several states, including Texas and Massachusetts. In Texas, restructuring legislation passed in 1999 calls for grandfathered plants to reduce NOx emissions by 50% and SO_2 emissions by 75%, beginning in 2003. Emissions allowances will be established for several regions in Texas and these allowances can be traded so that the market can help determine the most cost-effective way to reach the emissions reduction targets (Texas Legislature 1999). In Massachusetts, new, tighter emissions standards have been adopted for large, pre-1977 power plants subject to the Federal Acid Rain Program. The program covers SO_2 and NOx, with the new standards gradually phasing-in over the 2004–2008 period (Clean Air Task Force 2001).

To model the impact of these policies, we estimate that 25% of the generation from old, grandfathered power plants can be displaced by generation from state-of-the-art natural gas-fired power by 2010 and 50% by 2020. These estimates result in the replacement of approximately 36,000 MW of generating capacity by 2010, and 73,000 MW of capacity by 2020 (although it is likely that most of the old plants would still be kept in reserve for short-duration periods when extra capacity is needed). Due to the better heat rate of new power plants, energy used to generate electricity would be reduced by about 37%, saving 1.55 quads in 2010 and 3.10 quads in 2020.[13]

These policies would have an even bigger impact on emissions of the key air pollutants since the old power plants are especially dirty and the new ones are cleaner than average. A 2000 analysis by the Environmental Law Institute and Resources for the Future found that replacing half of the old coal plants with new cleaner plants (primarily natural gas, but with a small contribution by wind and other sources) would reduce power industry SO_2 emissions by 50%, NOx by 40%, mercury by almost 60%, and CO_2 by 25% (a 172 MMT reduction in annual carbon emissions). They examined the economic impacts of completing this transition by 2010 and found that the principal economic impact would be a six-tenths of a cent rise in the price of

[13] These savings calculations are based on 1999 generation from these old plants; we take no credit for the fact that the new plants would likely have higher capacity factors than the old plants and that some of the old plants are likely to be retired or "mothballed" due to other factors. Also, as discussed in the "Integrated Effects" section later in this report, energy and carbon savings from retiring old power plants overlap with savings from efficiency measures since efficiency measures reduce the need for power, helping to spur the retirement of marginal generation plants. The numbers discussed here are for power plant upgrades only, in the absence of any other efficiency policies. The incremental effects beyond the other efficiency measures are discussed in the "Integrated Effects" section.

electricity above a business-as-usual scenario, which was about 9% of the average price of electricity in 2000—a modest price to pay for cleaner air (ELI 2000).[14]

9. Greater Adoption of Current Model Building Energy Codes and Development and Implementation of More Advanced Codes

Building energy codes require all new residential, commercial, and industrial buildings to be built to a minimum level of energy efficiency that is cost-effective and technically feasible. "Good practice" residential energy codes, defined as the 1995 (or a more recent) version of the Model Energy Code (now known as the International Energy Conservation Code or IECC), have been adopted by 27 states. "Good practice" commercial energy codes, defined as the ASHRAE 90.1-1989 model standard, have been adopted by 29 states (BCAP 2000). Some major states (such as Arizona, Illinois, Michigan, New Jersey, and Texas) have not adopted these "good practice" energy codes. However, the Energy Policy Act of 1992 (EPAct) requires that all states adopt a commercial building code that meets or exceeds ASHRAE 90.1-1989, and consider upgrading their residential code to meet or exceed the 1995 (or later) Model Energy Code.

Furthermore, building codes are being regularly updated. In the case of residential codes, the 2000 IECC includes higher insulation requirements than the 1995 code and also includes additional measures to reduce heat gain in hot climates. The code in California also includes measures to reduce air infiltration and duct leakage—these measures could be models for other states. In the case of commercial codes, ASHRAE has adopted a new 90.1-1999 standard that reduces energy use approximately 6% compared to the 1989 standard (Office of Codes and Standards 2001). Here too, substantial additional improvements are possible as measures with 10–20% additional savings were included in early drafts but dropped as part of a political process to gain "consensus."

Overall, we estimate that about half of the new homes built today do not meet the 2000 IECC, and upgrading them to meet the IECC would reduce energy use by about 15%. We further estimate that adoption of enhanced codes by 2010 could improve new home efficiency by a further 20%. For the commercial sector, we estimate 10% savings on average from adoption of 90.1-1999, and a further 20% savings from advanced codes adopted by 2010. Not all states would adopt these codes and we make allowance for this by assuming that 10% of homes and buildings would not be covered by the current codes and 25% would not be covered by the advanced codes. Based on these estimates, energy savings from improved codes would total 0.3 quads in 2010 and 1.5 quads in 2020. These energy savings would translate into GHG emission reductions of nearly 30 MMT of carbon by 2020. Based on a variety of published and unpublished sources, we estimate that improved codes would provide positive cashflow to

[14] They also projected that the increase in natural gas use for power generation would increase natural gas prices paid by electric utilities by about 70 cents per million Btus. If the transition occurred more gradually, the impact on electricity and natural gas prices would likely be lower.

homebuyers, meaning that the annual energy savings would be greater than the annual additional mortgage payments needed to amortize the cost of the efficiency improvements. Similarly, the new commercial codes would result in simple payback periods of 3–6 years for commercial building developers.[15]

In order to achieve these savings, states should be directed to review their codes and encouraged to revise them. DOE should continue to provide technical assistance for these efforts, with preference given to states that adopt statewide mandatory codes at or above the model codes. The model code organizations (IECC and ASHRAE) should also be encouraged to regularly update their codes to incorporate the latest in cost-effective energy-saving measures. IECC has been doing well in this regard, but ASHRAE's 1999 standard was very disappointing in that the final standard achieved only about a fourth of ASHRAE's 25% savings target. Given ASHRAE's conservatism, DOE should broaden its funding activities to include organizations and consortiums of states that are interested in achieving higher levels of energy savings than ASHRAE is able to deliver.[16]

Integrated Analysis

In the preceding sections, each of the nine policies were discussed and analyzed individually. However, the policies do interact (and sometimes overlap) with each other. In this section, we discuss an integrated analysis, in which the data were carefully adjusted to eliminate overlap between policies,[17] and then data on all of the policies were entered into an integrated model of U.S. energy use.

Methodology and Key Assumptions

The analysis of the national policies and measures was undertaken using several models. The principal model used was the DOE/EIA National Energy Modeling System, known as NEMS (EIA 2000c). Likewise, many assumptions (including base case energy prices and various

[15] These economic calculations are based on the energy use of new homes and commercial buildings as collected in DOE's residential and commercial energy consumption surveys, and cost estimates for the efficiency improvements compiled by the Alliance to Save Energy, New Buildings Institute, and ACEEE.

[16] For example, the New Buildings Institute (headquartered in White Salmon, Washington) is now planning to develop a "Commercial Reach Code" that targets 30% savings relative to 90.1-1999. This code is intended for use by voluntary programs as well as by states that want a more advanced code than ASHRAE's. States and utilities on the West Coast and the Northeast are working with the New Buildings Institute on this effort.

[17] We adjusted for overlap by carefully considering the efficiency measures implemented under each policy, and where there was overlap with other policies, excluding the savings from one policy so savings would not be double-counted. These adjustments particularly affected our estimated savings for tax credits since we excluded savings from CHP (covered under the CHP policy), vehicles (covered under the passenger vehicle fuel economy policy), and advanced appliances and buildings (covered in part under appliance standards and building codes). Similar adjustments were made in a number of other cases.

technology cost assumptions) were taken from the NEMS model, specifically as it was applied to produce the *Annual Energy Outlook 2001* (EIA 2000c). Our base case is derived from and very similar to the reference case scenario in the *Annual Energy Outlook 2001*. Several changes have been made to the EIA's base case but these are mainly related to renewable energy technology assumptions. The one significant change we made to EIA's base case was to scale back the passenger vehicle fuel economy improvements included by EIA. As noted previously, passenger vehicle fuel economy has stagnated or declined for more than a decade. The EIA's base case assumes this trend will suddenly reverse and that passenger vehicle fuel economy will increase from 24.2 mpg in 1999 to 28 mpg in 2020 in the absence of any new policies. We find this assumption unrealistic and scaled back this increase to 26.3 mpg by 2020.

NEMS is a computer model that projects future U.S. energy consumption and supply based on energy technology and fuel choice for each sector and end-use, which in turn are derived from fuel prices, technology costs and characteristics, equipment turnover rates, and financial and behavioral parameters. These in turn affect the amounts, types, and cost of energy supplies necessary to meet these demands. In our analysis, NEMS was used for modeling the base case and policy case impacts on electricity supply and emissions and the amounts and cost of fuels supplied for electricity generation. The impacts of the efficiency policies on fossil use and emissions in buildings, industry, and transportation were calculated using spreadsheet models because NEMS is not set up to model end-use efficiency improvements in fossil fuel use.

The electricity supply module of NEMS includes detailed data for all existing power plants in each of the thirteen National Electric Reliability Council (NERC) regions of the United States and in neighboring Canadian regions. It simulates dispatch of these plants and new plants needed to meet electricity demand in each region, based on the costs and technical characteristics of the electricity supply options and their fuels. It takes account of regional power exchanges and the sulfur-dioxide cap and trade system of the 1990 Clean Air Act Amendments. It also accounts for the limited NOx trading regime for nineteen States. The model assumes some cost reductions for new power plants as the number of units placed in operation increases (i.e., from learning and economies of scale).

Policies that reduce projected end-use electricity requirements would affect the amount, type, size, and timing of new electric power supplies, as well as the amount and mix of generation dispatched each year, within each NERC region. Demand reductions thus result in avoided costs from reduced plant construction and operation, and avoided emissions from reduced generation. Electricity demand reductions can also result in lower cost of fuels not only for electricity generation but also for other uses in buildings and industry. Similarly, policies that constrain emissions from power supply, such as the coal power plant retirement policy, would affect electricity costs and emissions.

NEMS is used to obtain the impacts of the policies that induce efficiency improvements in the use of electricity in buildings and industry, and of the policies that induce fuel shifts in the electric generation mix. The cost and emission impacts of the electricity demand policies were obtained by reducing the electricity demand in each sector, per exogenous inputs as described in the previous report sections, for each year as the policies and their impacts phase in. These sectoral demands are then disaggregated by NEMS within each region. The model finds the least cost capacity expansion and dispatch to meet those regional demands. These results are then compared with the NEMS base case runs in order to obtain the net annual changes in costs and emissions.

The avoided costs and emissions from any given demand reduction, by policy, end-use, or sector, would be the marginal changes in capacity expansion and generation owing to that demand reduction. The results for each policy thus depends on the sequence with which these reductions are modeled, as each reduction changes the margin that the next reduction affects. Rather than adopt an arbitrary sequence, we modeled the aggregate impact of all demand-side energy efficiency together to obtain the total avoided costs and emissions. This yields an average emissions and costs savings across all kilowatt-hours saved. We then allocated the avoided energy use, costs, and emissions from the entire set of policies to the individual policies based upon the relative magnitude of their impacts when modeled separately.

The electricity supply policy was also modeled in NEMS. The coal retirement policy was modeled by iterating on a carbon tax to achieve a specified level of economic retirement of coal-fired power stations. The 2010 goal of an incremental 36 GW of retired coal capacity and the 2020 goal of an incremental 73 GW of retired coal capacity due to the retirement of old grandfathered power plants was modeled by imposing a \$8 per tonne CO_2 tax on the electric sector together with the demand-side policies.[18]

All fuel prices for the base case are taken from the *Annual Energy Outlook 2001* (EIA 2000c). Electricity costs for the policy case are modeled in NEMS taking account of the impacts of the demand reductions and shifts in generation mix caused by the policies. Fossil fuel prices reflect changes in demand through the fuel supply modules of NEMS. Economic growth is assumed to be the same in the base and policy cases. A 5% real discount rate is assumed in the analysis of costs and benefits. The costs of efficiency investments are amortized over the life of each efficiency measure in order to account for costs and benefits in a consistent manner. As a result, for efficiency measures with a life that extends beyond 2020, not all costs are included in the analysis, as some of these costs relate to benefits that occur after 2020. Likewise, benefits

[18] These retirements, combined with retirements induced by lower electricity demand due to demand-side efficiency policies, exceeded the amount of retirements we thought was reasonable and so we scaled back total retirements of coal capacity to 16 GW in 2010 and 113 GW in 2020, leaving 20%of the old plants still in the generation mix. Most of these retirements would be achieved if our demand-side policies are enacted, leaving only 6 GW of retirements in 2010 and 14 GW in 2020 that are not driven by demand reductions.

that occur after 2020 are also not included in the analysis. Finally, we assume that for every quad reduction in oil consumption in transportation or other sectors, there is an additional 0.2 quads of energy savings in oil refining (Delucchi 1999; EIA 2000c).

Energy Impacts

Table 1 provides the overall energy use, carbon emissions, air pollutant, and economic impacts for 2010 and 2020. In the base case, total primary energy consumption reaches 114.6 quads by 2010 and 128.1 quads by 2020, a 1.3% per year growth rate on average. Energy growth in our base case is slightly higher than the reference case forecast in the *Annual Energy Outlook 2001* (EIA 2000c) primarily due to the modifications we made (discussed above) to EIA's projections of passenger vehicle fuel economy improvements in the absence of new policy interventions.

Table 1. Summary of Overall Results for the Base and Policy Cases

	1990	1999	2010 Base Case	2010 Policy Case	2020 Base Case	2020 Policy Case
End Use Energy (Quads)	63.9	71.6	86.5	79.4	98.3	78.9
Primary Energy (Quads)	84.6	96.1	114.6	102.2	128.1	94.2
Energy Use by Fuel (Quads)						
Coal	19.1	21.4	25.2	18.1	26.2	9.5
Oil	33.5	38	44.9	41.9	51.7	42.1
Natural gas	19.3	22	28.7	26	35.5	27.5
Nuclear	6.2	7.8	7.7	7.8	6.1	6.3
Hydro	3	3.2	3.1	3.1	3.1	3.1
Other renewables	3.5	3.4	4.8	5.1	5.2	5.5
Carbon Emissions (Million Metric Tons)	1,338	1,505	1,817	1,540	2,063	1,338
Other Emissions (Million Metric Tons)						
Sulfur dioxide	19.3	20.5	16.5	14.9	16.9	13.1
Nitrogen oxides	21.9	15.8	12.8	11.6	12.7	6.6
Particulate matter (PM-10)	1.7	1.5	1.5	1.4	1.6	1.4
Cumulative Net Savings ($ billions)			-	152	-	591

The nine policies reduce primary energy consumption 11% by 2010 and 26% by 2020, relative to energy use in the base case in those years, through increased efficiency and greater adoption of CHP. Primary energy use rises slightly during the next decade but falls significantly during 2010–2020 (see Figure 1).

Figure 1. U.S. Energy Consumption Over Time in the Base and Policy Cases

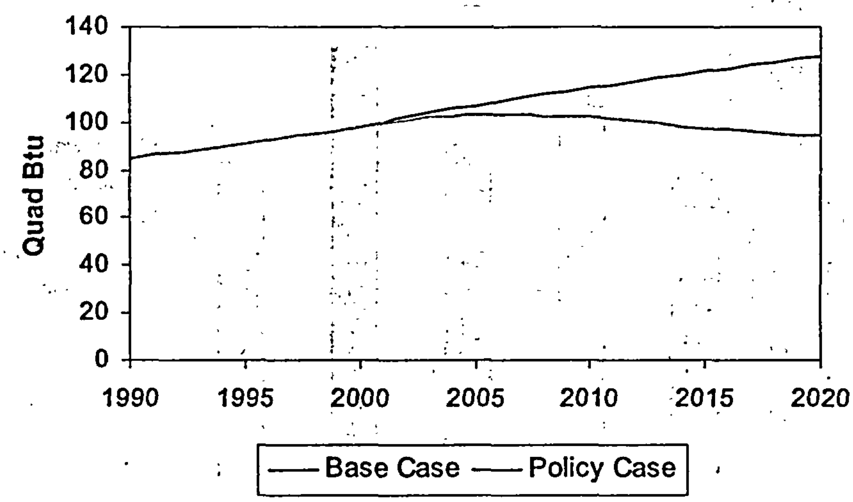


Figure 2 summarizes the breakdown of energy use by fuel type in each scenario over the 1999–2020 period. Oil consumption increases by about one-third by 2020 in the base case, with oil imports increasing more than 60% over that period. Thus, the oil import fraction is projected to rise from a little over 50% today to about 70% of total U.S. oil use by 2020. The policies evaluated here would significantly reduce overall oil imports. Relative to the base case, annual oil use by 2010 would be reduced by about 7% while annual imports would decrease by about 9%, assuming that domestic production remains unchanged. By 2020, annual oil use would be reduced by about 19% and imports by about 25%.

With implementation of the nine policies, U.S. total energy use in 2020 would be about 2% lower than energy use in 1999. Within this overall trend, use of some fuels increases and use of other fuels decreases. For example, use of coal declines 56% over this period, primarily due to substantial retirements of old, coal-fired power plants and replacement with natural gas. Due to increased use of natural gas for electricity generation, natural gas use grows 25% under the policy case relative to 1999 consumption, indicating that increased natural gas supplies would be needed. This growth in natural gas use in the policy case is substantially less than the 62% increase in natural gas use in the base case. As for petroleum, even with substantial efficiency improvements, petroleum use in the policy case is 11% higher than use in 1999. With domestic production at best stagnant, this would mean that oil imports will grow modestly, even with a full array of efficiency policies. By way of comparison, petroleum use grows 36% in the base case. Finally, electricity use in 2020 would be about the same as 1999 use although growth in CHP systems would decrease the need for centrally generated power relative to 1999. In total, while our nine policies would dramatically reduce the need for new energy supplies, even with these policies, there would be some need for new supplies, particularly natural gas.

Figure 2. Allocation of U.S. Energy Consumption by Energy Type in the Base and Policy Cases

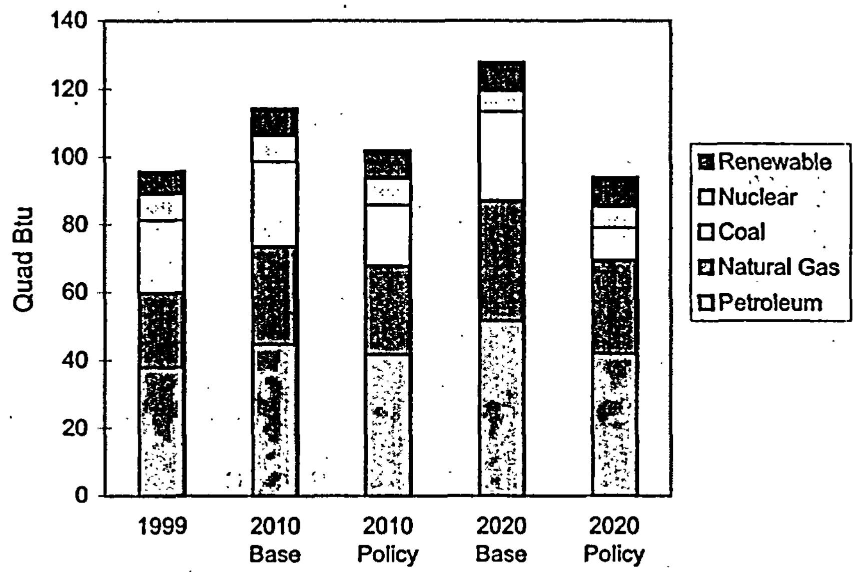


Table 2 summarizes savings from the different policies by sector. In this breakdown, energy savings arising from all policies that reduce electricity use are credited to the buildings or industrial sectors. With this perspective, the buildings-related policies are responsible for about 44% of the overall reductions (including 23% in the commercial sector and 21% in the residential sector), largely through impacts on electricity generation. The industrial policies are responsible for about 29% of the total reductions, the transportation policies about 23%, and the electric supply policy about 4%. Figure 3 displays these results graphically.

Table 2. Energy Use Reductions by Sector in the Policy Case

	1999	2010	2020	
Total Policy Case Consumption	96.1	102.2	94.2	
Reduction from residential policies		2.5	7.2	Residential
Reduction from commercial policies		2.7	7.9	Commercial
Reduction from industrial policies		4.5	9.5	Industrial
Reduction from transport policies		2.1	7.7	Transport
Reduction from electric supply policies		0.6	1.5	Electric Supply
Total Base Case Consumption	96.1	114.6	128.1	

Figure 3. Energy Use Reductions in 2020 by Sector

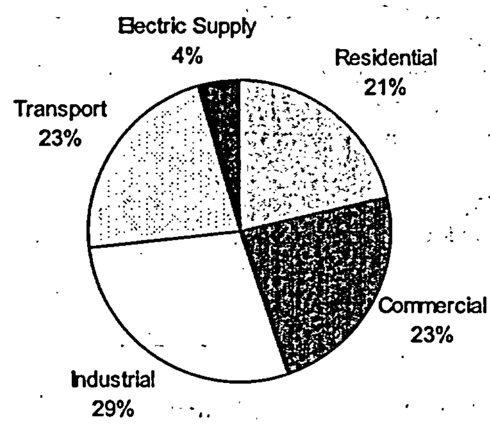


Table 3 and Figure 4 report on integrated savings by policy. These estimates take total integrated savings across all the policies and allocate them to the individual policies based on each policy's share of total unintegrated savings. Each of the policies has a substantial impact on U.S. energy use, with all saving at least 1.5 quad by 2020 (although tax credits are listed with lower savings since a substantial portion of their savings are subsumed under the CAFE standards, CHP, appliance standards, and building code policies). The largest savings estimates are achieved by CAFE standards and related policies to improve the fuel economy of light duty vehicles. Public benefit funds and industrial voluntary programs have the next largest savings. These three policies together account for about 60% of the savings in our policy case. However, for these policies to achieve such savings, they need to be stringent along the lines discussed in preceding sections of this report, including a 38 mpg CAFE standard, a two-tenths of a cent matching system benefit fund, and an industrial targets program backed by significant "carrots and sticks." Scaled-back versions of these policies would result in significantly lower savings.

Intermediate levels of estimated energy savings are achieved by updated and expanded appliance and equipment efficiency standards, expanded federal R&D and deployment efforts; increased use of combined heat and power systems, and tax credits. Finally, more moderate (albeit still substantial) savings are achieved by building codes and retirement of old, inefficient power plants. Savings from this latter policy are somewhat limited by our analytical approach whereby demand-side measures are first applied before supply-side measures. With this convention, efficiency programs lead to substantial power plant retirements, leaving only about half of the old "grandfathered" plants to be affected by the power plant policy. If we had instead considered supply-side policies first, power plant retirements would be included among the policies with intermediate energy savings.

Table 3. Energy Use Reductions by Policy

	1999	2010	2020
Total Policy Case Energy Consumption (quads)	**96.1**	**102.2**	**94.2**
Reduction from passenger vehicle effic. policy	0.0	2.1	7.7
Reduction from public benefits fund	0.0	2.5	6.5
Reduction from industrial voluntary program	0.0	3.3	6.4
Reduction from appliance standards	0.0	1.2	3.6
Reduction from R&D and deployment programs	0.0	0.9	3.3
Reduction from CHP	0.0	1.1	2.9
Reduction from power plant retirement policy	0.0	0.6	1.5
Reduction from building codes	0.0	0.3	1.5
Reduction from tax credits	0.0	0.3	0.6
Total Base Case Energy Consumption	96.1	114.6	128.1

Figure 4. Energy Use Reductions Over Time by Policy

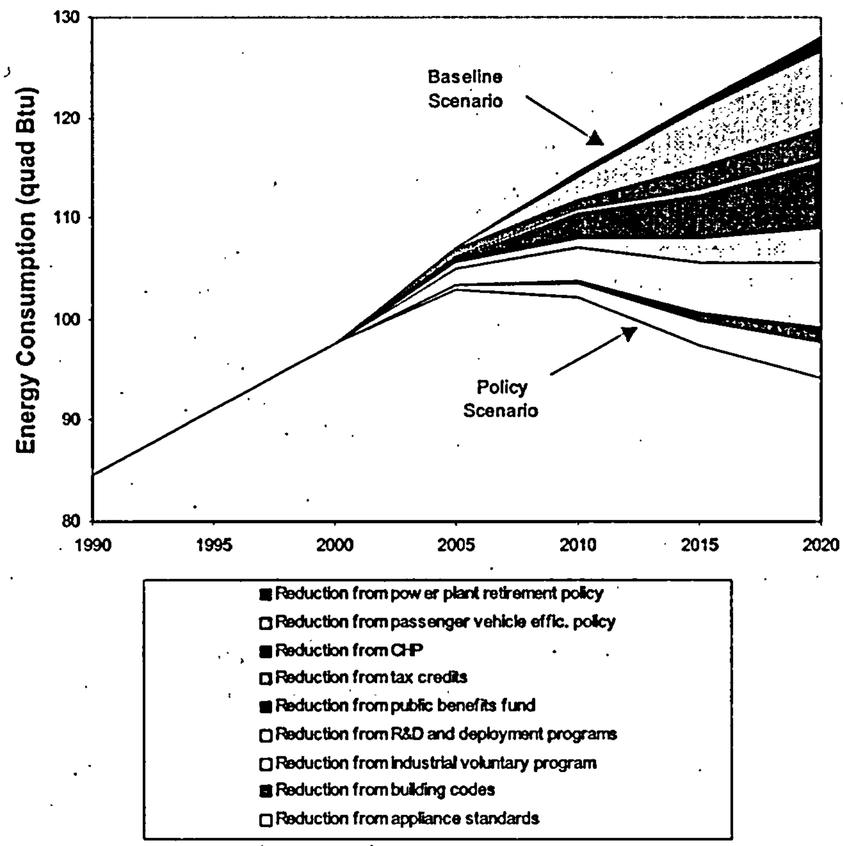
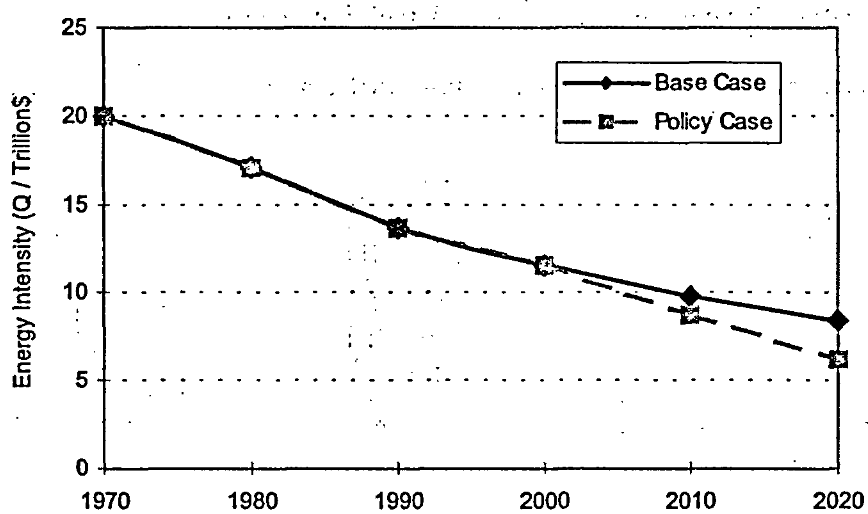


Figure 5 shows the history of the energy intensity of the U.S. economy (primary energy use per GDP) from 1970 to the present, as well as in the base case and policy case projections. The historic decrease in energy intensity is dramatic, at about 1.85% per year during 1970–2000. Energy intensity decreased 2.6% per year on average during 1973–86 but the decline fell to 1.1% per year during 1987–96. From 1996–2000, the energy intensity decline picked up speed, averaging 3.6% over the period.

Figure 5. Energy Intensity (GDP Basis) in the Base and Policy Cases

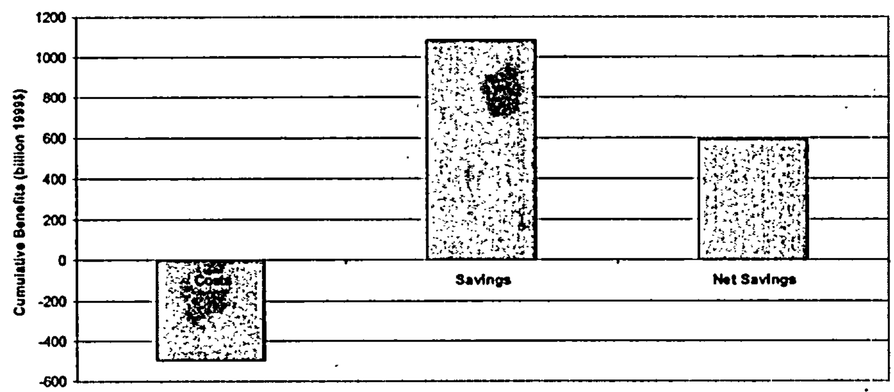


The base case forecast envisions a continued decline in energy intensity at about 1.3% per year so that energy intensity would be about 80% of the current level by 2020. In the policy case, the energy intensity of the economy drops about 2.6% per year on average through 2020, twice the rate in the base case but approximately equal to the rate of energy intensity reduction that occurred during 1973–86 and slightly slower than the improvement in the past few years. In the past few years there has been particularly rapid decline in energy intensity, driven in part by high economic growth, high capital investment in new technologies, and modest growth in residential energy demand (residential sector energy use has significantly lagged economic growth in recent years). These factors, and thus the 3.6% rate of energy intensity improvement, are probably not sustainable in the long term. Additional details on energy use by year in the base and policy cases are provided in Appendices A and B.

Economic Impacts

Figure 6 summarizes the direct economic costs and benefits in the policy case. The policies would induce incremental investments in high-efficiency motors; advanced industrial processes; more efficient buildings, lighting, and appliances; more fuel-efficient cars and trucks; cleaner and more efficient power plants; and so on. We estimate a total investment of $127 billion through 2010 and $495 billion through 2020, expressed in 1999 dollars using a 5% real discount rate. To place these figures in context, total U.S. energy expenditures (excluding on-site renewables) equaled about $558 billion in 1999 (EIA 2000c). The implementation of energy efficiency measures leads to lower utility bills, less fuels purchased, and some operating cost savings in areas such as petroleum refining. Overall, we estimate that end-users will save over one trillion dollars through 2020 as a result of these policies. This energy bill and operating savings more than offset the investment costs, with net savings of about $150 billion through 2010 and nearly $600 billion through 2020. The net savings grow over time since energy efficiency measures have more time to pay back their initial cost.

Figure 6. Costs, Savings, and Net Savings for the Policies by 2020



Note: Figures are cumulative present value by 2020, in billion 1999$.

Table 4 shows further details on the cost-effectiveness of the various policies, considering all costs and savings through 2020. The demand-side policies in aggregate are very cost-effective, with fuel and O&M savings that are nearly three times the investment costs, thereby yielding net benefits of about $655 billion. On the other hand, the supply-side policy—requiring coal-fired power plants to meet tougher emissions standards—is not cost-effective by itself, due in part to the switch from a less expensive to a more expensive fuel (coal vs. natural gas). For the power plant policy, investment costs exceed the fuel and O&M savings by $64 billion. Thus, combining all of the policies results in a net savings of $591 billion during the 20-year period. Appendix C provides further data on costs and savings.

Table 4. Net Benefits by Policy (Cumulative PV by 2020, billion 1999$)

	Costs	Savings	Net Savings
Total Policy	495	1087	591
passenger vehicle effic. policy	102	251	148
public benefits fund	130	231	101
industrial voluntary program	48	159	112
appliance standards	26	110	84
R&D and deployment	33	86	53
CHP	63	189	125
power plant retirement policy	64	0	-64
building codes	11	34	23
tax credits	17	26	8

Note: Figures are cumulative present value by 2020, in billion 1999$.

The nine policies would also have a positive impact on the economy by weakening demand for different energy sources, which would result in lower energy prices. In the base case, NEMS projects that domestic electricity and coal prices decline somewhat in real terms over the 1999–2020 period (e.g., declines of 8% and 25% respectively) while natural gas prices increase by 49%. In 2020, base case prices are projected by NEMS to be $0.061 per kWh for electricity, $12.71 per ton for coal at the mine mouth, and $3.10 per million Btus for natural gas at the wellhead (1999$). Under the policy case, electricity and coal prices are projected to drop by an additional 7% and 1%, respectively. More dramatically, natural gas prices are projected to decline to below 1999 levels (e.g., to $1.90 per million Btus in 2020), a *37%* decline from the base case. These trends are illustrated in Figure 7.[19]

These price declines would have a substantial and positive impact on the U.S. economy and would benefit all consumers and businesses. These indirect benefits are in addition to the direct benefits discussed above. Figure 8 summarizes the NEMS model results for energy expenditures in the base and policy cases incorporating both the direct and indirect effects. In the base case, U.S. energy expenditures are projected to rise from $557 billion in 1999, to $703 billion in 2010, to $809 billion in 2020 (all figures in 1999$). In the policy case, total energy expenditures would be reduced to $605 billion in 2010 (a savings of $98 billion relative to the base case) and $538 billion in 2020 (a savings of $271, a 33% reduction relative to the base case). Looked at on a per household basis, in the base case, energy expenditures per household (including energy used in homes, transportation, and businesses) would gradually climb from $5,355 in 1999 to $6,249 in 2020 (1999$). In the policy case, expenditures per household would be only $4,156, an annual

[19] The policies may also have a moderate impact on gasoline prices since 2020 gasoline consumption declines 27% in the policy case relative to the base case. However, since we did not use the NEMS transportation module, gasoline prices were not modeled.

savings of $2,093 per household (some of these savings would be in reduce household energy bills and some in lower prices for other goods and services).

Figure 7. Gas, Coal, and Electricity Prices Over Time in the Base and Policy Cases

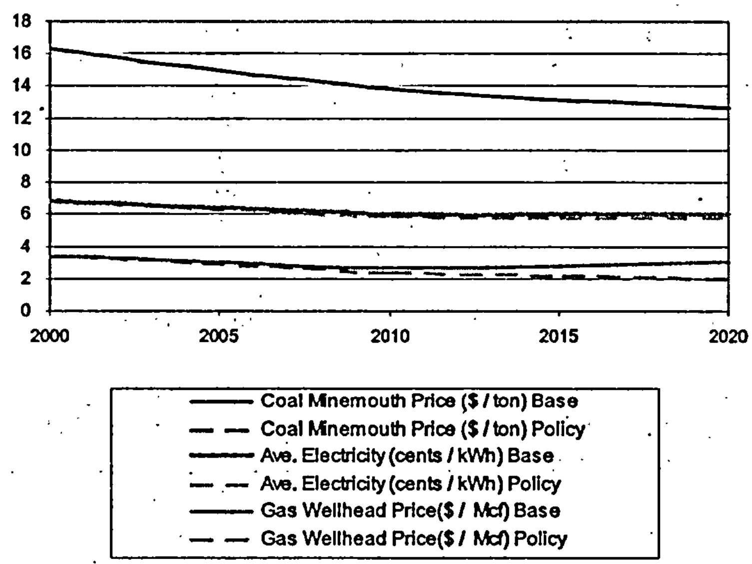
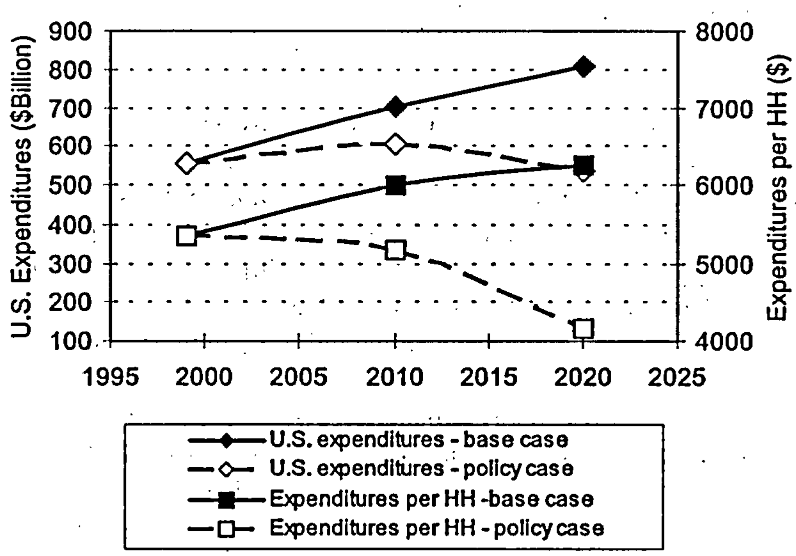


Figure 8. Energy Expenditures in the Base and Policy Cases



The companies that produce, market, and service the energy efficiency and renewable energy measures implemented in the policy case would employ workers and add to personal income while the energy supply industries would lose workers as demand for conventional fuels falls. The efficiency measures would also lower the energy bills of the businesses, industrial firms, and households that utilize the more efficient equipment, as well as the energy bills of all consumers due to the downward pressure on energy prices. Re-spending of these energy bill savings would create additional jobs and income since expenditures would be shifted to areas of the economy (such as food, housing, and entertainment) that are more labor-intensive than the energy supply sectors. The combination of the direct expenditures and re-spending would occur broadly across all sectors, and much of it would be local. Thus, national job increases—in construction, services, education, finance, manufacturing, agriculture, etc.—would be spread throughout the country.

While an analysis of overall macroeconomic impacts was not undertaken in this study, prior studies of this type show a net increase in jobs and personal income when energy efficiency and renewables measures are widely implemented (Bernow et al. 1999; Geller, DeCicco, and Laitner 1992; Goldberg et al. 1998; Laitner, Bernow, and DeCicco 1998; Sanstad, DeCanio, and Boyd 2000). These analyses used an input-output (I-O) model that represents interactions among different sectors of the economy. The most recent national analysis, *America's Global Warming Solutions,* indicated a potential net increase of nearly 900,000 jobs by 2010 (Bernow et al. 1999). While there are uncertainties in such an analysis, and a variety of dynamic economic phenomena that are not captured, this study gives an indication of the overall macroeconomic impacts likely to result from pursuing the nine policies considered here. Furthermore, this analysis includes only the impacts of direct energy savings and does not include the impacts of reduced energy demand on energy prices, which would likely add to the job gains.

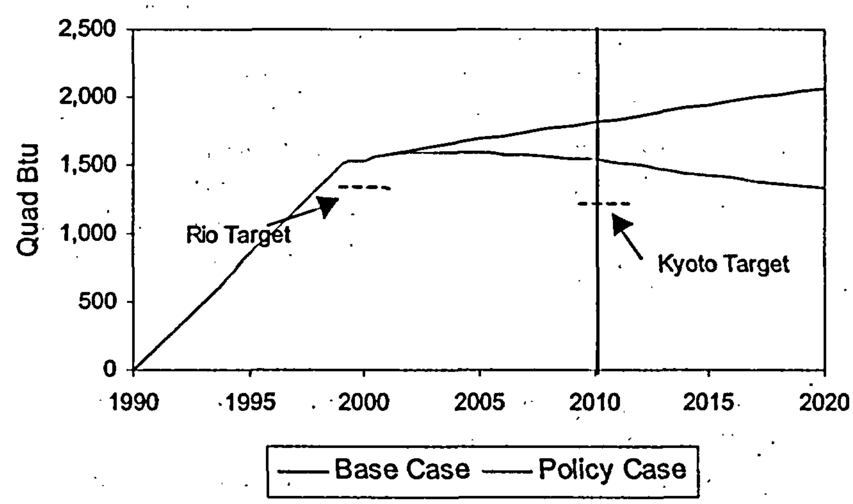
It also should be noted that our analysis does not take full account of the economies of scale, learning, or leadership in technology innovation that could be stimulated by the set of policies (Arthur 1994; Azar 1996). Nor does it account for the ancillary benefits, such as the human, systems, and organizational productivity improvements that could accompany the accelerated diffusion of advanced technologies and new energy resources (Porter and van Linde 1995). Such technological innovation and diffusion could have dramatic impacts on both the economic well-being and carbon intensity of society over the long run (Grubler, Nakicenovic, and Victor 1999).

Emission Impacts

U.S. carbon emission trends in the base and policy cases are summarized in Figure 9. In the base case, carbon emissions from burning fossil fuels reach 1,817 MMT of carbon equivalent by 2010 and 2,063 MMT by 2020, a 1.5% annual average growth rate during 2000–2020. Base case emissions are 36% greater than the 1990 level by 2010 and 54% greater by 2020. In the policy case, carbon emissions decline by 2010 so that they are the same as 2000 emissions and about 15% above 1990 emissions. Carbon emissions in 2010 in the policy case are about 280 MMT (16%) less than in the base case.

While this would not be enough to reach the U.S.'s Kyoto Protocol target of 7% below 1990 emissions during 2008–2012, it would be a strong step in that direction. It should be possible to achieve the Kyoto target (i.e., a further 290 MMT annual reduction) through some combination of: (1) further domestic reductions from additional policy initiatives such as policies to promote use of renewable energy sources and policies to reduce vehicle use as well as energy use for air and truck transportation; (2) reductions in emissions of other GHGs; (3) purchase of emissions reductions from other Annex 1 countries; and (4) reductions in developing countries from Clean Development Mechanism projects. A recent study for the World Wildlife Fund examines the impacts of these other policies, in combination with the nine policies discussed here, and concludes that all of these actions together would bring the United States to within its Kyoto target (Bailie et al. 2001).

Figure 9. U.S. Carbon Emissions Over Time in the Base and Policy Cases



The set of nine policies continues to provide carbon emissions reductions after 2010 while the economy is expanding. For some of the polices, such as stimulating vehicle efficiency improvements and removing barriers to CHP, the impact of the policies accelerates after 2010. This is due to the time required to commercialize new technologies, increase their market share, and deploy them in a significant fraction of the eligible market. Compared to the base case, carbon emissions are cut 741 MMT (36%) in 2020 in the policy case. Emissions in 2020 in the policy case also are about 14% less than carbon emissions in 2000 and 1% less than energy sector emissions in 1990. When combined with the other actions discussed in the previous paragraph, this level of carbon emissions reduction is consistent with a climate stabilization scenario whereby industrialized nations cut their absolute carbon emissions by over 50% by 2050 and over 90% by 2100 (Bailie et al. 2001; PCAST 1997).

Figure 10 shows the history of the carbon intensity of the U.S. energy mix (carbon emissions per quad of primary energy) of the economy from 1970 to the present, as well as in the base case and policy case projections. The carbon intensity of primary energy consumption declined modestly (0.3% per year on average) during 1970–2000. The reduction was caused by expansion in nuclear, bioenergy, and hydro power, although growth in coal use offset much of the de-carbonization due to nuclear and renewable energy expansion during this period. The carbon intensity of U.S. energy supply actually has been declining over the past two centuries, falling at an average rate of about 0.9% per year during 1900–90 (Grubler, Nakicenovic, and Victor 1999.). The base case forecast, however, projects a slight increase in carbon intensity (0.1% per year on average) through 2020. The policy case, on the other hand, is more consistent with long-term trends and shows a 0.5% per year average drop in carbon intensity due to shifts from coal to natural gas within the electric sector.

Figure 10. Carbon Intensity (Energy Basis) in the Base and Policy Cases

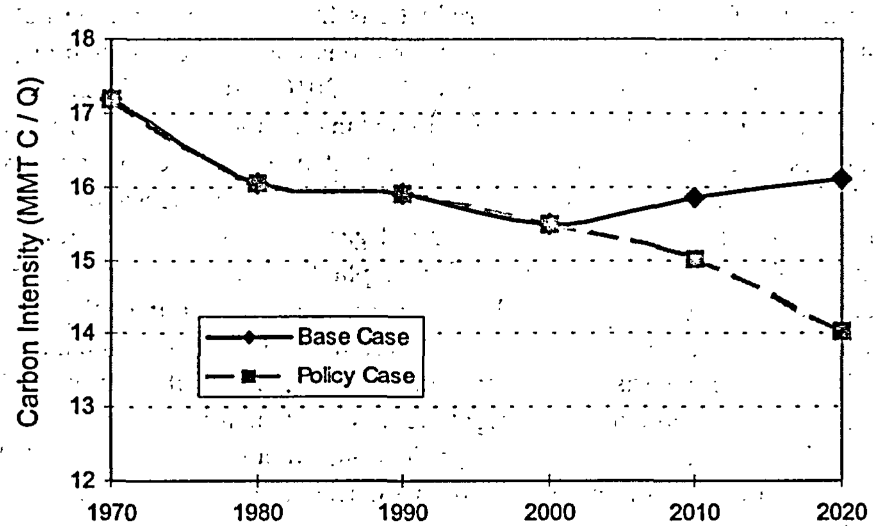


Figure 11 combines the impacts of changing energy intensity (Figure 5) and carbon intensity of energy use (Figure 10) to arrive at the carbon intensity of the overall economy. Carbon intensity has declined by nearly 50% over the past three decades—a compound annual average of 2.2%. In the base case, it is projected to decline at a slower rate—about 24% from 2000 to 2020 (1.4% per year) due to continued modest reductions in energy intensity. In the policy case, the projected decline is much more dramatic, by 51% from 2000 to 2020 (3.5% per year), owing to both energy intensity reduction and decarbonization of energy supplies.

Figure 11. Carbon Intensity (GDP Basis) in the Base and Policy Cases

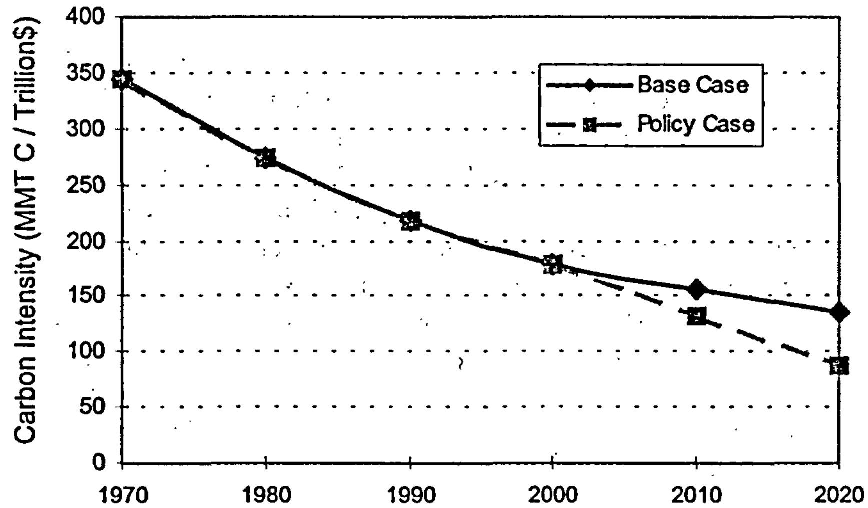


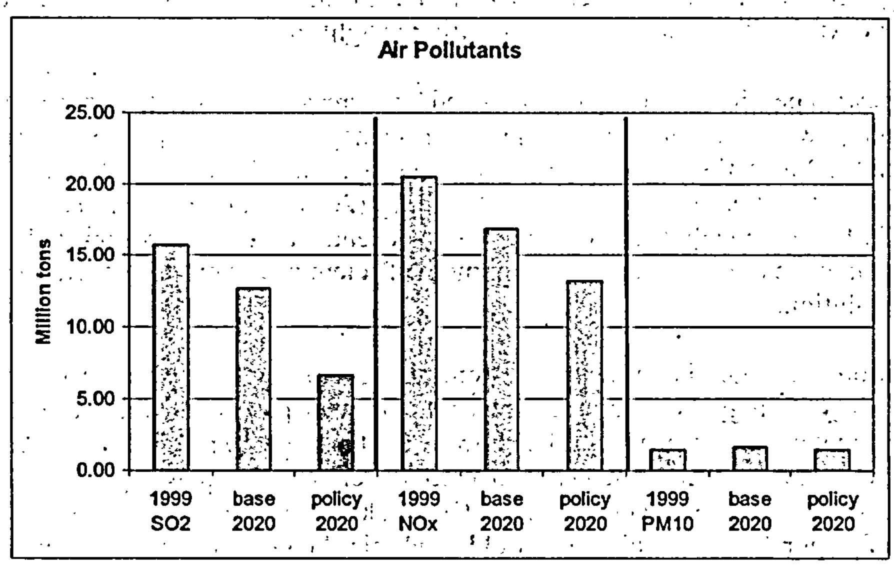
Table 5 presents the carbon emissions reductions from each of the nine policies. Upon inspection, it may appear surprising that tighter emissions standards on coal-fired power plants cause rather modest carbon reductions of 43 MMT in 2010 and 71 MMT in 2020. As noted above, this is in part a result of the convention adopted in this study that carbon reductions from the supply policies are computed after the impacts of the demand policies are taken into account. The set of demand policies results in significant reductions in electricity generation and emissions. Demand reductions reduce both natural gas and coal-fired generation, with coal displacement weighted towards the less efficient plants. The effect of tighter coal plant emissions standards were computed based on a percentage reduction in coal generation; thus, with the demand policies in place it would give lower emissions reductions than without these policies in place. For comparison, we computed the impacts of the supply policy before implementing the demand policies. If the tighter emission standards are considered before any of the demand-side policies, then the carbon reductions are about 83 MMT in 2010 and 104 MMT in 2020. Additional information on carbon emission reductions by year can be found in Appendices D and E.

In addition to carbon emission reductions, the set of nine policies also reduces criteria air pollutants. Air pollutants such as fine particulates (PM-10), carbon monoxide (CO), SO_2, and ozone (formed by a mix of volatile organic compounds [VOC] and NOx in the presence of sunlight) cause or exacerbate health problems that include premature mortality and morbidity. Small children and the elderly are particularly at risk from these emissions (Dockery et al. 1993; Schwartz and Dockery 1992.). These emissions also damage the environment, adversely affecting agriculture, forests, water resources, and buildings. Figure 12 presents the impacts of the nine policies on combustion-related emissions of several criteria air pollutants (data for this table can be found in Appendix F). Implementing the nine policies would reduce SO_2 emissions the most—9% by 2010 and 48% by 2020. Emissions of NOx would be cut 7% by 2010 and 19% by 2020 and PM-10 emissions would drop 6% by 2010 and 13% by 2020. Clearly, taking action to reduce energy use as proposed in the policy case would provide significant public health and local/regional environmental benefits.

Table 5. Carbon Emissions Reductions by Policy

	2010	2020
Total Policy Case Carbon Emissions (MtC)	**1540**	**1338**
Reduction from passenger vehicle effic. policy	23	71
Reduction from public benefits fund	6	28
Reduction from industrial voluntary program	67	132
Reduction from appliance standards	19	65
Reduction from R&D and deployment programs	46	127
Reduction from CHP	4	10
Reduction from power plant retirement policy	29	78
Reduction from building codes	40	142
Reduction from tax credits	43	71
Total Base Case Carbon Emissions	**1817**	**2063**

Figure 12. SO_2, NOx and Particulate Emissions Over Time in the Base and Policy Cases



Discussion and Conclusion

Energy efficiency is an important cornerstone for America's energy policy. Taken together, the nine policies recommended here would reduce U.S. energy use by more than 20% in 2020.

These savings could well exceed projected growth in U.S. energy use over the next two decades. These efficiency policies alone will not solve all of our energy problems—energy use would continue to grow for a decade or so while these energy-saving policies gradually take effect. Furthermore, new sources of energy supply and distribution will be needed as current surpluses are exhausted and portions of current infrastructure need to be replaced. In addition, infrastructure may need to be expanded in rapidly growing regions. However, these efficiency policies would substantially reduce our energy problems, making it easier to find reasonably priced and environmentally acceptable energy supplies to meet future U.S. energy demand. In other words, relative to a supply-focused energy strategy, a balanced energy strategy that complements efforts to expand supplies with a major focus on improving efficiency has a greater chance of success in terms of ensuring the reliability of the U.S. energy system, reducing economic costs (since the efficiency strategies incorporated here save consumers and businesses money at projected energy costs), and protecting the environment. Furthermore, all consumers and businesses would benefit from adoption of these policies due to the reduction in energy prices expected as demand falls relative to business-as-usual trends.

ACEEE is not the only organization suggesting that national policymakers should increase support for and adopt new policies to raise energy efficiency. The Council on Foreign Relations convened an independent task force that recently completed an in-depth report on the United States' energy challenges and what should be done about them (Council on Foreign Relations 2001). The Council concludes: "Energy policy has underplayed energy efficiency and demand-management measures for two decades." The Council urges that the United States "take a proactive government position on demand management" including to "review and establish new and stricter CAFE mileage standards, especially for light trucks."

Many newspapers have recently editorialized for increasing energy efficiency and a balanced energy strategy with a major focus on energy efficiency. These newspapers include *Business Week* (Raeburn 2001), the Los Angeles Times (2001), *Miami Herald* (2001), *New York Times* (2001), *Seattle Post-Intelligencer (2001), USA Today* (2001), and *Washington Post* (2001). For example, *USA Today* concluded: "[F]or an energy-dependent nation, more power plants and new oil and gas supplies aren't enough. Making more efficient use of existing energy must also be part of the solution."

In addition, the general public voices strong support for increasing energy efficiency and a balanced energy strategy. For example, a recent nationwide poll conducted for the *Los Angeles Times* found that when people were asked how to meet our energy needs, "15 percent called for greater conservation efforts, 17 percent supported development of new supplies and 61 percent said they favored both steps in equal measure (Barabak 2001)." Similarly, in a May 2001 Gallop Poll, 47% of respondents said the U.S. should emphasize "more conservation" versus only 35% who said we should emphasize production (an additional 14% volunteered "both"). In this same poll, when read a list of 11 actions to deal with the energy situation, the top four actions (supported by 85–91% of respondents) were "invest in new sources of energy," "mandate more energy-efficient appliances," "mandate more energy-efficient new buildings," and "mandate more energy-efficient cars." Options for increasing energy supply and delivery generally received significantly less support (Moore 2001).

Ten years ago the previous Bush Administration issued its National Energy Strategy. It gave considerable priority to greater energy efficiency and called for expansion of energy efficiency R&D and technology deployment programs, new policies to stimulate utility energy efficiency programs, establishment of new appliance and equipment energy efficiency standards, and new federal incentives to increase energy efficiency (DOE 1991). Many of these proposals were incorporated in the Energy Policy Act of 1992, and the budget for and impacts of DOE's energy efficiency programs rose throughout the previous Bush Administration.

The current Bush Administration and the current Congress should make improving energy efficiency a cornerstone of its energy strategy and adopt policies that would truly make a difference. In May 2001 the Administration released its *National Energy Policy*. This policy calls for "advanc[ing] new, environmentally friendly technologies to increase energy supplies and encourage cleaner, more efficient energy use." Unfortunately the policy details do not bear this rhetoric out. Instead, the plan proposes many specific policies for increasing energy supplies, but the major specific efficiency policy is a call for tax incentives for efficient vehicles and CHP systems (a subset of the tax credits we propose). In addition, the plan calls for "reviewing" CAFE and "tak[ing] steps" to set new appliance efficiency standards. These latter actions fall well short of our specific policy prescriptions (National Energy Policy Development Group 2001).

Congress is now beginning to consider energy legislation, and these efforts so far go farther than the Bush Administration proposes with respect to advancing energy efficiency, but they are still well short of what is needed. As of this writing, legislation passed by the House of Representatives includes some of the tax incentives and appliance standards we call for and an extremely modest increase in CAFE standards. At the same time, both houses of Congress have passed appropriations bills for R&D and deployment programs in 2002 that essentially leave funding for DOE and EPA R&D deployment programs level with 2001, a substantial improvement relative to the original Bush budget proposal, but well short of the increases that are needed. All of our other policies unfortunately are not included in the House legislation.

Overall, Congress so far merits a grade of "D" in terms of meaningful action to raise energy efficiency and is doing much less than the American people want, as indicated in the polls. Congress, starting with the Senate, needs to redouble its efforts in order to properly value and support energy efficiency in new energy legislation and in appropriations for energy programs. In particular, we urge Congress to adopt substantial energy efficiency provisions along the lines of our proposals. Implementation experience with the energy efficiency provisions included in the Energy Policy Act of 1992 indicates that most of the energy savings actually achieved in practice are from a few major provisions (e.g., new equipment efficiency standards), and that smaller provisions tend to have little impact but can divert needed attention from implementation of the major provisions (ACEEE and ASE 1997).

In this report, we show that energy efficiency policies can make a very large contribution towards meeting U.S. needs for new energy sources while reducing emissions and saving consumers and businesses billions of dollars. However, without strong policies, many of these benefits would be lost, costing the U.S. dearly in terms of excessive energy bills, adverse impacts on public health, over-dependence on imported energy, and increased risk of dangerous climate change. Congress now has it in its power to take a different tack—it is time for Congress to rise to the occasion and adopt a comprehensive and strong set of policies that would increase energy efficiency throughout the U.S. economy for decades to come.

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7

Opportunities for New Appliance And Equipment Efficiency Standards: Energy and Economic Savings Beyond Current Standards Programs

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September 2001

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EXECUTIVE SUMMARY

Appliance and equipment efficiency standards have been one of the most successful policies used by state governments and the federal government to save energy. Appliance and equipment efficiency standards prohibit the production and import or sale of appliances and other energy-consuming products less efficient than the minimum requirements. These standards not only save energy but also reduce pollutants, improve electric system reliability, and save consumers and business owners significant amounts of money over the life of the equipment.

In the United States, minimum-efficiency standards for appliances and other equipment were adopted by Congress in 1987, 1988, and 1992 and signed by Presidents Reagan and Bush to address market failures and replace a patchwork of state standards. These initial efficiency standards focused on the "low-hanging fruit"—major residential appliances (e.g., refrigerators, air conditioners, water heaters, washers and dryers, etc.) as well as the most common commercial equipment (e.g., fluorescent lamps, motors, furnaces, etc.) Since then, technology and programmatic advances provide the opportunity to extend the standards programs to additional products that are now "ripe" for harvest of energy/economic savings. These developments include widespread availability of more advanced products; work on new standards by Canada and several states in the United States; development of ENERGY STAR® specifications for many products; updates of key industrial standards; and additional research on the energy savings potential, usage, and cost of these products.

While the efficiency standards established to date have provided significant energy and economic savings, the United States is still experiencing overall growth in energy demand and an increasingly tight supply. Many other regions might become "the next California"—the Northwest, Northeast, Midwest, and South currently face tight supply/demand balances and might face electricity shortages in the next few years. Savings from new products that are now "ripe" for appliance and efficiency standards could reduce the need for additional power plants and ease electric load on already stressed transmission lines and transformers, significantly contributing to improved system reliability.

In this report we describe opportunities for state governments and the federal government to set minimum-efficiency standards for 13 appliances and other types of equipment currently not covered by federal legislation. These are furnace, air conditioner, and heat pump fans[1]; ceiling fans; consumer electronics (standby power); residential torchiere lamps; commercial unit and duct heaters; distribution transformers; commercial food service refrigerators and freezers; refrigerated vending machines; traffic signals; exit signs; commercial clothes washers; commercial ice-makers; and large packaged air conditioners.

Table ES.1 summarizes the potential for energy and economic savings from adopting national minimum-efficiency standards for the above 13 products. Table ES.2 shows the potential peak load and emission reductions from adopting these standards.

[1] We generically refer to these fans as "furnace fans."

Table ES.1 Estimated Energy Savings and Economics of Proposed New Standards

Products	Effective Date (year)	National Energy Savings in 2010 (TWh)	National Energy Savings in 2010 (tril. Btu)	National Energy Savings in 2020 (TWh)	National Energy Savings in 2020 (tril. Btu)	NPV for Purchases Thru 2020 ($million)	Benefit-Cost Ratio
Furnace, A/C, & heat pump fans	2008	12.2	124.7	61.1	609.2	28,300	7.8
Consumer electronics (standby power)	2005	25.5	259.9	32.4	323.1	16,128	5.7
Ceiling fans	2008	7.4	75.1	29.4	293.3	8,074	2.8
Torchiere lamps	2005	10.6	108.0	19.3	191.9	7,658	3.4
Commercial unit and duct heaters	2005	NA	53.1	NA	149.7	4,241	6.2
Dry type transformers	2005	1.9	19.7	5.4	54.1	2,796	5.8
Beverage vending machines	2008	1.2	12.1	4.0	40.0	1,198	4.5
Commercial refrigerators & freezers	2005	1.9	19.9	3.2	31.8	1,375	6.8
Traffic signals	2005	1.0	9.8	2.6	26.2	710	2.6
Exit signs	2005	0.8	8.5	2.3	23.3	1,179	7.5
Commercial clothes washers	2008	0.7	6.8	2.1	21.3	2,000	6.7
Beverage merchandisers	2008	0.6	6.1	2.0	20.2	621	5.1
Ice-makers	2005	1.1	10.9	1.7	16.5	564	3.0
Large packaged A/C equipment	2008	0.3	2.9	1.4	14.2	387	3.4
TOTAL		65	717	167	1,815	75,231	5.0

Note: Net benefits are NPV benefits minus NPV costs.

Table ES.2 Estimated Summer Peak Load and Pollutant Reductions from New Standards

Products	Summer Peak Load Reduction in 2010 (GW)	Summer Peak Load Reduction in 2020 (GW)	Carbon Reduction in 2020 (MMT)	NOx Reduction in 2020 (1000MT)	SOx Reduction in 2020 (1000MT)	PM10 Reduction in 2020 (1000MT)
Furnace, A/C, & heat pump fans	5.42	27.10	11.65	34.91	160.91	1.77
Consumer electronics (standby power)	3.44	4.38	6.18	18.52	85.36	0.94
Ceiling fans	2.36	9.42	5.61	16.81	77.48	0.85
Torchiere lamps	3.39	6.16	3.67	10.99	50.68	0.56
Commercial unit and duct heaters	-	-	2.21	6.26	0.04	0.51
Dry type transformers	0.36	1.00	1.04	3.10	14.30	0.16
Beverage vending machines	0.38	1.29	0.77	2.29	10.58	0.12
Commercial refrigerators & freezers	0.62	1.02	0.61	1.82	8.39	0.09
Traffic signals	0.13	0.35	0.50	1.50	6.91	0.08
Exit signs	0.11	0.32	0.45	1.34	6.16	0.07
Commercial clothes washers	0.21	0.69	0.41	1.22	5.63	0.06
Beverage merchandisers	0.19	0.65	0.39	1.16	5.32	0.06
Ice-makers	0.34	0.53	0.32	0.94	4.35	0.05
Large packaged A/C equipment	0.28	1.38	0.27	0.81	3.75	0.04
TOTAL	17.2	54.3	34.1	101.7	439.9	5.3

These new standards would save 167 terawatt-hours (TWh) of electricity and over 1.8 quads of primary energy in the year 2020, while generating $75 billion in net savings for consumers and business owners for equipment purchased through 2020. The electricity savings amounts to 5% of projected residential and commercial sector U.S. electricity use in 2020. Stated another way, these standards could reduce projected growth in residential and commercial electricity use over the next 2 decades by nearly 20%. The primary energy savings from new standards is well over one-third the savings from all existing federal standards, with an overall benefit-to-cost ratio of 5 to 1—far better than the 3 to 1 ratio for existing standards. These standards are also incredibly cost-effective from a government perspective, with net benefits probably on the order of 1,000 times greater than government expenditures.

Another significant benefit from appliance standards is their impact on summer peak load. We estimate that the proposed standards would save a total of over 54 gigawatts (GW) of power in the year 2020. This is roughly equal to the generating capacity of 180 average power plants (i.e., 300 MW each).

Emissions reductions from the reduced energy consumption would also be significant. In the year 2020, over 34 million metric tons (MMT) of carbon could be reduced, which is equivalent to the annual carbon emissions from over 27 million "average" passenger cars. In addition to carbon, emissions could be reduced significantly for smog-forming nitrogen oxides (NOx), sulfur oxides (SOx; the main component of acid rain), and fine particulate matter.

Clearly, significant savings potential exists for these products at a small increase in first cost, resulting in large energy savings, economic savings, peak load reductions, and emission reductions over the life of the equipment.

Given these benefits, we recommend that states and/or the federal government adopt new efficiency standards on these projects. For most of these, this report provides specific language and recommendations that can be used to craft the appropriate legislation and regulations.

8

CLEAN ENERGY BLUEPRINT

A Smarter National Energy Policy for Today and the Future

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WITH
AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY
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The Union of Concerned Scientists is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions.

The UCS Clean Energy Program examines the benefits and costs of the country's energy use and promotes energy solutions that are sustainable both environmentally and economically.

More information about UCS and the Clean Energy Program is available at the UCS site on the World Wide Web, at *www.ucsusa.org.*

The American Council for an Energy-Efficient Economy is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. Further information can be found at *www.aceee.org.*

The Tellus Institute is a nonprofit research and consulting organization that analyzes evolving environmental problems and evaluates options for technological and institutional change. Further information can be found at *www.tellus.org.*

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Preliminary results of a partial set of scenarios presented in this full analysis were released in June 2001 as *Clean Energy Blueprint, Phase I.*

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Executive Summary

Can America develop a balanced portfolio of clean energy solutions that will stop wasting energy and also develop diverse, domestic energy supplies to increase energy security?

Can America develop an energy system that will save consumers money, provide security and jobs, and leave a heritage of clean air, clean water, and pristine wilderness?

Can the United States restore international good will and credibility by reducing carbon dioxide emissions that threaten to destabilize the global climate?

This report demonstrates that the answer to those questions is "Yes."

The Union of Concerned Scientists, with assistance from the American Council for an Energy-Efficient Economy and the Tellus Institute, investigates the costs and benefits of a Clean Energy Blueprint to promote diversity in energy production and energy conservation. We also examine a subset of Clean Energy Blueprint policies included in the Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333). We compare our results with the business-as-usual forecast of the US Energy Information Administration. That forecast underlies the administration's proposal, as part of a National Energy Policy, to develop 1,300 new power plants by 2020.

We find that the United States can

- meet at least 20 percent of its electricity needs by renewable energy sources—wind, biomass, geothermal, and solar—by 2020
- save consumers a total of $440 billion by 2020, with annual savings reaching $105 billion per year or $350 for a typical family
- reduce the use of natural gas by 31 percent and coal by nearly 60 percent compared to business as usual by 2020, and save more oil in 18 years than can be economically recovered from the Arctic National Wildlife Refuge in 60 years
- simultaneously avoid the need for 975 new power plants (300 megawatts each), retire 180 old coal plants (500 MW each), retire 14 existing nuclear plants (1,000 MW each), and reduce the need for hundreds of thousands of miles of new gas pipelines and electricity transmission lines
- reduce carbon dioxide emissions by two-thirds from business as usual by 2020, while also reducing harmful air emissions of sulfur dioxide and nitrogen oxides by more than 55 percent

What Is the Clean Energy Blueprint?

The Clean Energy Blueprint is a suite of policies to increase energy efficiency and renewable energy:

- **A renewable portfolio standard** would require utilities to increase nonhydropower renewable energy from about 2 percent today to 20 percent by 2020.
- **A public benefits fund** would be created by a 0.2 cent per kilowatt-hour (kWh) charge on electricity, equivalent to about $1 per month for a typical household. It would be used to match state programs for energy efficiency, renewable energy, research and development, and low-income customer protection.
- **Production tax credits** of 1.7 cents per kWh for renewable energy would be extended and expanded to cover all clean, nonhydro renewable resources, helping to level the playing field with fossil fuel and nuclear generation subsidies.
- **Net metering** would treat fairly those consumers who generate their own electricity with renewable energy systems by allowing them to feed surplus electricity back to the grid and spin their meters backward.
- **Research and development** spending on renewable energy and efficiency would increase 60 percent over three years to levels recommended by the president's committee of advisors on science and technology in 1997.
- **Combined heat and power:** Incentives would be provided and regulatory barriers removed for power plants that produce both electricity and useful heat at high efficiencies.
- **Improved efficiency standards:** National minimum efficiency standards would be established for a dozen products, generally to the level of good practices today. In addition, existing national standards would be revised to levels that are technically feasible and economically justified.
- **Enhanced building codes:** States would adopt model building codes established in 1999/2000, as well as new more advanced codes established by 2010.
- **Tax incentives** would promote efficiency improvements for buildings and equipment beyond minimum standards.
- **Industrial energy efficiency measures:** Industry would improve its efficiency by 1 to 2 percent per year through voluntary agreements, incentives, or national standards.

Our analysis uses the US Energy Information Administration's NEMS computer model. We based our business-as-usual scenario on *Annual Energy Outlook 2001* (EIA, 2000), the EIA's long-term forecast of US energy supply, demand, and prices. The UCS analysis removes the EIA's artificial constraints on renewable energy growth, consistent with a recent analysis by the Interlaboratory Working Group, the five national laboratories that do energy research. Additional adjustments were made as necessary to update assumptions to use the most recent data available. Most importantly, the IWG examined a renewable portfolio standard of 7.5 percent by 2010. The Blueprint increases the standard to 10 percent by 2010 and extends it to 20 percent by 2020. In addition, it uses more advanced energy-efficiency measures developed by the American Council for an Energy-Efficient Economy.

The Clean Energy Blueprint Creates a More Diverse Energy Supply

Under business as usual, and under the administration's National Energy Policy, the United States needs to build at least 1,300 new power plants by 2020. Natural gas use would increase from 16 percent to 36 percent over that period, and coal use would increase by 21 percent. Renewable electricity (not including hydropower) would increase from 2 percent today to only 2.4 percent by 2020.

Under the Clean Energy Blueprint, total energy use would be 19 percent lower than business as usual by 2020 and only 5 percent higher than 2000 levels, due to increased energy efficiency in homes, offices, and factories. Natural gas use would be 31 percent less than business as usual by 2020. Oil use would be reduced by 5 percent, saving over 400 million barrels per year by 2020. More oil would be saved over the next 18 years than is economically recoverable from the Arctic National Wildlife Refuge over 60 years. Coal use would be reduced by nearly 60 percent.

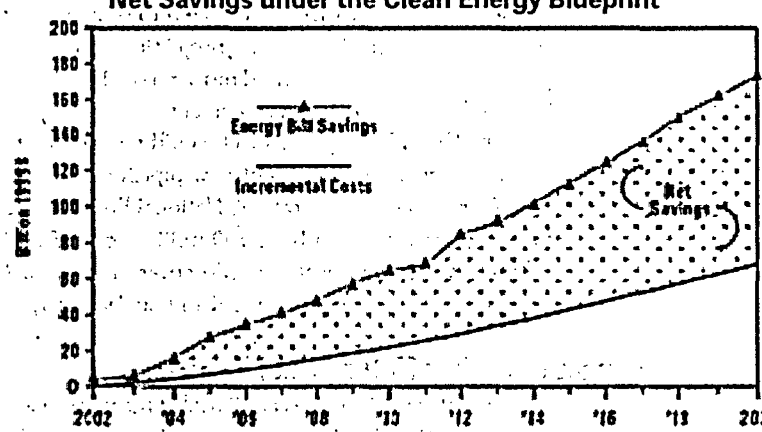
Nonhydro renewable energy sources (wind, biomass, geothermal, and solar) would produce 20 percent of the nation's electricity by 2020. Energy efficiency measures would offset projected growth in electricity use. Combined heat and power plants would meet 39 percent of commercial and industrial electricity needs. Thus, the Clean Energy Blueprint would replace 975 of the 1,300 new power plants the National Energy Policy says we need by 2020, and retire 180 existing coal plants and 14 nuclear plants.

The Clean Energy Blueprint Saves Consumers Money

Under the Clean Energy Blueprint, net energy savings would grow to $105 billion per year by 2020, totaling $440 billion between 2002 and 2020. (Total savings between 2002 and 2020 are in 1999 dollars using a 5 percent real discount rate.) A typical family would save $350 per year in lower energy bills by 2020.

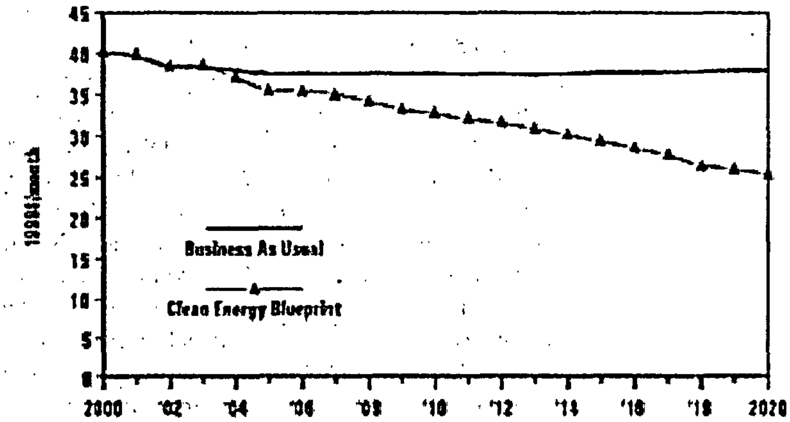
Monthly electricity bills for a typical household would decline from about $40 per month in 2000 to about $25 per month in 2020 under the Clean Energy Blueprint;

Net Savings under the Clean Energy Blueprint[a]



a. Net savings equal energy bill savings minus incremental costs. Energy bill savings include energy savings to consumers due to installing energy-efficient technologies and lower prices for certain fuels (mainly natural gas), minus the costs of Blueprint policies included in electricity prices. Incremental costs include the direct costs of purchasing energy-efficient technologies by consumers annualized over the life of the equipment and the costs of administering and implementing Blueprint policies not directly reflected in consumer energy bills.

Typical Household Electricity Bill[a]



a. The business-as-usual scenario assumes a typical household uses 500 kWh/month on average. Residential electricity use is 39 percent lower in 2020 under the Clean Energy Blueprint than business as usual due to energy efficiency measures. Savings presented do not include the cost of implementing the efficiency measures, but do reflect the impacts of slightly higher electricity prices than business as usual.

as opposed to $38 per month under business as usual. Consumers spending these savings on goods and services other than energy would provide an important boost to the US economy.

The Blueprint's efficiency and renewable energy policies reduce natural gas prices by 27 percent by 2020, saving businesses and homes that use natural gas nearly $30 billion per year.

The Clean Energy Blueprint Reduces Damage to the Environment

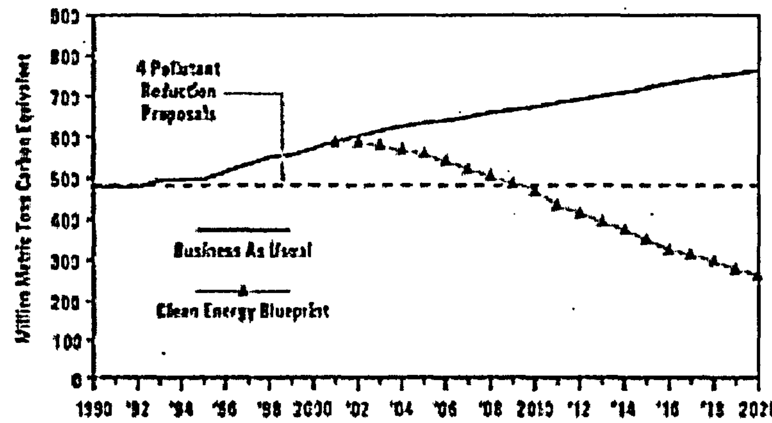
The Clean Energy Blueprint would reduce power plant carbon emissions—which are heating up the earth and threaten to destabilize the climate—two-thirds by 2020 compared to business-as-usual projections. Sulfur dioxide emissions, which are the primary cause of acid rain, and nitrogen oxide emissions, a major cause of smog, would both be reduced more than 55 percent.

The Clean Energy Blueprint would reduce the "need" to drill for natural gas and to build over 300,000 miles of new pipelines and 7,000 miles of new power lines, as called for in the administration's National Energy Policy. It would also reduce the need to mine, transport, and burn 750 million tons of coal per year by 2020 compared to business-as-usual projections. Moreover, energy efficiency and renewable energy can be increased faster than new fossil and nuclear energy supplies could be developed.

Impact of Higher Natural Gas Prices

Recent experience has emphasized the volatility of natural gas prices, which is not reflected in the EIA's business-as-usual projections. We examined a scenario in which gas prices are 20 percent higher than under business as usual. We found that annual savings from the Blueprint would reach nearly $132 billion per year by 2020. Over the entire period between 2002 and 2020, cumulative energy bill savings exceed the incremental costs by nearly $500 billion.

Power Plant Carbon Dioxide Emissions



The Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333)

S. 1333 (Jeffords, I-VT) includes some of the most important Clean Energy Blueprint policies: a renewable portfolio standard, a public benefit fund, and net metering. By 2020, S. 1333 would significantly increase the use of wind, biomass, geothermal and solar generation, while reducing coal use 24 percent compared to business as usual. S. 1333 calls for 75 percent more of these renewables than does the Clean Energy Blueprint because it assumes a higher electricity demand and does not increase combined heat and power systems.

Combined with increased research and development, S. 1333 would save consumers a total of $70 billion between 2002 and 2020, with savings reaching $35 billion per year by 2020. Under a higher-gas-price scenario, cumulative savings would reach $130 billion between 2002 and 2020. Monthly bills for a typical household would decline from about $40 per month in 2000 to $34 per month in 2020, as against $38 per month under business as usual and $25 per month under the Clean Energy Blueprint.

Carbon dioxide emissions from power plants would be nearly one-third lower than under business as usual by 2020, while sulfur dioxide emission levels would be 8 percent lower and nitrogen oxide emissions 15 percent lower. The Clean Energy Blueprint, however, would reduce both by more than 55 percent.

Energy efficiency and renewable energy technologies are ready to serve us. Now we need vision, leadership, and determination to provide a clean, affordable energy future.

CHAPTER 1

THE NEED FOR NATIONAL ENERGY POLICY

Can America develop a national energy system that will provide security and jobs, and also leave a heritage of clean air, clean water, and pristine wilderness areas for the children and grandchildren?

Can the United States increase international good will and credibility by reducing carbon dioxide emissions that threaten to destabilize the global climate, and also have economic growth?

Can the country plan for the long term and also respond to immediate problems and meet short-term energy needs?

Can the nation develop a truly balanced portfolio of clean energy solutions that will stop wasting energy and also develop diverse, domestic energy supplies that can reduce its dependence on energy imports?

The Union of Concerned Scientists, with assistance from the American Council for an Energy-Efficient Economy and the Tellus Institute, explores these questions in this report. We used the US Energy Information Administration's National Energy Modeling System to analyze the costs and benefits of a suite of proposals to

- increase the use of domestic renewable energy sources
- save electricity and fossil fuels by using more efficient energy technologies in homes, businesses, and industry

The administration launched a national debate on energy policy when it released the National Energy Plan last spring (NEPDG, 2001). According to that plan, "America in the year 2001 faces the most serious energy shortage since the embargoes of the 1970s."

Can America develop an energy system that provides security and jobs, and also leaves a heritage of clean air, clean water, and pristine wilderness areas?

Energy prices had increased sharply after a long period of decline. Americans were facing higher prices for natural gas, electricity, and gasoline. California faced a genuine power crisis, with periodic rotating blackouts and wholesale electricity prices ten times higher than in previous years.

The National Energy Plan proposed building 1,300 to 1,900 new electric power plants over the next 20 years—one to two plants every week—along with hundreds of thousands of miles of new gas pipelines and power lines. It recommended many measures—including rolling back environmental and siting rules and exploiting the Arctic National Wildlife Refuge—to develop additional fossil fuel supplies, revive the nuclear industry, and build new pipelines, power lines, and power plants (NEPDG, 2001).

By September 2001, however, fuel price spikes have largely subsided. Widespread blackouts from inadequate power supplies did not occur in California or elsewhere during the summer of 2001. The Federal Energy Regulatory Commission capped wholesale power prices in the Western electricity grid, and prices declined to more typical levels. Media stories shifted from energy shortages to predictions of energy gluts.

In the interim, the US House of Representatives passed the Securing America's Future Energy Act of 2001. The act included a number of tax credits for energy conservation and renewable technologies. But the combined tax breaks for fossil fuel production and distribution, nuclear generation, and electricity transmission are much greater than the tax breaks for clean energy sources, including over $3 billion in tax credits for "clean coal" technologies (JCT, 2001). The House also voted to open the Arctic National Wildlife Refuge to oil drilling.

In this report, we analyze a package of the strongest energy efficiency and renewable energy policies Congress is considering.

Neither the administration nor the House of Representatives has presented a comprehensive analysis of the costs and benefits or the environmental impacts of their plans. Nor have they examined the costs and benefits of many proposals for expanded investments in energy efficiency and renewable energy.

Ironically, the National Energy Plan extols the progress America has made in improving energy efficiency and developing clean renewable energy sources. It acknowledges that, without the efficiency improvements made since 1973, the US economy would need 30 to 50 percent more energy than it does today. The plan also notes that the cost of making electricity with solar or wind power has decreased more than 80 percent (NEPDG, 2001). Indeed, wind and solar are the fastest growing energy sources in the world, but America is losing its leadership position in the clean energy technologies that it developed.

The National Energy Plan provides no benchmarks, goals, or standards for increasing renewable energy (not including hydropower) beyond 2.8 percent of electricity by 2020, from 2 percent today. While the administration has said that the 2.8 percent figure does not represent its renewable energy goal, it has not yet met the challenge of stating an alternative goal or of supporting the policies that would achieve one.

The administration has also rejected the Kyoto Protocol, an agreement by 170 nations to reduce carbon dioxide emissions, the principal greenhouse gas that threatens to destabilize the climate. It has promised but not yet produced a plan to reduce domestic carbon emissions. The electricity sector is the largest source of such emissions, producing over 40 percent of the US total.

Secretary of Energy Spencer Abraham has challenged critics of the administration's energy policy to produce an alternative energy plan (Lobsenz, 2001). This report proposes such a plan: the Clean Energy Blueprint. We describe and analyze a package of the strongest energy efficiency and renewable energy policies Congress is considering, plus several others. We assess their direct costs, energy savings, and impacts on air emissions of carbon dioxide, sulfur dioxide, and nitrogen oxides.

Because fossil fuel prices are volatile, we also consider the costs and benefits of the policies under higher natural gas prices than the US Energy Information Administration's most recent forecast. Finally, we assess the costs and benefits of the Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333), the most comprehensive clean energy bill being considered in the 107th Congress.

CHAPTER 2

THE CLEAN ENERGY BLUEPRINT

UCS and its co-authors analyzed a set of policies that includes standards and incentives to increase investment in clean energy by consumers and the electricity sector and to help overcome existing market barriers that currently slow investment. UCS has analyzed transportation efficiency policies in a separate report, *Drilling in Detroit* (UCS, 2001). The analysis reported here examines the following 10 renewable energy and energy efficiency policies:

- renewable portfolio standard
- public benefits fund
- net metering
- production tax credit
- increased R&D funding
- combined heat and power
- improved efficiency standards
- enhanced building codes
- energy efficiency tax incentives
- industrial energy efficiency measures

We also analyzed the impacts of a subset of the Blueprint policies included in the Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333)—the renewable portfolio standard, public benefits fund, and net metering—plus increased R&D funding for renewable energy.[1]

UCS has previously described the renewable energy technologies and policies, and how they work, in *Powerful Solutions: Seven Ways to Switch America to Renewable Electricity* (Nogee et al., 1999). ACEEE has discussed the efficiency policies in detail in *Smart Energy Policies: Saving Money and Reducing Pollutant Emissions Through Greater Energy Efficiency* (Nadel and Geller, 2001).

Renewable Portfolio Standard

Under a renewable portfolio standard (RPS), all retail electricity providers must supply a growing percentage of electricity from renewable energy sources. By using

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[1] Congress is poised to maintain the renewable energy R&D budget and could increase it by as much as 16 percent this year, despite the administration's proposed funding cuts of 50 percent to solar, wind, and geothermal R&D. We assume that if Congress enacts the policies in S. 1333, increased R&D funding will continue to be necessary to help lower the cost and improve the performance of technologies that are competing to meet the RPS, as well as to make higher-cost emerging technologies better able to compete for the RPS and broader market share.

tradable "renewable energy credits," the RPS achieves compliance at the lowest cost. The RPS would function in much the same way as the Clean Air Act emission allowance trading system, which lowers the cost of compliance with air pollution regulations. This market-based approach provides the greatest amount of clean power for the lowest price and creates an ongoing incentive to drive down costs. Twelve states have enacted minimum renewable energy standards.

The Clean Energy Blueprint includes a national RPS of 2 percent in 2002, growing to 10 percent in 2010 and 20 percent in 2020, using wind, biomass, geothermal, solar, and landfill gas energy sources. This standard is similar to the one proposed by Senators James Jeffords (I-VT), Diane Feinstein (D-CA), Joseph Lieberman (D-CT), John Kerry (D-MA), Charles Schumer (D-NY), and Olympia Snowe (R-ME) in the Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333).

Public Benefits Fund

The public benefits fund (sometimes called system benefit fund) is a small surcharge on electricity bills used to fund energy efficiency, renewable energy, low income assistance, and research and development for new technologies that benefit the public. The fund helps ensure that existing clean energy efforts can continue to operate and provides incentives for new energy efficiency initiatives and renewable energy development. Traditionally, state regulators required electric utilities to collect funds and implement programs. However, utilities cut these programs in half between 1993 and 1998 as several states began to implement and consider electricity restructuring. To date, 19 states have adopted new public benefits programs, while several others continue to implement utility-based programs.

The public benefits fund provides incentives for new energy efficiency initiatives and renewable energy development.

The Clean Energy Blueprint includes a small federal charge of up to two-tenths of a cent ($0.002) per kilowatt-hour (equivalent to $1 per month for a typical household), collected from all electricity customers. This charge provides matching funds to states to implement energy efficiency, renewable energy, research and development, and low income energy programs. We based the public benefits fund in the Clean Energy Blueprint on the proposal in S. 1333.

Net Metering

Net metering allows consumers who generate their own electricity from renewable technologies (e.g., a rooftop solar panel or small wind turbine) to feed excess power directly back into the electricity system, thereby running their electricity meters backward. Net metering customers are billed only for the net electricity consumed. This policy encourages the direct use of renewable resources by making the investment more cost-effective for individual consumers. Electricity providers also benefit from net metering, because it reduces the need to build costly new power lines and the demand for electricity during peak load periods. This is particularly true for rooftop solar systems, which work best on hot sunny days when the demand for power is typically high. Thirty-four states currently have net metering policies.

The Clean Energy Blueprint includes net metering implemented nationally, as proposed in S. 1333. Eligible renewable energy systems are those that produce 100 kilowatts or less using wind, solar, biomass, or geothermal energy sources. They must be located on the customer's premises and used to offset some or all of the electricity the customer uses. In addition, they must be connected to the transmission and distribution system.

Production Tax Credit

Most renewable energy technologies are more capital intensive than competing conventional technologies. While higher up-front costs and lower operating costs make the long-term prices of renewable energy more stable and predictable, they also tend to discourage investment in these technologies. Several studies have shown that renewable technologies pay considerably more in property taxes and financing costs than fossil fuel facilities in states that do not have explicit tax policies that overcome this inequity (e.g., Hadley, Hill, and Perlack, 1993). Other studies have found that fossil fuel and nuclear generation have received much higher tax subsidies than renewable technologies (e.g., Goldberg, 2000, and Sissine, 1994). The production tax credit helps to overcome these inequities by allowing facility owners to receive a tax credit based on the amount of renewable electricity they produce.

Currently, new facilities that use wind, biomass crops grown for energy, or poultry litter receive a tax credit of 1.7 cents per kWh for 10 years. Although the production tax credit is set to expire at the end of 2001, the US House of Representatives voted to extend these credits through 2006. The House also expanded eligibility to include facilities that use landfill gas and other forms of biomass and organic wastes in the Securing America's Future Energy (SAFE) Act of 2001.

The Clean Energy Blueprint extends the 1.7 cents per kWh production tax credit through 2006 and expands eligibility to include geothermal, solar, landfill gas, and other forms of biomass and organic wastes, for facilities coming on line after December 31, 2001. Biomass cofiring in existing coal plants becomes eligible for a production tax credit of 1.0 cent per kWh.

Increased R&D Funding

Investment in research and development is essential for commercializing renewable energy and energy-efficient technologies. R&D brings advances in performance and lowers the cost of emerging technologies. The Clean Energy Blueprint assumes a three-year ramp-up in federal R&D spending on renewable energy and energy efficiency from fiscal year 2001 (FY01) levels to the total long-term funding levels recommended in a 1997 report by the President's Committee of Advisors on Science and Technology (PCAST, 1997). For renewable energy technologies, we project total R&D funding for DOE's programs to increase from $375 million in FY01 to $652 million in FY05, a 74 percent increase. For energy efficiency, we project total R&D funding for DOE's programs and EPA's Energy Star Program to increase from $600 million in FY01 to $900 million in FY05, a 50 percent increase. We also assume that FY05 funding levels continue through 2020 and are matched by industry through investments in new equipment. This approach is consistent with the increase recommended in the advanced scenario in the 2000 study by five national energy laboratories, *Scenarios for a Clean Energy Future* (IWG, 2000).

The Clean Energy Blueprint increases R&D funding by $575 million a year.

In contrast, the Bush administration's budget proposed cutting R&D spending on wind, geothermal, and solar energy, and certain energy efficiency programs by about 50 percent. Congress, however, is expected to increase funding for efficiency and renewable energy by about 10 percent in FY2002.

Combined Heat and Power

Combined heat and power (CHP) systems produce both heat and electricity for a facility (and potentially the surrounding community) from a single source of fuel. These economical and highly efficient technologies conserve fuel by recovering and utilizing heat that is normally wasted in conventional systems. Some CHP technologies can reach efficiency levels of greater than 80 percent compared to the 33 percent average for conventional facilities (USCHPA, 2001).

Although CHP systems account for over 8 percent of the electricity generated in the United States, significant barriers prevent the technology from reaching its full potential. For example, current environmental standards do not recognize the efficiency gains that CHP systems realize compared to conventional systems. Further, many prospective CHP projects seeking to interconnect with the electricity grid face discriminatory pricing practices and technical hurdles created by uncooperative utilities. To reduce these barriers, the Clean Energy Blueprint establishes a standard permitting process, uniform tax treatment, accurate environmental standards, and fair access to electricity consumers.

The Blueprint also includes a 10 percent investment tax credit (or a shortened depreciation period of 7 years for industrial systems and 10 years for building systems) for CHP systems achieving efficiency improvements of 60 to 70 percent, depending on the size of the system. This proposal is also included in a Senate bill soon to be introduced by Senator Jeff Bingaman (D-NM). The House of Representatives included a 10 percent investment tax credit for combined heat and power property in the SAFE Act of 2001, but the House bill also *lengthened* depreciation periods, substantially reducing the total incentive provided for CHP systems.

Improved Efficiency Standards

Federal appliance and equipment efficiency standards remove the most inefficient product models from the market while continuing to provide a full range of product options for consumers. Since their inception in 1987, efficiency standards have been one of the federal government's most effective energy-savings initiatives. ACEEE estimates that existing standards have already saved 2.5 percent of annual US electricity consumption and that these savings could rise to nearly 8 percent in 2020 (Geller, Kubo, and Nadel, 2001).

The Clean Energy Blueprint assumes that new or upgraded federal efficiency standards for several appliances and equipment types are put into place over the next five years. These include national standards equivalent to

- new California standards for torchiere lighting, exit signs, traffic lights, and commercial refrigerators
- Massachusetts and Minnesota standards for distribution transformers
- current federal commercial furnace standard extended to additional types of commercial heaters
- existing federal purchase specifications for ice makers

- energy use of 1 watt or less for standby power of consumer electronics such as televisions and VCRs, in line with President Bush's recent executive order for federal purchases

In addition, this policy assumes the 30 percent efficiency improvement established by the previous administration for air conditioning systems and heat pumps is maintained. In contrast, the current administration is seeking to roll back this standard to a 20 percent improvement.

Enhanced Building Codes

Building energy codes require that new residential and commercial buildings meet minimum energy efficiency criteria. This policy stimulates the widespread deployment of cost-effective efficiency technologies and practices in all new construction.

Under the Clean Energy Blueprint, the US Department of Energy would enforce the Energy Policy Act of 1992, which requires that all states meet or exceed the ASHRAE 90.1 commercial building codes. In addition, all states would upgrade their residential building codes to late 1990s standards either voluntarily or through a new federal requirement. Under the Blueprint, model energy codes would be continuously improved over the next decade, so that by 2010 all states would be enforcing mandatory standards that go significantly beyond current "good practice."

Tax Incentives

Many proven energy-efficient products experience difficulty gaining market share because of high production costs, consumer's lack of familiarity with the product, and entrenched competition. Temporary initial tax incentives help to surmount these barriers by attracting consumers to energy-efficient products that they could otherwise not afford. Tax incentives also encourage companies to mass-market innovative products. As the technology achieves a greater market share, costs decline and the tax incentive can be phased out.

The Clean Energy Blueprint includes tax incentives for a wide range of energy-efficient measures and products, including

- up to $2,500 for new houses that demonstrate 50 percent reductions in space heating and cooling costs compared to homes that meet the current Model Energy Code. The SAFE Act of 2001 includes tax credits for homes with 30 percent energy savings.
- $50–$100 for the manufacturers of high-efficiency refrigerators and clothes washers as is included in the SAFE Act of 2001.
- 20 percent investment tax credit for new high-efficiency building technologies, including air conditioners, heat pumps, stationary fuel cell power systems, and furnaces. The fuel cell provision is included in the SAFE Act of 2001, while the other provisions are found in a draft bill by Senator Bingaman.
- $2.25 per square foot tax deduction for commercial building and multifamily residential investments that result in at least 50 percent reductions in heating and cooling costs below the current ASHRAE model energy standards (these are included in the SAFE Act of 2001).

To prevent "free riders" and permanent subsidies, the tax incentives specify high eligibility criteria and limited duration.

Industrial Energy Efficiency Measures

The industrial sector can also benefit from many cost-effective opportunities to improve energy efficiency. For example, an analysis of 49 energy efficiency technologies for the iron and steel industry found a total cost-effective energy savings potential of 18 percent (Worrell, Martin, and Price, 1999). Voluntary agreements between the government and industry may be an effective means to achieve this potential (e.g., Kauffman, 1999, and Romm, 1999).

Under the Clean Energy Blueprint companies or industry sectors would identify opportunities for improving energy efficiency and pledge to reduce energy use by a meaningful percentage (1 to 2 percent annually) over a multiyear period. The federal government would encourage broad participation by offering to postpone new regulatory and tax proposals, provide technical and financial assistance, and increase federal R&D and demonstration programs. Should industries not adequately respond to federal initiatives to establish and meet energy efficiency goals, a mandatory energy-intensity standard could be implemented to ensure that those targets are met.

CHAPTER 3

OUR METHODS

UCS used the National Energy Modeling System (NEMS), a computer model maintained by the US Energy Information Administration, to compare the costs and benefits of the Clean Energy Blueprint described in Chapter 2 with business as usual.[2] The business-as-usual scenario is based on *Annual Energy Outlook 2001* (EIA, 2000a), the EIA's most recent long-term forecast of US energy supply, demand, and prices. The year 1999 is the last year of history in the model, which makes projections through 2020.

UCS used the National Energy Modeling System computer model to compare the costs and benefits of the Clean Energy Blueprint with business as usual.

UCS modified several NEMS assumptions for renewable energy in order to model these technologies more accurately and applied these modifications to both the business-as-usual scenario and the Clean Energy Blueprint. We used the changes to NEMS made by the Interlaboratory Working Group of the five national energy laboratories in *Scenarios for a Clean Energy Future* as the starting point for our analysis (IWG, 2000). The IWG removed or modified several NEMS assumptions that artificially constrain the growth and raise the cost of renewable energy technologies. These modifications are described in Appendix C-4 of the IWG document (IWG, 2000). Like the IWG study, UCS's analysis assumes that implementing the Clean Energy Blueprint will help remove market barriers and lower the cost of developing renewable energy over time.

We diverged from some of the IWG study's renewable energy assumptions in several respects:

- For wind energy, we conservatively assumed somewhat higher initial capital costs to conform to recent data and reduced the land area potentially available for development to account for additional siting restrictions.
- For geothermal energy, we assumed lower capital costs, based on recent experience. We also assumed a technical potential for geothermal energy that is over 40 percent lower than in the IWG study, based on recent EIA revisions to NEMS.
- For solar energy, we estimated that over 4,000 megawatts (MW) of grid-connected rooftop photovoltaic systems would be installed on homes and businesses throughout the United States by 2020 through a combination of net metering, R&D funding, public benefits funding, and the DOE Million Solar Roofs Program. We based this estimate on the 25 percent annual average growth scenario in the US Photovoltaics Industry Roadmap report (DOE, 2001).

[2] Tellus Institute performed the NEMS modeling for UCS.

- For biomass energy, we assumed that a maximum of 10 percent of the heat input of existing coal plants can be cofired with biomass, rather than up to 5 percent as in NEMS and the IWG study, based on recent experience with that technology. While the EIA estimate of available forest residues already excluded roadless areas, steep slopes, and more than half the remaining residues, we reduced the amount of potential forestry residues included in the NEMS model by half again to provide an extra margin against using unsustainable sources. We also excluded an additional 5 percent of construction and demolition debris, on top of the EIA's 75 percent exclusion, to provide an extra margin against using contaminated materials.

Perhaps most importantly, the IWG examined a set of policies in the electricity, buildings, and industrial sectors that were less extensive than the Clean Energy Blueprint policies. For example, the IWG study included a renewable portfolio standard (RPS) of 7.5 percent by 2010, with no subsequent renewable energy support. The Clean Energy Blueprint expands the RPS to 10 percent by 2010 and 20 percent by 2020. On the other hand, under the Blueprint, neither municipal solid waste nor black liquor (a biomass waste from the pulp and paper industry) are eligible for the RPS. The IWG assumed that all black liquor and over 60 percent of municipal solid waste would be eligible for the RPS.

Rooftop photovoltaic systems were the only technology included in NEMS that would be eligible for net metering. This limitation means that our analysis underestimates the potential renewable energy development that could occur through net metering of such technologies as small wind turbines, biomass methane digesters and gasifiers, and fuel cells using renewable fuels.

Our assumptions for the costs and energy savings resulting from policies to increase energy efficiency and use of combined heat and power systems in the residential, commercial and industrial sectors were based on a recent study by the American Council for an Energy-Efficient Economy (Nadel and Geller, 2001). The energy savings resulting from these policies are summarized in Table 1. We used this information to reduce electricity and fossil fuel use in NEMS. Then we ran the NEMS model to calculate reductions in electricity generation, fossil fuels, emissions, energy prices, and energy bills resulting from these policies. Overall, fossil fuel use by consumers would be 3.5 quadrillion Btu or 9 percent lower in 2020 than under business as usual.

Combined heat and power was modeled as an electricity demand reduction in the commercial and industrial sectors. This reduces fossil fuel use from central station power plants, but results in an increase in natural gas use in the commercial and industrial sectors, as shown in Table 1.[3] When fossil fuel savings from central station power plants are included, the new CHP capacity would result in a net energy savings of approximately 3 quadrillion Btu in 2020. This is because CHP is considerably more efficient than producing electricity and heat separately.

Forecasting natural gas prices under today's market conditions is a difficult task. Despite the recent drop from record levels this past year, the large increase in natural gas use for electricity generation projected by the EIA over the next 18 years is likely to put upward pressure on gas prices. The natural gas price forecast used in this analysis from the *Annual Energy Outlook 2001* version of NEMS did not predict the

[3] The reduction in fossil fuel use from central station power plants is not included in Table 1.

spike in natural gas prices that occurred over the past year. The forecast shows a smooth trajectory that does not correspond to the historic volatility in gas prices.

For this analysis, in addition to using EIA's gas price forecast, we also modeled the impact of higher gas prices on both the business-as-usual scenario and the Clean Energy Blueprint policies using assumptions from the EIA's Slow Technology Progress case in *Annual Energy Outlook 2001* (EIA, 2000a, p. 86). This case assumes a 25 percent reduction in the annual rates of technological progress and a 25 percent increase in costs of oil and natural gas supply technologies relative to business as usual. While we do not believe that technical progress in extracting oil and natural gas is necessarily likely to be slow, we believe this approach is a reasonable proxy for simulating the effects of higher gas prices that could result from increased gas supply constraints due to the projected increase in demand for gas to generate electricity.

Additional details of our methods and assumptions will be included in a technical appendix to this report released separately.

Table 1. Consumer Energy Savings from the Energy Efficiency and Combined Heat and Power Policies

Electricity Savings (billion kilowatt-hours)

Policy	2010	2020
Appliance Standards	119	317
Building Codes	22	100
Public Benefits Fund[a]	291	803
Industrial Measures	129	275
R&D Funding	59	187
Tax Incentives	25	52
Subtotal	645	1,734
Combined Heat and Power[b]	270	778
Total	915	2,512

a. Savings due to federal public benefits fund.
b. CHP was treated as a demand reduction in the electricity sector.

Fossil Fuel Savings[a] (quadrillion Btu)

Policy	2010	2020
Appliance Standards	0.13	0.47
Building Codes	0.10	0.47
Industrial Measures	2.33	4.13
R&D Funding	0.40	1.20
Tax Incentives	0.08	0.20
Subtotal	3.04	6.47
Combined Heat and Power[b]	-1.08	-3.00
Total	1.96	3.47

a. Includes direct consumer natural gas, oil, and coal savings from efficiency measures and CHP. Does not include additional coal and natural gas savings from central station power plants.
b. Represents the increase in natural gas use in the commercial and industrial sectors for CHP.

CHAPTER 4
WHAT WE FOUND

Below we present the results for two policy scenarios compared to the business-as-usual scenario. The first scenario illustrates the impacts of the full package of Clean Energy Blueprint policies. The second identifies the impacts of the subset of the Blueprint policies included in the Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333)—the renewable portfolio standard, public benefits fund, and net metering—plus increased R&D funding for renewable energy.

The findings of our analysis fall into five categories. First, we identify the impacts of the policy scenarios on total energy use. Second, we present the impacts of the policy scenarios on the generation and use of electricity. Third, we show the economic benefits of these policies. Fourth, we illustrate how those changes reduce power plant emissions. Last, we highlight the impact that higher natural gas prices would have on the policy and business-as-usual scenarios.

The Clean Energy Blueprint

Total Energy Use

Business as Usual. Under the business-as-usual scenario, the United States primarily increases its reliance on fossil fuels to meet the nation's growing appetite for energy (Table 2). Between 2000 and 2020, total US energy use grows over 30 percent, an average increase of 1.3 percent per year. Most of the 57 percent increase in natural gas use and 18 percent increase in coal use over the period is for generating electricity in new and existing power plants and to make up for the 24 percent decline in nuclear power. Almost all of the 33 percent increase in petroleum use over the period is for transportation. Hydropower remains relatively flat over time.

Other renewable energy sources, such as wind, biomass, geothermal and solar energy increase 57 percent between 2000 and 2020 (includes primary energy for electric and nonelectric use, see note a in Table 2), largely due to existing state policies. However, their share of total energy use increases only from 3.2 percent in 2000 to 3.8 percent in 2020, due to the increase in overall energy demand over this period.

Clean Energy Blueprint. Under the Clean Energy Blueprint, energy efficiency, combined heat and power, and renewable energy provide a much greater share of U.S. energy needs. By 2020, total energy use is 19 percent lower than business as usual and only 5 percent higher than 2000 levels. Wind, biomass, geothermal and solar energy use is more than twice as high as business as usual in 2020 and 3.4 times higher than 2000 levels (includes primary energy for electric and nonelectric use, see note a in Table 2), as these resources provide 20 percent of the nation's electricity by 2020.

The Clean Energy Blueprint policies result in a significant reduction in coal and natural gas use compared to business as usual. Total coal use is 58 percent lower than

Table 2. Total US Energy Use (quadrillion Btu)

Fuel	2000	2010 Business as Usual	2010 Clean Energy Blueprint	2020 Business as Usual	2020 Clean Energy Blueprint
Petroleum	38.1	44.4	43.4	50.6	48.3
Natural Gas	22.6	28.7	23.2	35.5	24.4
Coal	22.2	25.1	19.1	26.2	11.0
Nuclear Power	8.0	7.7	7.7	6.1	4.9
Hydropower	2.9	3.1	3.1	3.1	3.1
Other Renewables[a]	3.1	4.4	8.4	4.9	10.6
Other[b]	0.5	0.5	0.4	0.4	0.2
Total	97.4	114.0	105.3	126.8	102.5

a. Includes grid-connected electricity from wind, solar, geothermal, biomass, and landfill gas energy sources; and nonelectric energy from solar, wood, and ethanol included in ethanol/gasoline blends of 85 percent or more. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
b. Includes liquid hydrogen, methanol, supplemental natural gas, some domestic inputs to refineries, and municipal solid waste.

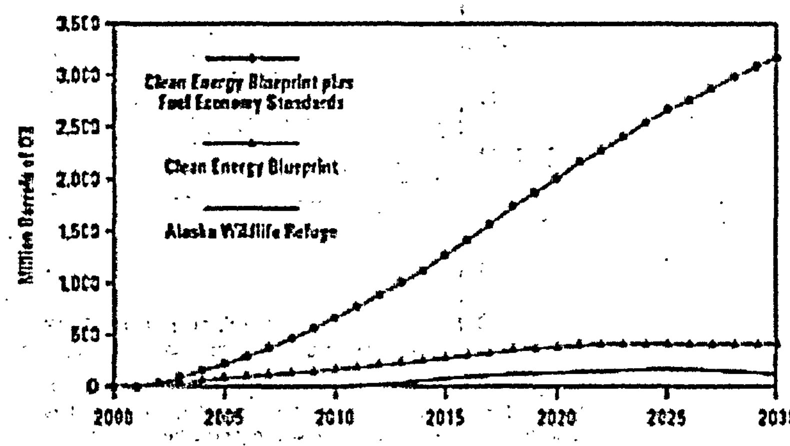
business as usual in 2020 and 50 percent lower than 2000 levels, as less coal is used to generate electricity and to a lesser extent for industrial energy needs. By 2020, the Clean Energy Blueprint would eliminate the need for mining, transporting, and burning 750 million tons of coal per year. It would take the equivalent of approximately 7.8 million train cars to transport this much coal across the country.

Total natural gas use is reduced by 11 quads (quadrillion Btu), or 31 percent, compared to business as usual in 2020, although it is still 8 percent higher than 2000 levels. Most of the reduction comes from eliminating the need for over 900 new conventional gas-fired power plants, due to investments in energy efficiency, renewable energy, and combined heat and power. Gas efficiency measures in homes and businesses also make an important contribution to the reduction. The Clean Energy Blueprint would eliminate the need for much of the 301,000 miles of new natural gas transmission and distribution pipelines projected under the administration's National Energy Policy (NEPDG, 2001).

Total US petroleum use would be 5 percent lower than business as usual in 2020, due to energy efficiency improvements in factories and buildings, and 27 percent higher than 2000 levels. By 2020, the Clean Energy Blueprint would save 410 million barrels of oil per year, or nearly 3 times more oil than the Arctic National Wildlife Refuge would be producing at $22 per barrel and if development were begun there today (Figure 1).[4] Cumulative oil savings under the Blueprint would reach over 4 billion

[4] Arctic Refuge production schedule is based on UCS estimates from *Drilling in Detroit* (UCS, 2001), using economically recoverable volume at projected world oil prices (USGS, 1998) and projected development rates (EIA, 2000b).

Figure 1. Oil Savings from Clean Energy Blueprint and Fuel Economy Standards vs. Potential Arctic Refuge Supply



barrels by 2020, which is 25 percent more oil than the US Geological Survey projects is economically recoverable from the Wildlife Refuge at this price (USGS, 1998). However, even if refuge oil began flowing in 2010, it could take up to 60 years to extract all of the oil at historic production rates.

The Clean Energy Blueprint does not include any oil savings from increased energy efficiency and renewable energy use in the transportation sector. Another recent UCS study has shown that fuel economy improvements in cars and light trucks would provide significant oil savings (UCS, 2001). If these savings were combined with the savings from the Clean Energy Blueprint, the United States would save more than 15 times the oil available in the Arctic Refuge at today's oil prices and total oil use would be 9 percent lower in 2010 and 23 percent lower in 2020 than under business as usual (Figure 1).

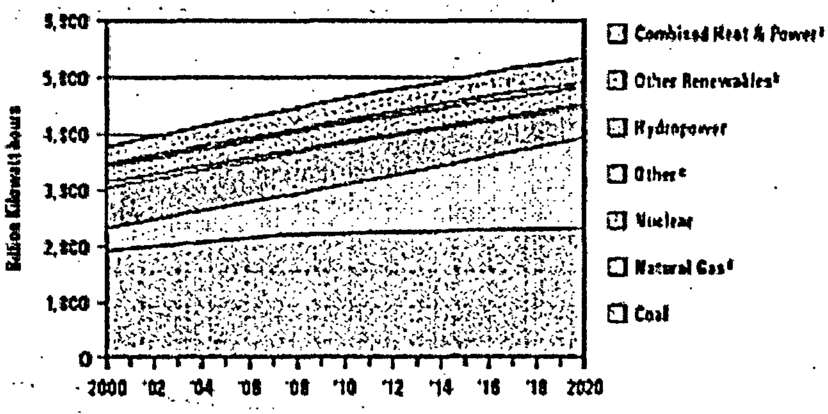
Electricity Generation and Use

Business as Usual. Under the business-as-usual scenario, the nation increases its reliance on coal and natural gas to meet strong growth in electricity use (Figure 2). As in the administration's National Energy Plan, electricity use increases by 42 percent between 2000 and 2020 due to significant under-utilization of energy-efficient technologies and practices. Meeting this increase in electricity use and replacing existing plants that retire would require the construction of nearly 1,300 power plants of average size (300 megawatts).

Under business as usual, natural gas fuels most of the new electricity generation, rising from 16 percent of today's total electricity generation (including combined heat and power) to 36 percent in 2020. Electricity generated from coal-fired power plants increases 21 percent between 2000 and 2020. Nuclear power generation declines by 23 percent over the same period, as the EIA's NEMS model predicts that some existing plants will be retired and no new plants will be built because they are not economically viable to operate relative to other new power plants. Electricity from hydropower plants remains unchanged from today's levels.

Electricity generated by renewable resources, including wind, solar, geothermal, biomass, and landfill gas (i.e., nonhydro renewable resources) more than doubles

Figure 2. Electricity Generation under Business as Usual

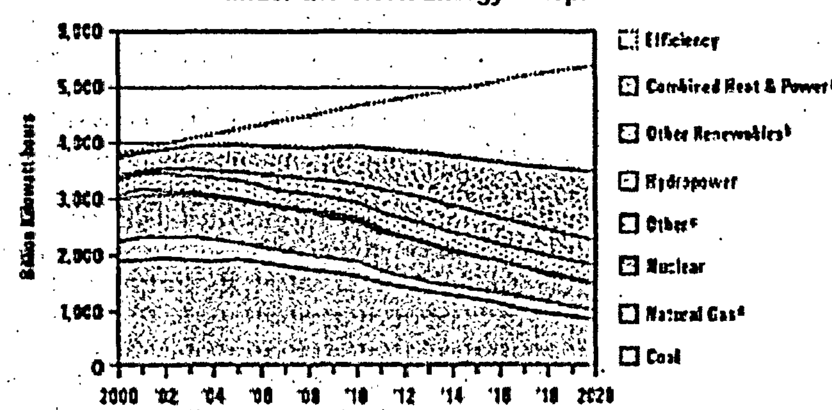


a. Over 71% of CHP generation comes from natural gas in 2020.
b. Includes wind, biomass, geothermal, solar, and landfill gas.
c. Includes oil, municipal solid waste, and other wastes.
d. Includes major stand-alone plants only.

between 2000 and 2020, largely due to state policies currently in place. However, because of increasing demand for electricity, the overall contribution of nonhydro renewable resources rises from today's 2.0 percent to only 2.4 percent of total generation in 2020.

Clean Energy Blueprint. Under the Clean Energy Blueprint, energy efficiency, combined heat and power (CHP), and renewable energy meet a much larger share of future electricity needs (Figure 3, Table 3). By 2020, energy efficiency measures, such as advanced industrial processes, and high efficiency motors, lighting, and appliances offset all of the growth in electricity use projected under business as usual. CHP provides 39 percent of commercial and industrial electricity needs by 2020. Largely because of the renewable portfolio standard (RPS), wind, biomass, geothermal, solar,

Figure 3. Electricity Generation and Efficiency under the Clean Energy Blueprint



a. Over 91% of CHP generation comes from natural gas in 2020.
b. Includes wind, biomass, geothermal, solar, and landfill gas.
c. Includes oil, municipal solid waste, and other wastes.
d. Includes major stand-alone plants only.

Table 3. Electricity Generation and Efficiency (billion kWh)

Source	2000	2010 Business as Usual	2010 Clean Energy Blueprint	2020 Business as Usual	2020 Clean Energy Blueprint
Coal	1,894	2,195	1,655	2,295	891
Natural Gas	399	899	250	1,569	177
Nuclear	748	720	718	674	450
Other[a]	90	44	36	48	31
Hydropower	286	290	299	298	297
Other Renewables					
Wind	5	12	92	13	176
Biomass[b]	19	33	141	36	147
Geothermal	13	27	75	28	87
Landfill Gas	6	13	18	17	29
Solar	1	2	2	3	13
Subtotal	46	63	328	97	451
Combined Heat and Power[c]	299	363	630	419	1,180
Efficiency	n.a.	n.a.	644	n.a.	1,735
Total	3,748	4,597	4,562	5,300	5,220

a. Includes oil, municipal solid waste, and other wastes.
b. Includes a small amount of combined heat and power from biomass sources that are assumed to be eligible for the RPS.
c. In 2020, natural gas constitutes over 91% of CHP generation under the Blueprint and over 71% under business as usual.

and landfill gas resources provide 10 percent of the nation's electricity by 2010 and 20 percent by 2020.

Energy efficiency, CHP, and renewable energy eliminate the need for 975 average (300 megawatt) new major gas and coal-fired power plants built under the business-as-usual scenario. However, nearly 225 new average-sized gas plants are still needed between 2000 and 2020, primarily to generate electricity for periods of high demand.

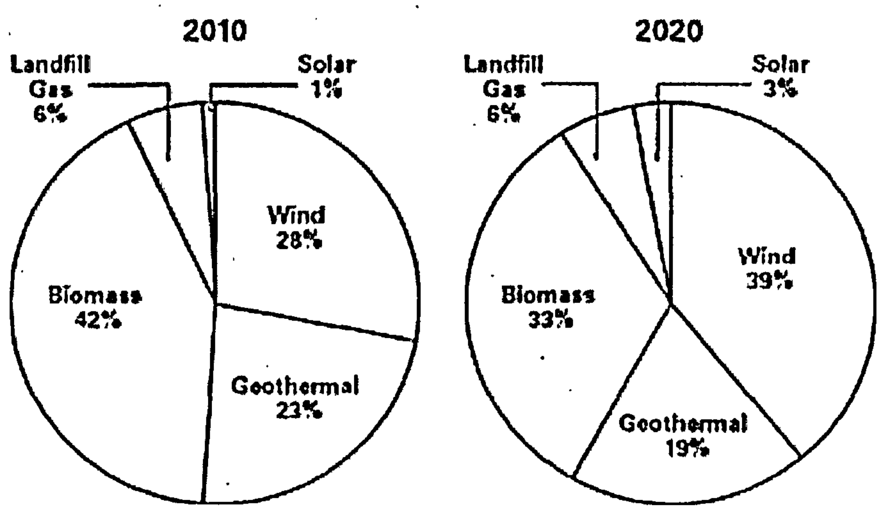
Energy efficiency, CHP, and renewable energy also displace the need for over 120,000 MW of existing power plant capacity, three-quarters of which are dirty coal-fired plants. This would lead to the retirement of approximately 180 average-sized coal plants (500 MW each). Coal-fired electricity generation is 61 percent below business as usual in 2020 and 53 percent lower than today's levels.

By 2020, natural gas consumption at major power plants is 89 percent lower than business as usual. However, when CHP plants are included, natural gas still fuels 36 percent of total electricity generation in 2020 under the Clean Energy Blueprint. Because of lower electricity demand and because natural gas is used both to generate electricity and to produce useful heat, overall natural gas generation is 33 percent lower than business as usual in 2020.

As in the business-as-usual case, hydroelectric generation continues at current levels. Nuclear generation declines by 39 percent between 2000 and 2020, compared to a 23 percent decline under business as usual, as 14 more average-sized nuclear power plants are retired (1,000 MW each).

Wind, biomass, and geothermal energy sources provide most of the nonhydro renewable energy generation under the Clean Energy Blueprint (Figure 4).

Figure 4. Renewable Energy Generation under the Clean Energy Blueprint



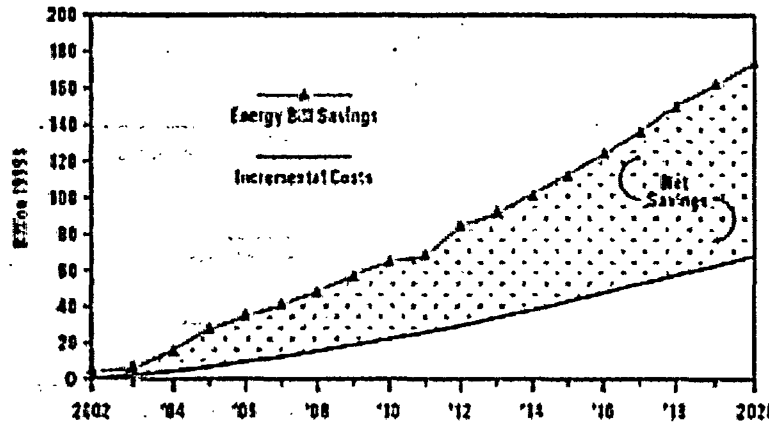
Economic Benefits

The Clean Energy Blueprint saves consumers money in two important ways. First, energy efficiency measures decrease energy use in homes, businesses, and industry. Second, using less energy overall and using more renewable energy sources puts downward pressure on the prices of fuels like natural gas used to generate electricity and for heating and industrial needs. Lower natural gas prices bring down the direct cost of gas to consumers, and bring down electricity prices as well.

The annual savings exceed the costs of the Clean Energy Blueprint in every year, growing to over $105 billion per year by 2020 (Figure 5). Over the entire period, between 2002 and 2020, cumulative energy-bill savings exceed the incremental costs of the Blueprint by nearly $440 billion.[5] The total savings would actually be greater than reported here, because the figures do not include additional net savings that would continue beyond 2020 from efficiency and renewable energy measures installed through that year. Another recent UCS study showed that fuel economy improvements in cars and light trucks could provide significant net economic benefits to consumers (UCS, 2001). If these savings were combined with the savings from the Clean Energy

[5] Net savings between 2002 and 2020 are in 1999 dollars using a 5 percent real discount rate.

Figure 5: Net Savings under the Clean Energy Blueprint[a]



a. Net savings equal energy bill savings minus incremental costs. Energy bill savings include energy savings to consumers due to installing energy-efficient technologies and lower prices for certain fuels (mainly natural gas), minus the costs of Blueprint policies included in electricity prices. Incremental costs include the direct costs of purchasing energy-efficient technologies by consumers annualized over the life of the equipment and the costs of administering and implementing Blueprint policies not directly reflected in consumer energy bills.

Blueprint, net savings to consumers would increase to over $150 billion per year by 2020 and $645 billion between 2002 and 2020.

Natural Gas Prices

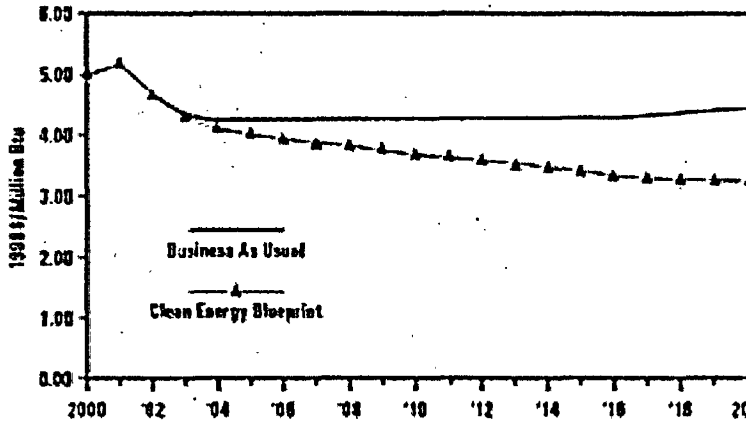
Lower natural gas prices contribute to the economic benefits of the Clean Energy Blueprint. The energy efficiency measures and renewable energy policies in the Clean Energy Blueprint reduce the demand for fossil fuels and thereby lower their prices. In particular, the large reduction in natural gas use for electricity generation, relative to business as usual, results in a significant reduction in projected natural gas prices for both consumers and electric generators. Total US natural gas use under the Clean Energy Blueprint is 11 quadrillion Btu or 31 percent lower than business as usual in 2020. This significant reduction in natural gas use produces average natural gas prices that are 27 percent lower in 2020 than business as usual (Figure 6).

These lower prices, combined with natural gas efficiency measures, would allow households and businesses that use natural gas for heating and industrial processes to save money on their gas bills starting in 2002. We project that savings grow to nearly $30 billion annually by 2020 under the Clean Energy Blueprint. Annual savings for a typical household that heats with natural gas (using 850 therms per year) would be $90 in 2010 and $200 in 2020. This would be welcome relief to consumers in many parts of the country whose natural gas bills more than doubled in the last year.

Household Electricity Bills

The energy efficiency measures in the Clean Energy Blueprint reduce electricity use, contributing to the plan's economic benefits (Figure 3). Total electricity bills to consumers are lower under the Blueprint than they are both today and under the business-as-usual scenario (Figure 7). Monthly bills for a typical household decline from about $40 per month in 2000 to about $25 per month in 2020 in the Clean Energy

Figure 6. Natural Gas Prices[a] (national average)



a. In the *Annual Energy Outlook 2001* version of the National Energy Modeling System used for this analysis, the first year of the forecast is 2000. Actual natural gas prices in 2000 were significantly higher than shown in the figure.

Blueprint scenario and $38 per month under business as usual. Annual savings to consumers from lower electricity bills range from nearly $58 in 2010 to over $150 in 2020 compared to business as usual. When combined with savings on natural gas bills, a typical household would save $150 per year in 2010 and $350 per year in 2020 on their overall energy bill (not including transportation).

Electricity Prices

Consumers' electric bills are a function of how much they use and the price per unit of electricity (cents/kWh). In both scenarios, electricity prices decline over time, although they decline slightly more under business as usual. Between 2000 and 2020, average consumer electricity prices fall almost 4 percent under the Clean Energy Blueprint and nearly 11 percent under business as usual (Figure 8).[6] However, the savings from reduced electricity use and lower natural gas prices under the Clean Energy Blueprint more than offset this price difference, resulting in lower total electricity bills (Figure 7).

Power Plant Emissions

The Clean Energy Blueprint significantly reduces air pollution from power plants. By 2020, carbon dioxide emissions from power plants are over two-thirds lower than under business as usual. Carbon dioxide emissions, primarily from power plants, are the number one contributor to global warming. Under proposals from Senator James Jeffords (I-VT) and Representative Henry Waxman (D-CA) for reducing multiple

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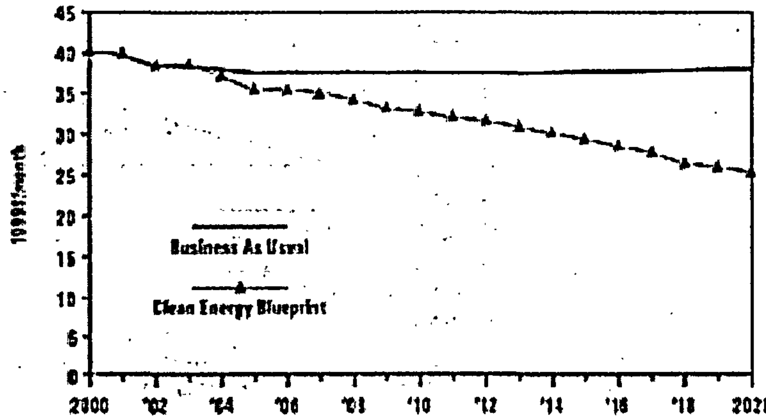
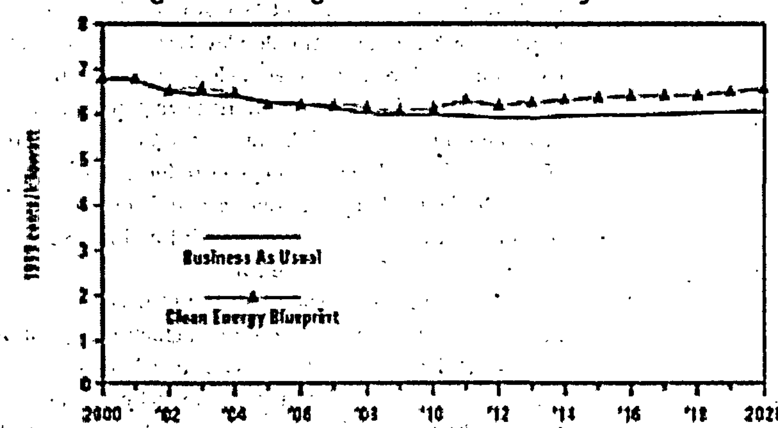
[6] Actual model input showed an unusual increase in coal prices in 2014 relative to the long-term projection of declining coal prices. This temporary increase in coal prices resulted in a fairly significant shift in electricity generation from coal to natural gas in 2015, which in turn resulted in a small spike in electricity and natural gas prices in that year. Over the next two years, there was a shift from natural gas back to coal due to a decline in coal prices. We believe this result is a modeling artifact, unconnected to any change in policy or technology inputs in that year. We have therefore assumed a linear extrapolation of prices and coal and natural gas generation between 2013 and 2016.

Figure 7. Typical Household Electricity Bill[a]



a. The business-as-usual scenario assumes a typical household uses 500 kWh/month on average. Residential electricity use is 39 percent lower in 2020 under the Clean Energy Blueprint than business as usual due to energy efficiency measures. Savings presented do not include the cost of implementing the efficiency measures (which are included in Figure 5 above), but do reflect the impacts of slightly higher electricity prices than business as usual.

Figure 8. Average Consumer Electricity Prices

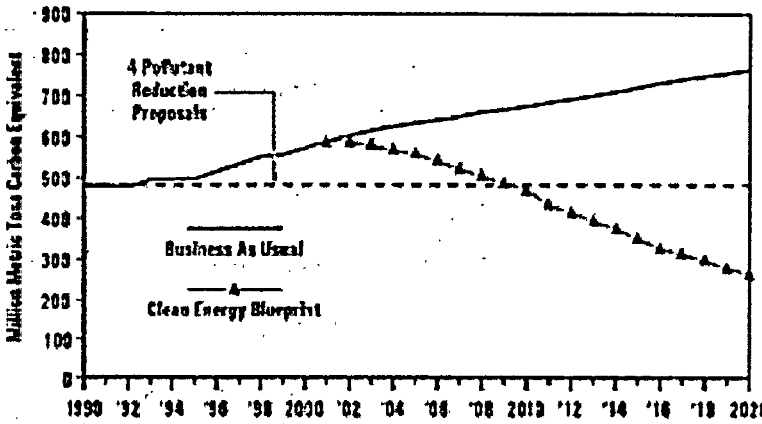


pollutants (carbon dioxide, sulfur dioxide, nitrogen oxides, and mercury), power plants would be required to reduce carbon dioxide emissions to 1990 levels by 2007 (Figure 9).[7] The results show that the Clean Energy Blueprint makes a significant contribution to reaching this requirement. Under the Clean Energy Blueprint power plants reach that target in 2009, indicating that a small additional amount of switching from coal to gas, or other measures, would be needed to meet the 2007 target. By 2020, carbon dioxide emissions from power plants are 47 percent lower than 1990 levels under the Clean Energy Blueprint.

The Blueprint policies also reduce sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions from fossil fuel power plants. SO_2 is the primary cause of acid rain, which

[7] The Senate bill is S. 556. The House bill is H. 1256.

Figure 9. Power Plant Carbon Dioxide Emissions



damages ecosystems and buildings, and of regional haze. It also forms fine particles in the air, which are associated with lung damage, cardiopulmonary disease, and premature death. NO_x is a primary contributor to the formation of smog, which is associated with asthma attacks, emergency room visits, and hospitalizations.

The business-as-usual scenario assumes SO_2 and NO_x emissions decline to the levels required by the 1990 Clean Air Act Amendments. By 2020, the Clean Energy Blueprint achieves SO_2 emission levels that are 59 percent below business as usual and NO_x emission levels 57 percent below business as usual.

S. 556 calls for NO_x reductions of 75 percent from 1997 levels and SO2 reductions of 75 percent below the full implementation mark of the CAA's acid rain program by 2007. The Clean Energy Blueprint reduces SO_2 and NO_x emissions only slightly by 2007. While the Blueprint policies would come close to meeting the targeted emission reductions by 2020, significant additional measures would be needed to meet the S. 556 targets by 2007 (Figure 10).

A recent EIA study showed that just meeting the NO_x target in S. 556 and a slightly higher SO_2 target in 2008 could be achieved with little impact on electricity prices, i.e., within 1 percent of business as usual (EIA, 2001). They projected that electric generators would install pollution-control equipment and switch to lower sulfur coal to meet the targets. Thus, we do not believe that meeting the SO_2 and NO_x targets would add much cost to the Blueprint.

The emission reductions produced by the Blueprint policies reduce the cost of complying with the Clean Air Act. For example, in 2020, SO_2 allowance prices (which represent compliance costs) are 91 percent ($260 per ton) less under the Clean Energy Blueprint than under business as usual.

Impact of Higher Natural Gas Prices

Projecting natural gas prices is highly uncertain. The smooth trajectory projected by the National Energy Modeling System in Figure 6 above does not reflect the recent and historic volatility in natural gas prices. Natural gas prices are likely to be more volatile in the future than shown in the figure, given the large increase in gas use for electricity production projected under the business-as-usual scenario. In this section, we analyze the impact of higher gas prices using the EIA's assumptions for the "slow-technological-progress" case from the *Annual Energy Outlook 2001.* This case assumes that costs will be higher and the rates of progress in exploring, drilling, and finding gas and oil will be lower than the EIA's reference-case projections. This results in lower gas supplies, which in turn leads to higher prices.

Using these assumptions, average natural gas prices are 20 percent higher in 2020 under the business-as-usual higher gas price scenario and 13 percent higher under the Clean Energy Blueprint higher gas price scenario (Figure 11).

The higher gas prices do not have much effect on the generation mix (Figures 2 and 3) and air emissions (Figures 9 and 10) shown above. However, they do have a significant impact on electricity prices and the overall costs of implementing the Blueprint policies. Under the business-as-usual higher gas price scenario, average consumer electricity prices are 7 percent higher in 2020 than under the business-as-usual scenario (Figure 12). Under the Clean Energy Blueprint higher gas price scenario,

Figure 10. Power Plant SO_2 and NO_x Emissions

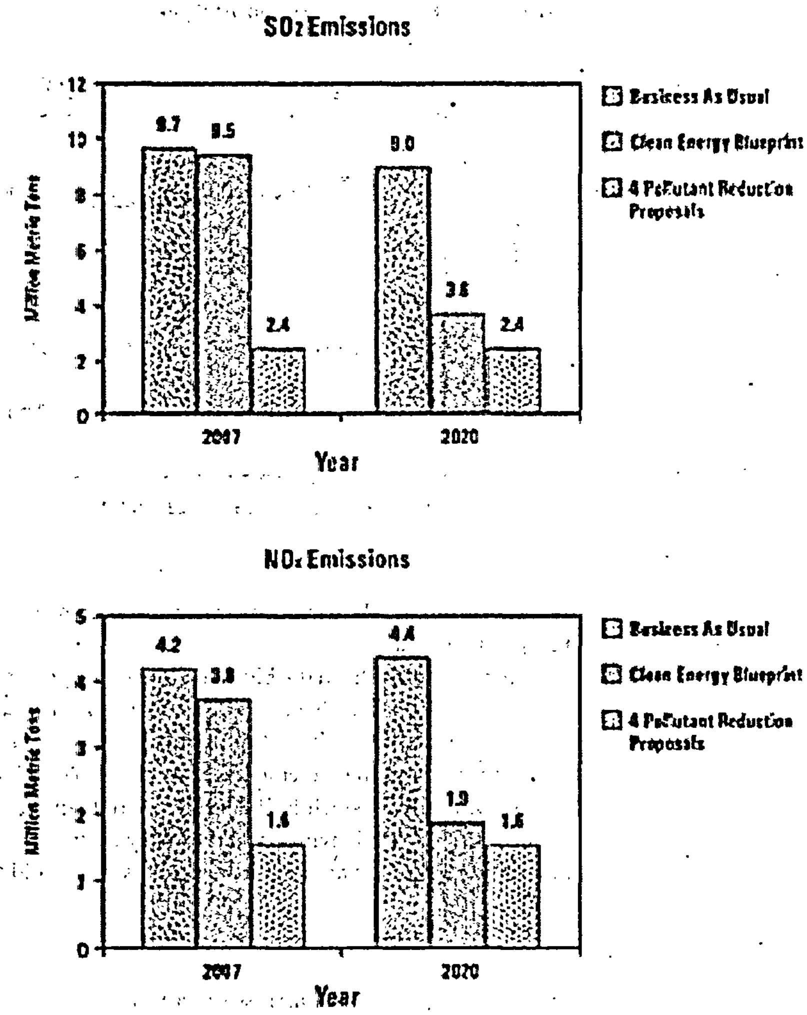
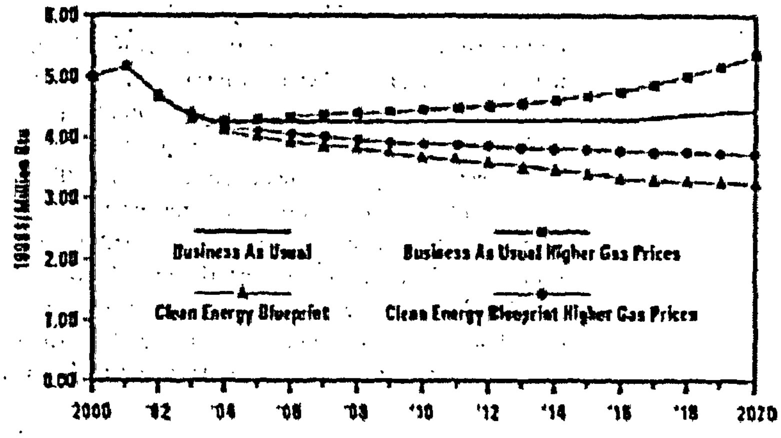
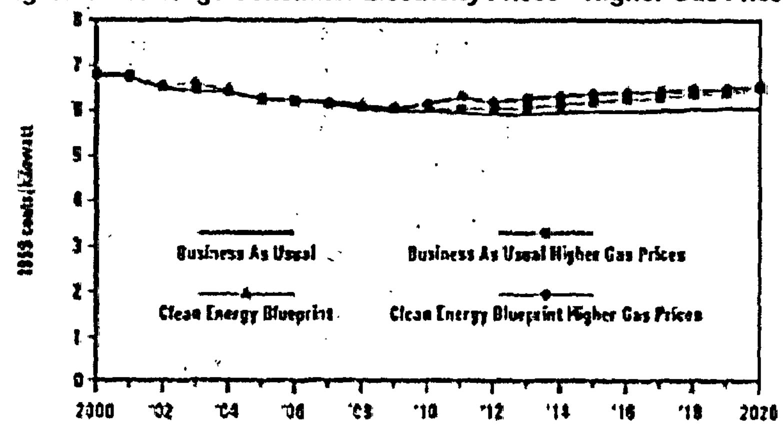


Figure 11. Natural Gas Prices—Higher Gas Prices[a] (national average)



a. In the *Annual Energy Outlook 2001* version of the National Energy Modeling System used for this analysis, the first year of the forecast is 2000. Actual natural gas prices in 2000 were significantly higher than shown in the figure.

Figure 12. Average Consumer Electricity Prices—Higher Gas Prices



average consumer electricity prices are roughly the same as under the Clean Energy Blueprint scenario.

Annual savings from the Blueprint higher gas price scenario are nearly $132 billion per year by 2020. This is nearly $27 billion higher than the Blueprint scenario with lower gas prices. Over the entire period, between 2002 and 2020, cumulative energy bill savings exceed the incremental costs of the Blueprint higher gas price scenario by nearly $500 billion, which is $60 billion more than the Blueprint scenario with lower gas prices.[8] The total savings would actually be greater than reported here, because the figures do not include additional net benefits that would continue beyond 2020.

[8] Net savings between 2002 and 2020 are in 1999 dollars using a 5 percent real discount rate.

The Renewable Energy and Energy Efficiency Investment Act of 2001 (S. 1333)

Electricity Generation and Use under S. 1333

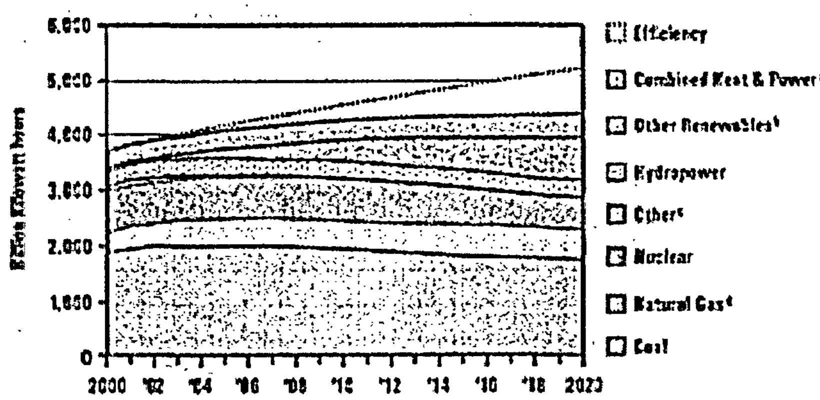
We have chosen to analyze S. 1333 separately because it is the single most comprehensive energy efficiency and renewable energy bill currently being considered in Congress. S. 1333 includes the renewable portfolio standard, public benefits fund, and net metering—plus increased R&D funding for renewable energy. It does not, however, include all of the energy efficiency, renewable energy, or CHP policies that are included in the Clean Energy Blueprint.

By 2020, increased investment in energy efficiency measures due to the public benefits fund results in electricity sales that are 17 percent lower than under business as usual (Figure 13, Table 4). With higher electricity demand than under the full set of Blueprint policies, and without an increase in CHP, S. 1333 requires 75 percent more wind, biomass, geothermal, and solar generation to meet the renewable portfolio standard in 2020 than the Blueprint does. Coal generation under S. 1333 is 24 percent lower in 2020 than under business as usual, but nearly double the amount of generation under the Blueprint. Total natural gas generation from major power plants and CHP plants is 52 percent lower under S. 1333 in 2020 than under business as usual, compared to 33 percent lower than business as usual under the Blueprint.

Economic Benefits under S. 1333

Beginning in 2008, the annual savings exceed the costs of S. 1333, growing to $35 billion per year by 2020 (Figure 14). Over the entire period, between 2002 and 2020, cumulative energy bill savings exceed the incremental costs of S. 1333 by nearly $70 billion.[9] The total savings would actually be greater than reported here, because the figures do not include additional savings that would continue beyond 2020.

Figure 13. Electricity Generation and Efficiency under S. 1333



a. Over 74% of CHP generation comes from natural gas in 2020.
b. Includes wind, biomass, geothermal, solar, and landfill gas.
c. Includes oil, municipal solid waste, and other wastes.
d. Includes major stand-alone plants only.

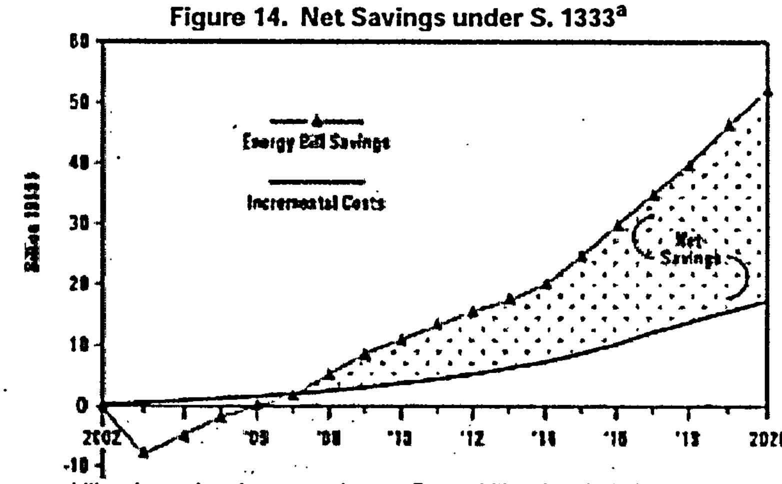
[9] Net savings between 2002 and 2020 are in 1999 dollars using a 5 percent real discount rate.

Table 4. Electricity Generation and Efficiency under S. 1333 (billion kWh)

Source	2000	2010			2020		
		Business as Usual	Clean Energy Blueprint	S. 1333	Business as Usual	Clean Energy Blueprint	S. 1333
Coal	1,894	2,195	1,655	1,923	2,295	891	1,748
Natural Gas	388	888	250	543	1,569	177	546
Nuclear	748	720	718	720	574	459	552
Other[a]	90	44	38	40	48	31	39
Hydropower	286	299	299	299	298	297	298
Other Renewables							
Wind	5	12	92	98	13	176	345
Biomass[b]	19	33	141	176	36	147	301
Geothermal	13	27	75	91	28	87	95
Landfill Gas	8	13	18	10	17	29	36
Solar	1	2	2	2	3	13	15
Subtotal	46	88	328	386	97	451	791
Combined Heat and Power[c]	298	363	630	365	419	1,180	458
Efficiency	n.a.	n.a.	644	291	n.a.	1,735	803
Total	3,748	4,597	4,562	4,573	5,300	5,220	5,236

a. Includes oil, municipal solid waste, and other wastes.
b. Includes a small amount of combined heat and power from biomass sources that are assumed to be eligible for the RPS.
c. In 2020, natural gas constitutes over 74% of CHP generation under S. 1333, 91% under the Clean Energy Blueprint; and 71% under business as usual.

Figure 14. Net Savings under S. 1333[a]

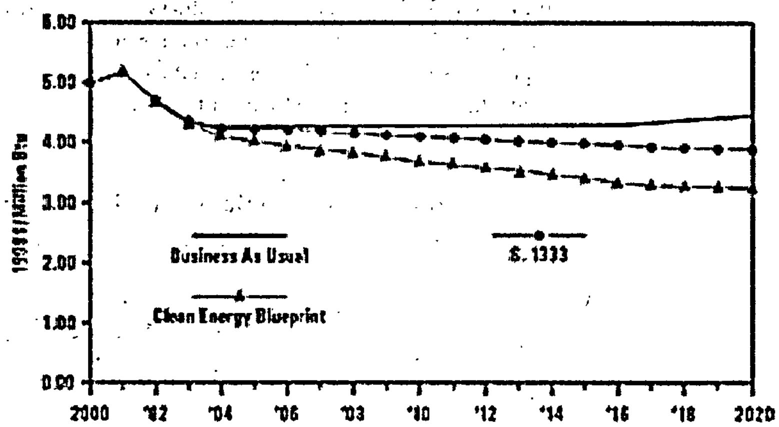


a. Net savings equal energy bill savings minus incremental costs. Energy bill savings include energy savings to consumers due to installing energy-efficient technologies and lower prices for certain fuels (mainly natural gas), minus the costs of S. 1333 policies included in electricity prices. Incremental costs include the direct costs of purchasing energy-efficient technologies by consumers annualized over the life of the equipment and the costs of administering and implementing the policies not directly reflected in consumer energy bills.

Natural Gas Prices under S. 1333

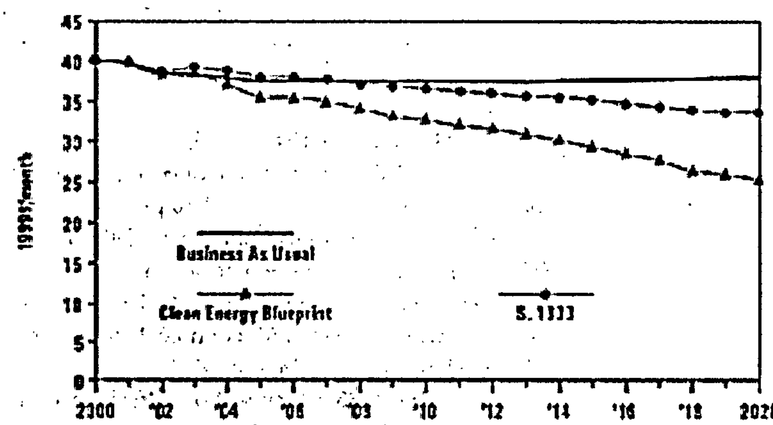
Like the Clean Energy Blueprint, the policies in S. 1333 reduce the demand for fossil fuels, resulting in lower fossil fuel prices for both consumers and electric generators. Total US natural gas use under S. 1333 is 6 quadrillion Btu or 17 percent lower in 2020 than under business as usual. As a result, average natural gas prices are 13 percent lower in 2020 than under business as usual, whereas under the Clean Energy Blueprint natural gas prices are 27 percent lower than under business as usual (Figure 15). Savings are projected to grow to over $14.5 billion annually by 2020 under S. 1333.

Figure 15. Natural Gas Prices under S. 1333[a] (national average)



a. In the *Annual Energy Outlook 2001* version of the National Energy Modeling System used for this analysis, the first year of the forecast is 2000. Actual natural gas prices in 2000 were significantly higher than shown in the figure.

Figure 16. Typical Household Electricity Bill under S. 1333[a]



a. The business-as-usual scenario assumes a typical household uses 500 kWh/month, on average. In 2020, residential electricity use is 17 percent lower than business as usual under S. 1333 and 39 percent lower under the Clean Energy Blueprint, due to energy efficiency measures. Savings presented do not include the cost of implementing the efficiency measures (which are included in Figures 5 and 14 above), but do reflect the impacts of slightly higher electricity prices than under business as usual.

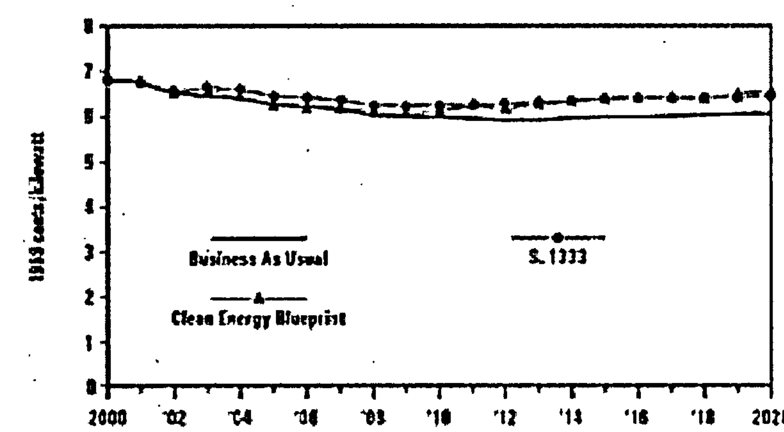
Household Electricity Bills under S. 1333

The energy efficiency measures in S. 1333 reduce electricity use (Figure 13). As a result, S. 1333 lowers total electricity bills to consumers compared to both today's levels and business as usual levels (Figure 16). Monthly bills for a typical household decline from about \$40 per month in 2000 to \$34 per month in 2020 under S. 1333, \$38 per month under business as usual, and \$25 per month under the Clean Energy Blueprint. Annual savings to consumers from lower electricity bills are nearly \$11 in 2010 and over \$50 in 2020.

Electricity Prices under S. 1333

Between 2000 and 2020, average consumer electricity prices fall by over 5 percent under S. 1333, 11 percent under business as usual, and 4 percent under the Clean Energy Blueprint (Figure 17). The savings associated with reduced electricity use and lower natural gas prices from the energy efficiency measures in S. 1333 more than offset this price difference, resulting in lower total electricity bills (Figure 16).

Figure 17. Average Consumer Electricity Prices under S. 1333



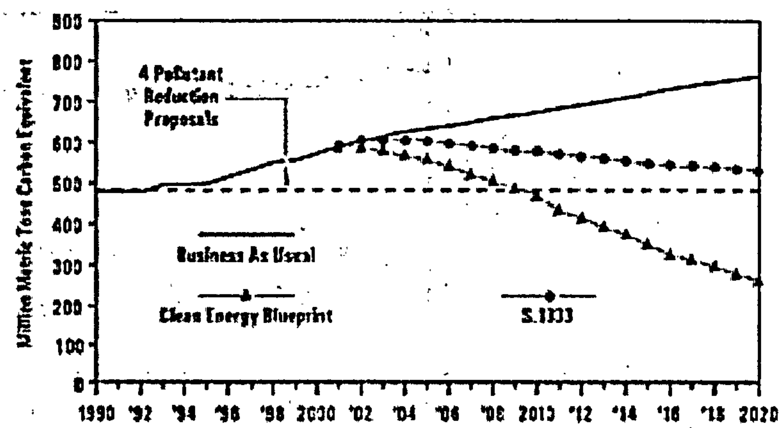
Power Plant Emissions under S. 1333

Under S. 1333, power plant CO_2 emissions in 2020 are nearly one-third lower than under business as usual, and 10 percent higher than 1990 levels (Figure 18). As discussed above, proposals from Senator Jeffords (S. 556) and Representative Waxman (H. 1256) would require reductions in carbon dioxide emissions to 1990 levels by 2007. The RPS and public benefit fund thus can make a significant contribution to meeting carbon dioxide reduction goals in four-pollutant reduction proposals, but additional measures would be needed.

By 2020, S. 1333 achieves SO_2 emission levels that are 8 percent below business as usual and NO_x emissions levels 15 percent below business as usual. SO_2 allowance prices (which represent compliance costs) are 77 percent (\$220 per ton) less under S. 1333 than under business as usual.

S. 556 also requires reductions in NO_x emissions of 75 percent from 1997 levels, and SO_2 emissions of 75 percent below the full implementation mark of the CAA's

Figure 18. Power Plant Carbon Dioxide Emissions under S. 1333



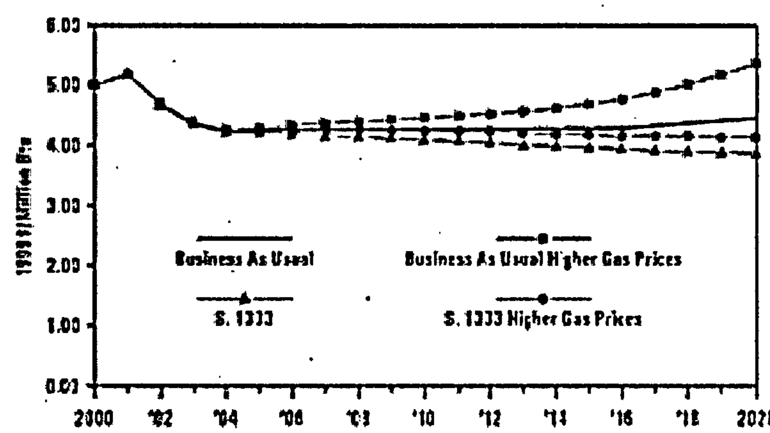
acid rain program by 2007. In 2007, S. 1333 achieves SO_2 emissions reductions of 2 percent and NO_x emissions reductions of 3 percent, making a small contribution toward the goals of S. 556.

Impact of Higher Natural Gas Prices under S. 1333

Using the EIA's assumptions for slow technological progress described above, average natural gas prices are 20 percent higher in 2020 under business as usual and 6 percent higher under S. 1333 (Figure 19). Under the S. 1333 higher gas price scenario, average consumer electricity prices are almost the same as under the S. 1333 scenario (Figure 20).

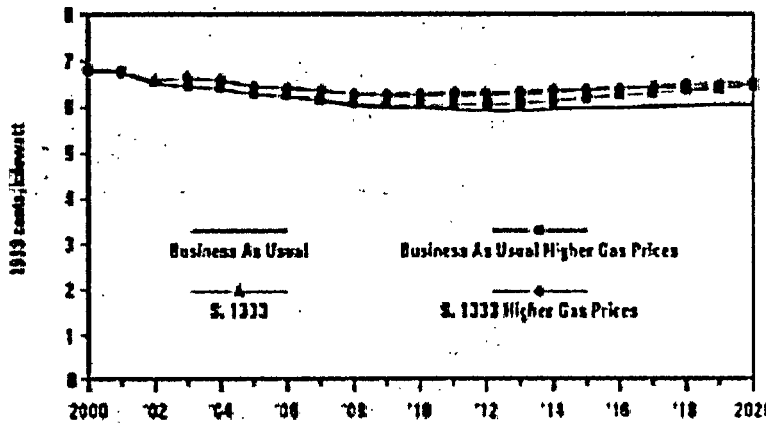
Under the S. 1333 higher gas price scenario, annual savings grow to nearly $60 billion per year by 2020, which is nearly $25 billion higher than under the S. 1333 scenario. Over the entire period, between 2002 and 2020, cumulative energy bill savings

Figure 19. Natural Gas Prices under S. 1333[a] (national average)



a. In the *Annual Energy Outlook 2001* version of the National Energy Modeling System used for this analysis, the first year of the forecast is 2000. Actual natural gas prices in 2000 were significantly higher than shown in the figure.

Figure 20. Average Consumer Electricity Prices under S. 1333



exceed the incremental costs of the S. 1333 higher gas price scenario by $132 billion, which is over $60 billion more than under the S. 1333 scenario.[10] The total savings would actually be greater than reported here, since the figures do not include additional benefits beyond 2020.

[10] Net savings between 2002 and 2020 are in 1999 dollars using a 5 percent real discount rate.

CHAPTER 5

ADDITIONAL BENEFITS OF THE CLEAN ENERGY BLUEPRINT

While they are not explicitly quantified in this study, the Clean Energy Blueprint would also provide many additional environmental, economic, and national security benefits.

Environmental Benefits

By reducing the use of natural gas and coal, the Clean Energy Blueprint decreases the need to expand natural gas drilling and coal mining, creating less pressure to open public lands and sensitive areas to fossil fuel exploration. Less gas must be transported, lessening pressure for the 301,000 miles in natural gas transmission and distribution pipelines that the National Energy Plan says must be built (NEPDG, 2001). Less coal mining means less damage to land and water. And with consumers using less electricity, fewer new transmission lines would be needed, reducing pressure for extreme measures like federal seizure of private land for power lines under eminent domain.

The NEMS computer model does not calculate emissions of toxic chemicals. But with coal use dropping by nearly 60 percent under the Clean Energy Blueprint, emissions of mercury, arsenic, and other toxic metals would also drop, reducing damage to ecosystems and threats to human health.

More efficient use of electricity increases the efficiency of the economy as a whole.

Economic Benefits

More efficient use of electricity increases the efficiency of the economy as a whole, making the United States more competitive around the globe. Overall, the nation's energy system will be more stable and reliable, which has numerous economic benefits. By lowering electricity demand, the Clean Energy Blueprint will reduce the threat of electricity shortages, helping to avoid price spikes as well as blackouts or brownouts. Adding renewable energy supplies will protect the consumer by diversifying the energy mix with resources that are not imported and that are less subject to supply and price manipulation.

Energy efficiency and renewable energy can also create more jobs and income than investments in fossil fuels and nuclear power. A 1997 study by UCS and others—*Energy Innovations*—found that implementing a more comprehensive package of clean energy policies and technologies than considered in this study would create nearly 800,000 more jobs, $14 billion in additional income, and nearly $3 billion in higher gross domestic product than business as usual (in 1993 dollars) (Alliance to Save Energy et al., 1997).

The increase in renewable energy would especially benefit rural economies and provide a new cash crop for farmers. For example, generating 5 percent of the country's electricity with wind power by 2020, would add $60 billion in capital investment in rural America, provide $1.2 billion in new income for farmers and rural landowners, and create 80,000 new jobs according to the US Department of Energy (DOE, 2000a). In the Midwest, wind developers are paying farmers $2,000 or more per year for each wind turbine installed on their land. Each turbine uses only about a quarter acre, so farmers can plant crops and graze livestock right to the turbine's base. The DOE also estimates that tripling US use of biomass energy could provide as much as $20 billion in new income for farmers and rural communities (DOE, 2000b). Under the Clean Energy Blueprint, biomass energy use doubles and wind power provides nearly 8 percent of the country's electricity by 2020. Thus, the Blueprint would capture many of these rural economic benefits.

Reducing air pollution through the Clean Energy Blueprint will also benefit the economy. With less acid rain damaging lakes, forests, and wildlife, revenues from tourism and fishing will increase. Decreasing smog and soot emissions will lower the number of asthma attacks, emergency room visits, premature deaths, and other illnesses, thereby lowering health care and insurance costs and increasing worker productivity.

National Security Benefits

Improving energy efficiency, increasing the diversity of supply, and developing small, distributed generation sources will all contribute to increasing national security (Lovins and Lovins, 1982). The Clean Energy Blueprint will reduce our use of oil and will reduce the vulnerability of our energy infrastructure.

Neither of these benefits are achievable quickly. We do not suggest that they are appropriate as emergency security measures or that they are substitutes for direct improvements in security at existing energy facilities. Over time, however, our energy choices will determine whether we face increased security risks, or decreasing vulnerability and risks.

As discussed on page 14 above, the Clean Energy Blueprint will reduce oil use by 410 million barrels of oil per year, or 5 percent less than business as usual, by 2020. While this reduction is modest, it is larger than the amount of oil that is economically recoverable over 60 years by drilling in the Arctic National Wildlife Refuge, which some have advocated as a security measure. When combined with transportation efficiency measures, the potential oil savings vastly outweigh the potential from drilling in the Wildlife Refuge. Moreover, oil savings through efficiency do not rely on a long pipeline through remote areas, which is itself highly vulnerable to disruption.

The Clean Energy Blueprint will decrease the number and size of vulnerable energy processing, storage, and distribution facilities, such as refineries, pipelines, gas storage facilities, and liquefied natural gas tankers. It will avoid the need for more than 900 new natural gas-fired power plants and allow for the earlier retirement of 14 large nuclear plants.

Renewable generators, such as solar and wind, are geographically dispersed and contain no volatile fuel stocks or radioactive materials. Distributed generation, including combined heat and power systems and small renewable energy systems, is also less vulnerable to disruption and can help the nation create a more secure and resilient energy system. James Woolsey, former head of the Central Intelligence Agency, Robert McFarlane, former national security advisor, and Admiral Thomas Moorer, former chair of the Joint Chiefs of Staff, recently urged Congress to enact a federal renewable portfolio standard, public benefit fund, and other measures, in order to help increase national security (Air Daily, 2001).

CHAPTER 6

A PROMISING ENERGY FUTURE

The nation needs a balanced approach to meeting future energy demands—one that invests in clean and efficient technologies both to reduce energy demands and to increase energy supplies. This analysis by UCS and its co-authors shows that energy efficiency and renewable energy sources can meet a large share of the country's energy needs both today and in the future, including replacing some of the most polluting power plants that operate today. Moreover, they do so while providing health and environmental benefits, lower energy bills, and net savings to consumers.

The policies in the Clean Energy Blueprint are practical and achievable. In fact, many of the policies proposed here have already proven successful and cost-effective at the national or the state level. Many states have been leaders in developing and demonstrating new approaches for improving energy efficiency and deploying renewable energy. Texas has been one such leader. Then-Governor Bush signed a law in 1999 that included a renewable portfolio standard—a policy completely ignored in the administration's National Energy Plan. The Texas law created the largest market for new renewable energy development in the country, requiring electricity companies to supply 2,000 megawatts of new renewable resources by 2009. The state may actually meet the goal for 2009 by the end of 2002, seven years early (AWEA, 2000).

Many of the policies proposed here have already proven successful and cost-effective at the national or the state level.

One of the greatest advantages that energy efficiency and renewable energy sources offer over new power plants, transmission lines, and pipelines is the ability deploy these technologies with almost no delay. Energy-efficient technologies can be deployed much faster than any alternative. It takes only six months to add new wind turbines to existing wind farms. We can implement the policies of the Clean Energy Blueprint now and begin seeing benefits right away.

Over 18 years, the policies of the Clean Energy Blueprint can save consumers nearly \$440 billion, with annual savings to consumers from lower total energy bills reaching \$350 by 2020. The Clean Energy Blueprint can also eliminate the need for nearly 1,200 fossil fuel and nuclear power plants, cut coal use for electricity generation by nearly 60 percent of what it would have been, and affordably reduce over two thirds of the carbon dioxide emissions from power plants.

Energy efficiency and renewable energy technologies are ready to serve us. Now we need vision, leadership, and determination to provide a clean, affordable energy future.

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9

Job Jolt

The Economic Impacts of *Repowering the Midwest: The Clean Energy Development Plan for the Heartland*

An Economic Study by the Regional Economics Applications Laboratory for the Environmental Law & Policy Center

›Citizens Action Coalition of Indiana ›Dakota Resource Council ›Iowa RENEW
›Izaak Walton League of America ›Minnesotans for an Energy-Efficient Economy
›RENEW Wisconsin ›Union of Concerned Scientists

Job Jolt

The Economic Impacts of Repowering the Midwest:
The Clean Energy Development Plan for the Heartland
... with clean, renewable and efficient energy

Executive Summary

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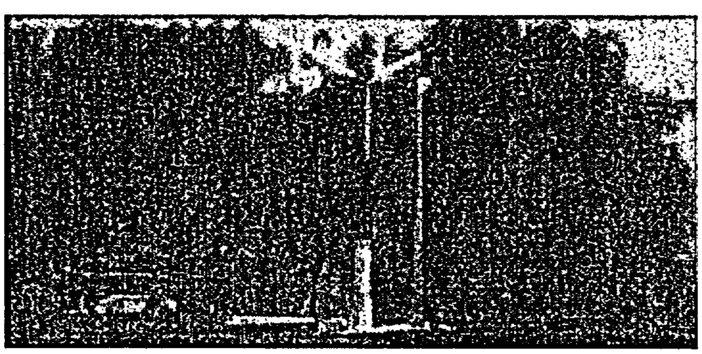
Introduction | Overview: Clean Energy = More Good Jobs

Implementing the *Repowering the Midwest* Clean Energy Development Plan would create more than **200,000** new jobs across the 10-state Midwest region by 2020, up to **$5.5 billion** in additional worker income, and up to **$20 billion** in increased economic activity.

Repowering the Midwest's Clean Energy Development Plan promotes modern, energy efficient technologies and development of renewable energy resources, especially wind power and biomass energy. This plan contrasts with a business-as-usual scenario, which relies almost entirely on polluting coal and nuclear power plants for electricty generation.

This huge resulting *Job Jolt* is the central finding of a comprehensive study of the economic impacts of phasing in more clean energy efficient technologies and renewable energy development across the Midwest and Great Plains. The Regional Economics Applications Laboratory (REAL), a nationally renowned research center of the University of Illinois, used its modeling techniques to determine the economic impacts of implementing the clean energy development plan proposed by the Environmental Law & Policy Center (ELPC) and its Midwest partners.

Repowering the Midwest: The Clean Energy Development Plan for the Heartland is a blueprint for producing economically and environmentally sound power by unleashing the Midwest's homegrown clean energy potential. It calls for a gradual reduction of overreliance on some of the Midwest's oldest and most polluting coal and nuclear generating plants that currently account for 95 percent of the region's electricity generation — and for a gradual increase in using modern clean energy technologies.



To achieve this, the Clean Energy Development Plan calls for:

[1] Implementing cost-effective energy efficiency technologies to level off the region's overall electricity demand. These energy efficiency technologies, ranging from efficient lighting and ballasts to Energy Star® appliances to state-of-the-art industrial motors, can save business and residential consumers money. On average, these new technologies cost 2.3¢ per kilowatt-hour, or less, which is below the cost of generating, transmitting and distributing electricity from coal, gas or nuclear plants.

[2] Diversifying the region's over-dependence on coal and nuclear plants by developing more renewable energy generating technologies: wind and solar power, and biomass energy locked inside agricultural crops, such as switchgrass and cornhusks. The environmental and public health advantages of this conversion are evident. Pollutants from coal plants are major contributors to smog, acid rain and global warming. Nuclear plants produce highly radioactive wastes and impose extraordinary costs for storage and disposal. However, these old technologies continue to hold a near-monopoly over the Midwest power market. Why?

One reason is the widespread myth that developing clean energy resources would be too expensive and cost jobs.

REAL finds that nearly the opposite is true. A partial switch to cleaner, smarter energy—as detailed in *Repowering the Midwest*—would energize the Midwest economy with hundreds of thousands of new jobs and billions of dollars in new income and economic activity.

The magnitude of these job and dollar gains is enormous. New jobs resulting from implementing the Clean Energy Development Plan would be more than twice the total employment in the Midwest electric utility industry.

The economic impacts from implementing the Clean Energy Development Plan would be distributed throughout the Midwest and Great Plains in both metropolitan and rural areas, and in every sector of the regional economy from manufacturing to construction to farming.

For example:

- Jobs manufacturing and installing modern commercial lighting and efficient ballasts, and Energy Star®-rated appliances.
- Jobs manufacturing and assembling wind turbines and solar panels.
- New sources of farm income from wind turbine leases and growing and processing biomass energy crops.

This job gain and economic growth greatly outweigh the projected loss of jobs and income in the electric utility industry caused by reducing demand for power from coal and nuclear plants.

A partial switch to cleaner, smart energy efficiency and renewable energy would energize the Midwest economy with hundreds of thousands of new jobs...

Summary of Regionwide Economic Impact of Repowering the Midwest

[illegible]	[illegible] 2010	[illegible] 2020	[illegible] 2010	[illegible] 2020
Energy Efficiency	83,900	140,900	$7.1 Billion	$12.7 Billion
Renewable Energy	36,800	68,400	$3.7 Billion	$6.7 Billion
Total	120,700	209,300	$10.8 Billion	$19.4 Billion

Source: Regional Economics Applications Laboratory

Reasonable Assumptions | Achievable Vision:
The Midwest Clean Energy Development Plan

Repowering the Midwest calls on both the public and private sectors to embark on a 20-year phase-in of more energy efficient technologies and renewable energy resources. Implementation strategies include Energy Efficiency Investment Funds created in each state, energy efficiency building codes, and renewable portfolio standards that require electric utilities make renewable energy a reasonable share of their power supply that is delivered to consumers.

Central to the report are the two ambitious and achievable implementation targets specified by *Repowering the Midwest*'s Clean Energy Development Plan:

[1] Energy Efficiency. By **2010**, electricity consumers in all sectors—industrial, commercial and residential—would improve efficiency and reduce power demand by **17 percent** below the projected business-as-usual rate of consumption. By **2020**, the difference would be a **28 percent** reduction. These reductions would be more than enough to achieve a flattening-out of Midwest electricity demand at current levels.

[2] Clean Renewable Energy Development. By **2010**, electric utilities would supply a more diverse fuel mix to consumers in which **8 percent** of electricity is generated by cleaner renewable energy technologies including wind power, biomass energy, and solar power. By **2020**, this clean renewable energy would increase to **22 percent** of electricity supplied to consumers. Moreover, developing and implementing efficient natural gas uses in appropriate locations, especially Combined Heat and Power (CHP), district energy systems and fuel cells,

Figure 1: Business As Usual Case
Source: Repowering the Midwest

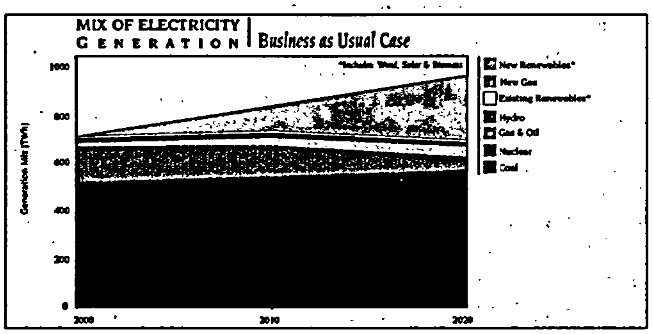
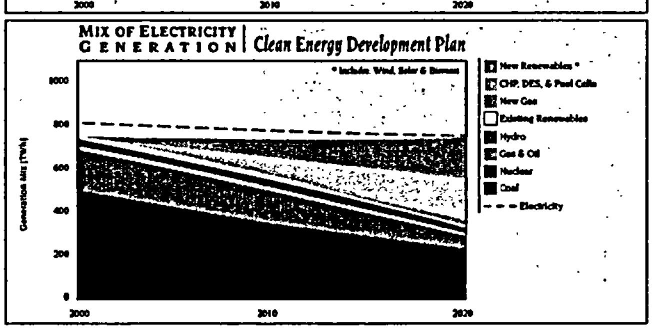


Figure 2: Clean Energy Development Plan
Source: Repowering the Midwest



would boost the cleaner energy component of the electricity supply to **18 percent by 2010 and to 46 percent by 2020.**

The environmental and health benefits of phasing out some of the oldest, most polluting coal plants alone would justify the Clean Energy Development Plan. Compared to a business-as-usual future (95 percent coal and nuclear), the reasonable shift outlined in *Repowering the Midwest* would reduce:

- Acid rain-causing sulfur dioxide emissions (SO_2) by 56 percent.
- Smog-causing nitrogen oxide emissions (NOx) by 71 percent.
- Global warming-causing carbon dioxide emissions (CO_2) by 51 percent.
- Emissions of particulates, mercury and other heavy metals.

These pollution reductions would lead to a significant reduction in asthma, respiratory ailments and other public health problems. The catastrophic risks of a nuclear power plant accident and the volume of radioactive nuclear wastes would also be reduced as some older nuclear plants are retired.

Another benefit would be better electricity reliability. Increased energy efficiency will ease the strain on transmission and distribution systems.

But what of the economic impacts? Would the expense of this clean energy transition punch a hole in family budgets and crimp the competitiveness of Midwest businesses? What about jobs, especially if some of the older coal plants are retired? To get answers, ELPC and its Midwest partners asked REAL to run the numbers.

	2010		2020	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wind Turbines	6,698	3.0	24,510	11.3
CHP-Biomass	2,949	3.4	6,003	6.8
Biomass Co-Firing	1,850	1.4	4,807	3.1
Photovoltaics	161	0.09	482	0.1
Biomass Gasification	75	0.1	575	0.6
Total Renewables	11,733	8.0	36,377	21.9
CHP-Natural Gas	5,650	6.5	12,250	13.8
District Energy Systems	3,223	3.6	6,446	7.1
Fuel Cells	282	0.3	3,237	3.6
Total Efficient Natural Gas	9,155	10.4	21,933	24.5
TOTALS	20,888 MW	18.4	58,310 MW	46.4

Figure 3: New Clean Energy Generation Capacity Included in Clean Energy Development Plan, [illegible]

By 2020, clean renewable energy would increase to 22 percent of electricity supplied to consumers in the Midwest and Great Plains.

Empirical Method | Emphatic Result:
REAL Models *The Repowering the Midwest Clean Energy Development Plan*

The economic impacts of implementing the Clean Energy Development Plan were estimated using regional econometric input-output models developed by REAL to forecast the local impacts of changing economic conditions and policies. Since 1989, REAL has developed, and continually refined, a portfolio of models covering metropolitan regions and states across the Midwest. Using primarily U.S. Census data, REAL's dynamic models track employment, income and output data across 53 industrial sectors, factoring in 13 demand variables (consumption, investment, government expenditures, etc.) and eight demographic variables (age, sex, migration, etc). Previous REAL studies have examined a broad range of economic phenomena, from the *Impact of the Monet Exhibition at the Art Institute of Chicago* to the *Impact of Electricity Deregulation on the Chicago Economy*. To evaluate the *Repowering the Midwest* impacts, REAL conducted two discrete studies involving 10 individual states: Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin. The two studies evaluated the key components of the Clean Energy Development Plan put forward in *Repowering the Midwest*:

- *Energy Efficiency Impacts for the Midwest* measures the changes in employment, income and economic output that would result from investments in energy efficiency that save up to 17 percent of electricity use by 2010 (versus business-as-usual) and 28 percent by 2020.
- *Renewable Energy Impacts for the Midwest* measures the changes in employment, income and economic output that would result from a program of clean energy development (wind, solar, biomass) in which 8 percent of Midwest electricity would be generated from renewable energy by 2010 and 22 percent by 2020. And, with efficient natural gas uses, 18% by 2010 and 46% by 2020.

A summary of the combined impacts of achieving these two goals is provided in Figure 4.

Energy Efficiency Implementation Impacts

The results of REAL's study indicate that the energy efficiency measures outlined in *Repowering the Midwest*'s Clean Energy Development Plan will generate as many as 84,000 jobs by 2010 (over and above a business-as-usual baseline) rising to 141,000 jobs by 2020. These jobs will generate local income—direct and indirect—of up to $1.8 billion by 2010 rising to $3.2 billion in the year 2020. The plan will increase Midwest economic output by as much as $7.1 billion by 2010 rising to $12.7 billion by 2020.

Many of the largest beneficiaries of a conversion to energy efficiency are manufacturers already located in the Midwest. More workers will be needed, for example, to make triple-glazed windows for Andersen Windows, smart thermostats for Honeywell and Johnson Controls, energy efficient lighting equipment for Osram Sylvania, and Energy Star® appliances for Whirlpool.

Clean Energy	Net Job Growth		Increased Annual Economic Output	
	2010	2020	2010	2020
Energy Efficiency	83,900	140,900	$7.1 Billion	$12.7 Billion
Renewable Energy	36,800	68,400	$3.7 Billion	$6.7 Billion
Total	**120,700**	**209,300**	**$10.8 Billion**	**$19.4 Billion**

Figure 4: Summary of Region-wide Economic Impacts of *Repowering the Midwest*.
Source: Regional Economics Applications Laboratory

Venture Lighting
Solon, Ohio

Venture Lighting, a division of Advanced Lighting Technologies, is a leading developer and manufacturer of energy efficient metal halide lighting systems. Metal halide can replace fluorescent tubes in indoor applications and sodium vapor in outdoor ones. It reduces energy consumption, reduces maintenance and improves the quality of lighting. The company employs 295 people at its Solon, Ohio facility.

Each state in the region has different manufacturing capabilities and, thus, different economic impacts from implementing the energy efficiency plan. Highly industrialized states such as Illinois, Indiana, Michigan and Ohio achieve the most substantial job gains from increased use of clean energy efficiency technologies. The REAL model incorporates these variables to compute the average state-by-state impacts described in Figure 5.

Energy efficiency installations will create new jobs in nearly all economic sectors – the largest gains are in trade (39 percent), professional and personal services (24 percent) and manufacturing (20 percent), as shown in Figure 6. These gains are partially eroded by a loss of jobs in the utility sector as demand for electricity flattens out.

Highly industrialized states such as Illinois, Indiana, Michigan and Ohio achieve the most substantial job gains from increased use of clean energy efficiency technologies.

Energy Efficiency Impacts

State	Net New Employment		Increased Annual Economic Output	
	2010	2020	2010	2020
IL	26,000	43,400	$2.6 Billion	$4.6 Billion
IN	8,800	15,500	$7 Billion	$1.2 Billion
IA	3,700	6,800	$200 Million	$300 Million
MI	16,100	29,100	$1.3 Billion	$2.4 Billion
MN	4,000	8,200	$200 Million	$400 Million
NE	1,500	2,900	0	$100 Million
ND	400	900	0	0
OH	18,900	25,500	$2 Billion	$3.4 Billion
SD	600	1,200	0	0
WI	3,900	7,400	$100 Million	$2.7 Billion
Total Region	**83,900**	**140,900**	**$7.1 Billion**	**$12.7 Billion**

Figure 5: Energy Efficiency: Summary of Economic Impacts by State
Source: Regional Economics Applications Laboratory. Represents impacts of Clean Energy Development Plan versus the Business-As-Usual baseline projections for Employment and Economic Growth.

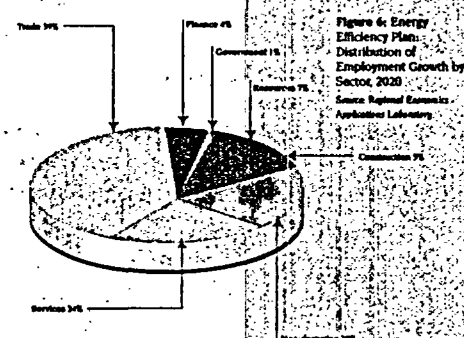


Figure 6: Energy Efficiency Plan: Distribution of Employment Growth by Sector, 2020
Source: Regional Economics Applications Laboratory.

Renewable Energy Development Impacts

REAL's study shows that implementing the renewable energy component of the Clean Energy Development Plan in *Repowering the Midwest* will generate 25,000 - 41,000 new jobs by 2010, and 58,000 - 74,000 jobs by 2020. These jobs will generate local income of $700 million - $1.3 billion in 2010, rising to $1.7 billion - $2.3 billion in 2020. Implementation also will increase annual Midwest economic output by $2.3 billion - $4.0 billion in 2010, and by $5.5 billion - $7.3 billion in 2020 as described in Figure 7.

Because business - as - usual electricity generation in the Midwest is predominantly dependent on imported fuels—such as western coal transported by rail car from Wyoming—its partial replacement will not produce significant job losses in the Midwest. Renewable energy will create new jobs—both directly and indirectly—in all major economic sectors. As shown in Figure 8, by 2020, the manufacturing sector will account for 17 percent of the job gains, construction for 15 percent, services for 33 percent, and agriculture for 12 percent. Many of these jobs and economic gains will be located in rural areas where they will provide a valuable boost to local economies.

Companies benefiting from increased investment in renewable energy will include small-but-growing businesses such as Energy Maintenance Service, Inc.—see company profile on page 9—which installs and maintains wind power equipment across the Midwest from its new facility in Howard, South Dakota. This facility has delivered a tonic to a town that lost 13 percent of its population during the 1990s. What's more, every time an Energy Maintenance Service repair crew eats at a restaurant or sleeps at a motel, or the company purchases a new truck or tool, some local Midwest business benefits, eventually enough to hire more help.

Construction and operation of wind power machines will account for 28 percent of the new jobs and biomass energy for 17 percent of the new jobs by 2020. As Figure 9 shows, a large number of jobs are also created by increasing the efficiency of new environmentally preferable uses of natural gas. New clean burning Combined Heat and Power (CHP) installations will create fully 27 percent of the new jobs, and district

Renewable Energy Impacts

State	Net New Employment		Increased Annual Economic Output	
	2010	2020	2010	2020
IL	8,700	13,500	$1 Billion	$1.5 Billion
IN	3,500	6,500	$300 Million	$600 Million
IA	2,400	5,700	$300 Million	$600 Million
MI	4,100	9,100	$400 Million	$1 Billion
MN	3,900	6,400	$400 Million	$700 Million
NE	1,500	2,600	$200 Million	$300 Million
ND	1,000	2,100	$100 Million	$200 Million
OH	7,200	13,500	$600 Million	$1 Billion
SD	1,300	2,600	$100 Million	$200 Million
WI	3,200	6,400	$300 Million	$600 Million
Total Region	36,800	68,400	$3.7 Billion	$6.7 Billion

Figure 7: Renewable/Clean Energy Summary of Economic Impacts by State

Source: Regional Economics Applications Laboratory

Energy Maintenance Service, Inc. Gary, South Dakota

Founded in 1998 by renewable energy entrepreneur Joe Kolbach, Energy Maintenance Service employs 35 people installing and maintaining wind turbines of all sizes and types, for both commercial and residential customers throughout the country. The company has benefited from state and federal incentives as well as renewable portfolio standard policies which have created a positive climate for wind power development.

Though headquartered in South Dakota, the company's crews are constantly on the road throughout North America. Every day the crews spend in the field, they are benefiting local economies through spending on motels, food and supplies.

energy systems — where a group of buildings is served by a single boiler/generator — will deliver 14 percent. This cleaner modern CHP will mostly displace power that would otherwise be generated by more polluting coal plants. State-by-state breakouts for jobs and economic output are presented in Figure 7 on page 8.

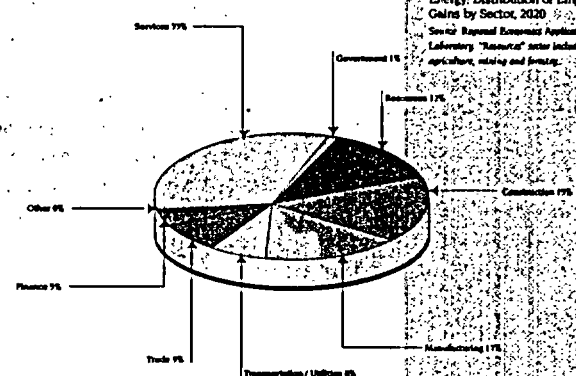


Figure 8: Renewable and Clean Energy: Distribution of Employment Gains by Sector, 2020

Source: Regional Economic Applications Laboratory. "Resources" sector includes agriculture, mining and forestry.

Implementing the renewable energy development plan will generate 25,000 - 41,000 new jobs by 2010 and 58,000 - 74,000 new jobs by 2020.

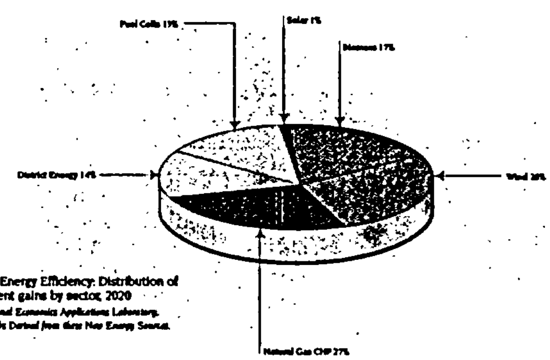
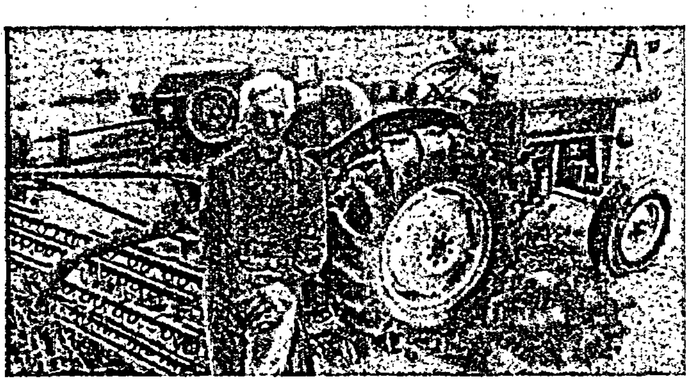


Figure 9: Energy Efficiency: Distribution of Employment gains by sector, 2020

Source: Regional Economics Applications Laboratory. Represents Jobs Derived from these New Energy Sources.

Conclusion: It's Time to Act

The Midwest needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable environmental, public health, employment and economic growth benefits. The Environmental Law & Policy Center and its Midwestern partners set forth a detailed plan to accomplish this goal in *Repowering the Midwest: The Clean Energy Development Plan for the Heartland*. (www.repowermidwest.org)



The environmental quality and public health benefits of *Repowering the Midwest* have never been seriously disputed. This analysis by REAL substantiates the job gains and economic benefits of putting the Clean Energy Development Plan in *Repowering the Midwest* into action.

Rather than impose an economic burden, the phase-in of more clean energy efficiency and renewable energy technologies would produce a job jolt of more than **200,000** new jobs, **$5.5 billion** in new household income and close to **$20 billion** in additional annual economic output by 2020.

The Midwest needs a strategic clean energy development plan that implements smart policies and practices to capture readily achievable benefits.

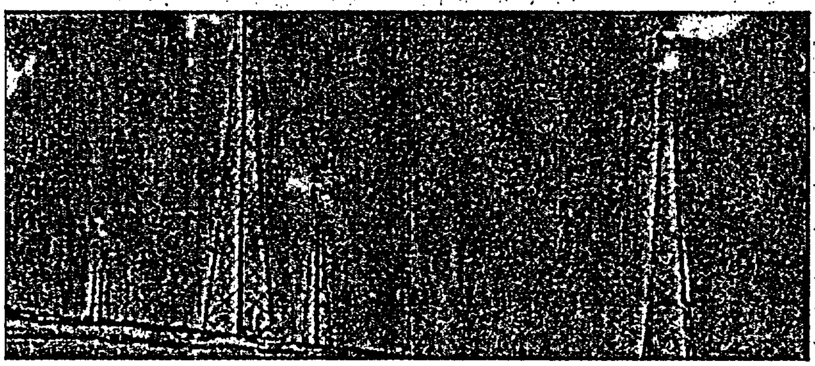
The energy choices facing the Midwest have never been more clear. Should the region stay chained to its over-reliance on aging coal and nuclear power plants, many of them built in the 1950s, 1960s and 1970s, now past their intended lives? Or is it time to diversify our energy portfolio with clean, 21st Century technologies—as technologies have profoundly changed and greatly improved in virtually every other sector of modern life?

Polls consistently show that Midwesterners are ready to seize the opportunities offered by energy efficiency and renewable energy technologies and systems. It is now time—past time, really—for public and private sector leaders to stand up and lead.

Our region's Congressional delegation must lead by insisting upon strong energy efficiency and renewable energy development provisions in energy, agriculture and transportation legislation.

State lawmakers must lead by enacting clean energy development policies, investments and incentives, beginning with "Renewable Portfolio Standards" that require all electric utilities to include a specified percentage of clean renewable energy in the mix of electricity that they supply to consumers.

Strong energy efficiency building codes should be adopted and implemented so that new commercial and residential buildings are constructed to achieve both long-term energy cost savings and pollution reduction benefits.



States should also create Energy Efficiency Investment Funds and Renewable Energy Investment Funds as described in the *Repowering the Midwest* plan. These Funds should be managed by independent and highly capable third-party administrators and overseen by boards that include environmental and consumer representatives.

Governors and their appointed regulators must lead by leveling the electricity playing field so that clean, renewable power can move through the transmission system under fair terms. Electric utilities and other businesses that own and operate transmission lines must not be allowed to discriminate against renewable energy, or impose transmission rate penalties on wind and solar power generation.

County, municipal and school officials must lead by strengthening their building codes and implementing more energy efficiency technologies. Public buildings should be models of energy efficiency both to save money and to reduce air pollution.

Decision-makers at all levels should recognize that increased energy efficiency and clean renewable energy development mean more new jobs and economic gains. There is no trade-off between the environmental and public health benefits from clean energy development and the economic impacts. That is a myth. It is a win-win for the environment and the economy.

Midwestern citizens need to lead as well. We all should understand and recognize that the opportunity for clean energy development is about our clean air and clean water, our healthy lungs, our pocketbooks and our future. In some matters — fashion, entertainment and social mores — the Midwest is said to follow the Coasts. On this matter — our nation's energy future — the bountiful and sensible Midwest region is in a unique position to get out front and lead.

It is time to act. It is time to Repower the Midwest.

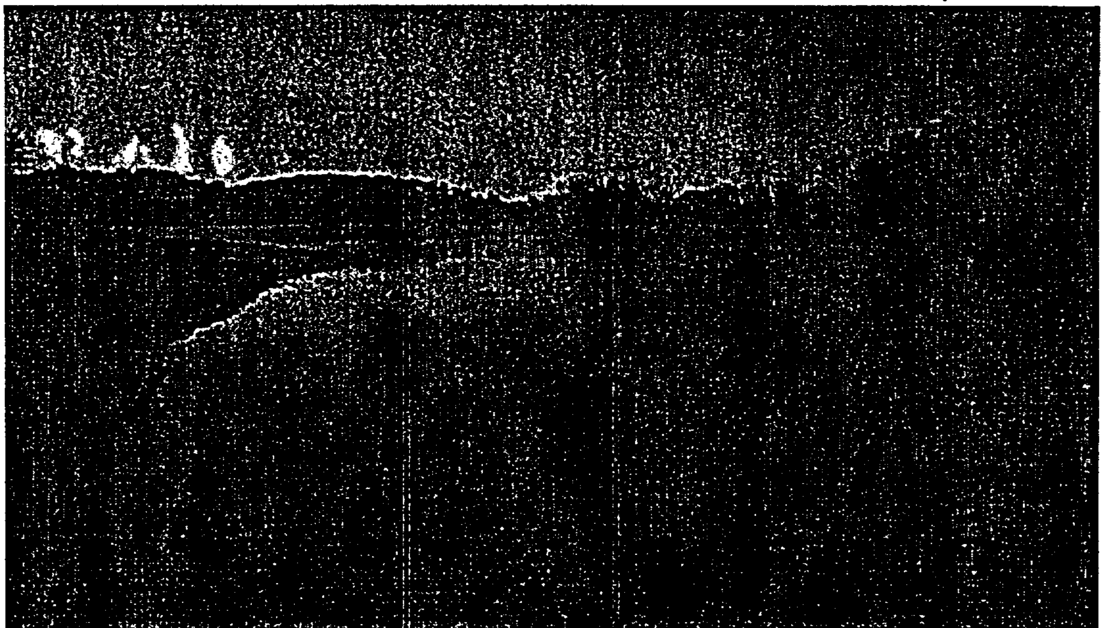
There is no trade-off between the environmental and public health gains from clean energy development and the economic impacts. That is a myth. It is a win-win for the environment and the economy.

ENVIRONMENTAL LAW & POLICY CENTER

Repowering the Midwest: The Clean Energy Development Plan for the Heartland

Repowering the Midwest, released in February 2001, presents the opportunity for the Midwest to develop its homegrown clean energy efficiency technologies and renewable wind, biomass, and solar power resources. The Clean Energy Development Plan achieves large environmental, public health and economic development benefits. Investing in energy efficiency and renewable energy will also diversify the region's electricity portfolio, thereby improving reliability.

To read more about Repowering the Midwest, please look at **www.repowermidwest.org** or call ELPC at **312-673-6500** to request a copy of the report.



The Regional Economics Applications Laboratory (REAL) was formed in 1989 to provide analytical capability to a range of policy and decision makers in the Midwest through the construction and application of economic models of urban, metropolitan and state economies. REAL maintains offices in both Chicago and Urbana. Applications have ranged from impacts of cultural events to implications of gas and steel price increases and, more recently, the role and impact of international trade on interstate trade among the Midwestern state economies.

While the initial focus remains on the Midwest, REAL has constructed models for regional economies in Japan, Indonesia, Korea, Columbia, Chile and Brazil. Personnel are drawn from a diverse set of disciplines, including agricultural economics, economics, geography and urban and regional planning. Many of these researchers are from countries outside North America.

The Environmental Law & Policy Center (ELPC) is the Midwest's leading environmental legal advocacy and eco-business innovation organization. We develop and lead strategic advocacy campaigns to protect natural resources and improve environmental quality. We are public interest entrepreneurs who engage in creative business dealmaking that puts into practice our belief that environmental progress and economic development can be achieved together.

ELPC's strategic approach involves proposing positive solutions when we oppose threats to the Midwest environment. We say "yes" to better solutions; we don't just say "no."

ELPC works to:

1. Promote sustainable energy strategies by developing energy efficiency and renewable energy resources to reduce pollution from coal and nuclear plants that harms our environment and public health;

2. Design and implement smart growth planning solutions to combat sprawl and innovative transportation approaches, such as the development of a Midwest high-speed rail network, that will lead to cleaner air and more jobs; and

3. Advocate sound environmental management practices that preserve natural resources and improve the quality of life in our communities.

REAL and ELPC appreciate the generous financial support provided by the Joyce Foundation to REAL for the economic analysis and related work to produce Job Jolt, and by the Energy Foundation, the Leighty Foundation and the McKnight Foundation to ELPC for its extensive work on Job Jolt.

Union Bug Recycled Soy

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Energy Efficiency and Economic Development in Illinois

Marshall Goldberg, Martin Kushler, Steven Nadel,
Skip Laitner, Neal Elliott, and Martin Thomas

December 1998

Report Number E982

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PREFACE

The American Council for an Energy-Efficient Economy (ACEEE) is a non-profit research organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. It is based in Washington, DC.

ACEEE has been conducting a series of national, state, and regional studies to examine the potential employment and macroeconomic benefits of increased investments in energy technologies. Funding for this study was provided by the Illinois Department of Commerce and Community Affairs.

Many people worked together to produce this report. Steve Nadel served as the project manager and provided overall guidance and review. Marshall Goldberg served as the lead researcher and analyst. He was also responsible for compiling the necessary background data and writing much of the report. To accomplish this he worked with a number of others to develop, coordinate, and refine the efficiency analysis and results. Skip Laitner developed the economic modeling tool and assisted with the macroeconomic analysis. Steve Nadel provided the preliminary modeling tool for the buildings and appliance analysis and review of the necessary data for analysis. Neal Elliot developed the modeling tool for the industrial analysis. Martin Thomas developed the modeling tool and conducted the preliminary analysis for the transportation sector. Marty Kushler wrote the policy section with the assistance of others noted above.

In addition to the ACEEE project team, extensive assistance preparing this report was provided by many other people. In particular we are indebted to David Kramer at the Illinois Department of Commerce and Community Affairs for conceiving the project, providing broad direction, and coordinating input from state agencies. We are also thankful to the many energy efficiency businesses in Illinois who provided information on their operations and to Val Jensen at the Chicago Support Office of the U.S. Department of Energy, Julia Klee at the Joyce Foundation, David Kramer and other Department of Commerce and Community Affairs staff, and Dan Rosenblum at the Energy and Environmental Policy Center of the Midwest for providing helpful comments on a draft of this report. However, while we are thankful for the important contributions of others, their participation does not mean they fully endorse our analysis, conclusions and recommendations; for these the authors retain full responsibility.

EXECUTIVE SUMMARY

The purpose of this report is to better understand how additional investments in energy efficiency technologies can contribute to lower energy expenditures and new employment opportunities for residents of Illinois, as well as generally strengthen economic activity and quality of life.

Energy is needed for light, heating and air conditioning, for production machinery, transportation, and in homes, schools, and businesses. Many of the electricity needs in Illinois have traditionally been met primarily by coal and nuclear power plants with a smaller portion from natural gas, petroleum and hydro resources. Yet, the inefficient use of these energy resources will likely constrain economic activity in Illinois.

High energy costs make the state's businesses less competitive and high energy bills reduce the amount of money the state's consumers can spend on goods and services. When money is spent on energy, much of it leaves the state. When money is spent on other goods and services, much more stays locally, creating economic growth and jobs.

In spite of significant reductions in energy use and real energy prices due to national trends in the past two decades, significant opportunities for cost-effective, energy-efficient investments exist in all sectors of the Illinois economy. Furthermore, many of these investments offer opportunities to improve product quality and productivity and lower operating and maintenance costs. Investments in energy-saving products and practices can lower energy bills for residents and businesses. Lower energy bills, in turn, will promote overall economic efficiency and create local jobs. Investments in energy efficiency can increase cash flow and operating margins, providing businesses a critical competitive edge.

Accelerated investments in energy efficiency will enhance the state's air quality by reducing emissions associated with energy production and use. Investments in energy efficiency can encourage the development of new, clean, energy-saving technologies and industries in Illinois. Improvements in energy efficiency can also help protect the state against the impacts of possible new taxes on pollutants contributing to global climate change and other air quality problems and help offset the need for spending on pollution control technologies.

In 1995, consumers in Illinois spent approximately $23 billion to provide heat, light, power, and transportation for their homes, schools, and businesses. To put these totals in perspective, energy bills were 40 percent higher than state tax collections in that year. Many community and business leaders are looking for ways to use state tax dollars more efficiently. The size of the total energy bill suggests that Illinois policy makers may also want to explore ways to use energy more efficiently.

This report examines the current energy consumption patterns and expenditures within the Illinois economy. It projects what "business-as-usual" or "baseline" energy patterns might look like through the year 2015. These findings suggest that by 2015 the state as a whole will be approximately 6 percent more efficient in how much energy it uses to support a dollar of economic activity (compared to 1995 as measured by Gross State Product [GSP]) due primarily to the fact that new equipment and buildings are generally more efficient than aging equipment and facilities that will be replaced over the next decade. But the findings also show that total energy consumption will increase by 28 percent as a result of a growing economy.

The study then develops two high-efficiency scenarios (one for total energy consumption and one for electricity consumption only) for the region through the year 2015. These high-efficiency scenarios are based upon detailed analysis of energy efficiency potential in buildings in the residential, commercial, and industrial sector (including industrial process improvements), as well as efficiency improvements in light duty vehicles in the transportation sector. The analysis provides estimates of the investments needed to achieve these additional energy savings as well as the resulting economic and environmental benefits.

The findings of the study show that by 2015, cost-effective investments in energy efficiency in Illinois can:

- Reduce energy use in Illinois by just under 32 percent, reducing consumer and business energy bills by more than $76 billion cumulatively over the 1999-2015 period;
- Create 59,400 jobs; and
- Reduce emissions of critical air pollutants by up to 30 percent, helping to improve environmental quality.

In other words, the untapped potential for energy efficiency represents a critical economic development and environmental protection strategy for Illinois. Increased investments in energy efficiency are an important step toward promoting a sustainable energy future for Illinois. More specific findings of the report include:

- Cost-effective investments in energy efficiency technologies can reduce energy use by just over 31 percent in 2015 relative to the baseline, including 43 percent reductions in electricity use and over 25 percent in fossil and other fuels outside of the utility sector.
- The additional investment in energy efficiency will increase Illinois' employment base — from a net increase of 20,700 jobs in the year 2005 to a net increase of 59,400 jobs by the year 2015. The rise in employment, driven largely by the spending of energy

bill savings, is equivalent to the number of jobs supported by the expansion or relocation of almost 400 small manufacturing plants in Illinois. Wage and salary compensation would similarly rise by a net of $1.6 billion by 2015 (in 1995 dollars), the equivalent of tourist expenditures from approximately 10.8 million visitor days.

- As a result of these additional energy savings, Illinois ratepayers would enjoy cumulative energy bill savings of $76.3 billion over the 1999-2015 period. The high-efficiency scenario will require a $37.8 billion cumulative investment over the same period of time. This relatively small level of investment (less than 1 percent of the state's cumulative GSP over the period) can be achieved by redirecting a small portion of other investments toward productive energy investments. Only a small portion of these investments will be financed by government or through electricity rates; the vast majority of funds will come from homeowners and businesses making cost-effective investments in their homes and facilities. With all values in 1995 dollars, the energy efficiency scenario generates a positive benefit-cost ratio of 2.02 over the 17-year period of analysis. But even this value understates the cost effectiveness of the energy savings investments since the energy savings and environmental benefits will continue for many years after the year 2015.

- The alternative energy strategy would have a positive benefit for the state's air quality as well. Carbon dioxide emissions, which contribute to global climate change, would be reduced by over 85 million short tons in 2015. Energy related pollutants such as sulfur and nitrogen oxides would be reduced by over 700 thousand short tons in 2015, also providing significant reductions over baseline emissions.

Many of these findings are summarized in Table ES-1 on the following page.

Table ES-1. Summary of Input-Output Analysis For 2015	
	Illinois
Baseline Scenario	
GDP (Billion 1995$)	$479
Jobs (Thousands)	7,993
Income (Billion 1995$)	$388
Energy (Trillion Btu)	4,853
Btu/GDP (1995$)	10,136
Carbon Dioxide Emissions (Thousand Short Tons)	290,200
High-Efficiency Scenario	
GDP (Billion 1995$)	$478
Jobs (Thousands)	8,053
Income (Billion 1995$)	$390
Energy (Trillion Btu)	3,330
Btu/GDP (1995$)	6,966
Carbon Dioxide Emissions (Thousand Short Tons)	204,930
Net Efficiency Gains	
GDP (Billion 1995$)	($0.7)
Jobs (Thousands)	59
Income (Million 1995$)	$1,620
Energy (Trillion Btu)	(1,523)
Btu/GDP (1995$)	(3,170)
Carbon Dioxide Emissions (Thousand Short Tons)	(85,270)

Notes: Individual columns may not add up due to rounding.

However, achieving these benefits will not be easy. Policy makers and business leaders will need to play an active role in helping to develop and implement a series of initiatives to make the high-efficiency scenario a reality. The types of actions should include:

- Developing strong and well designed policies to ensure that energy efficiency services play a major role in Illinois' restructured utility industry. These include a substantial "system benefits charge" to fund greater levels of energy efficiency, and carefully structured regulatory mechanisms for distribution utilities to make sure that these utilities have incentives to pursue cost-effective energy efficiency.

- Implementing strong building energy codes for residential and commercial buildings, including adoption of BOCA 1996 (including the residential Model Energy Code and the ASHRAE 90.1 code for commercial and high rise residential buildings), with the Illinois-specific increased lighting and chiller efficiencies described in the report.

- Developing and instituting a comprehensive and systematic set of policies to encourage industrial energy efficiency. These would include mechanisms and techniques for: opportunity identification, technical and design assistance, financial analysis, financing, operation improvements, promoting advanced technologies, and facilitating the adoption of combined heat and power (CHP) technologies.

- Promoting wherever possible policies which would improve the fuel economy of cars and light trucks operated in Illinois. These include incorporating "best in class" vehicle efficiency as an important criterion in state and municipal fleet decisions, and exploring creative policies such as "feebates" to encourage the purchase of fuel efficient vehicles. In addition, promoting policies that discourage urban sprawl and increased use of mass transit will help reduce transportation related energy use.

- Creating a Sustainable Energy Development Agency in Illinois that would fund applied R&D and demonstrations of advanced energy efficiency and renewable energy technologies; fund technology and market assessments; and provide support for technology transfer and commercialization. The agency could also help the state's utilities and state agencies in the design and evaluation of energy efficiency and renewable energy programs, and possibly assist with training or technical assistance concerning building code implementation or improving industrial energy efficiency.

I. INTRODUCTION

The state of Illinois is blessed with many resources. In addition to its historical sites and natural beauty, Illinois is home to a strong and diverse commercial and industrial center. The diversity of activities and healthy business climate combine to make Illinois both a popular tourist destination and a desirable place to live and work. However, while the state's population growth has been relatively modest, energy consumption continues to rise.

Energy is needed for light, heating and air conditioning, for production machinery, transportation, and in homes, schools, and businesses. Many of these energy needs have traditionally been met primarily by coal and nuclear power plants with a smaller portion from natural gas, petroleum and hydro resources. Yet, the inefficient use of these energy resources will likely constrain economic activity in Illinois. This, in turn, will reduce the state's capacity to provide new employment opportunities for its residents. Alternately, the efficient use of energy will create jobs and help reduce environmental degradation.

Residents and businesses in Illinois are faced with electric utility rates and annual bills above the national average. Despite the size of their electricity bills, few people understand the magnitude of energy expenditures within their individual home or business. One interesting way to underscore the importance of those expenditures is to compare them with the amount of taxes collected by state government.

One recent study notes that Illinois residents and businesses spent over $23 billion to meet their total energy needs in 1995. In contrast, Illinois collected an estimated $16.6 billion in state-generated taxes in that year. Thus, energy bills in Illinois are the equivalent of 140 percent of all the state taxes collected.[1] While citizens and public officials are asking good questions about how better to spend their state tax dollars, they often ignore the equally important issue of how to more efficiently use their energy resources.

The inefficient use of energy raises the cost of living and doing business in Illinois. As a result, it will continue to act as a brake on the state economy — offsetting other economic development and environmental initiatives. For these reasons, efforts to accelerate investments in energy efficiency technologies are generating interest in Illinois and throughout the nation.

1. See *Comparing State Energy Expenditures with State Government Tax Collections*, Economic Research Associates, Alexandria, VA, 1998. The data are for calendar year 1995, the latest year for which information on both energy expenditures and tax revenues are available. Taxes and energy bills overlap to a moderate degree as approximately 8 percent of regional energy bills go to state energy taxes.

The importance of maximizing energy efficiency as a strategy for enhancing both environmental quality and economic development opportunities is evidenced by the findings of many recent studies. Promoting energy efficiency investments not only cuts costs for the user, but it reduces pollutant emissions and yields positive benefits for the larger economy.[2]

In spite of the economic benefits documented by these recent studies, many states have been slow to develop and implement energy efficiency technologies and renewable energy resources. One reason is the significant up-front investment needed in order to reap full advantage of these alternative resources. In short, it takes money to make money.

Unfortunately, alternative energy strategies are also forced to compete against the significantly larger federal and state tax subsidies given traditional energy resources such as coal, oil, and nuclear.[3] Also, in contrast to many other business investments, the benefits of energy efficiency investments tend to be diffuse, accruing to many people over the long run rather than for a few investors in the short run.

New policy initiatives can go a long way to overcome the bias of present energy subsidies and provide energy efficiency and renewable energy technologies with the level playing field needed to encourage their widespread adoption. These same policies can also help bolster public trust in state energy decision making. In survey after survey, when voters are asked to rank energy sources from those most to least in need of government encouragement, energy efficiency and renewable energy come out at the top of the list and fossil fuels and nuclear power at the bottom of the list.

For example, in a December 1996 survey by the Republican pollster Research/Strategy/Management, Inc., when asked to select the energy source that should be the highest priority for U.S. Department of Energy funding, two-thirds selected energy

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2. Among others, see *Energy Innovations: A Prosperous Path to a Clean Environment*, Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, Washington, DC, 1997; H. Geller, J. DeCicco and S. Laitner, *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*, American Council for an Energy-Efficient Economy, Washington, DC, 1992; S. Nadel, S. Laitner, M. Goldberg, N. Elliot, J. DeCicco, H. Geller, and R. Mowris, *Energy efficiency and Economic Development in New York, New Jersey, and Pennsylvania*, American Council for an Energy-Efficient Economy, Washington, DC, 1997; and S. Laitner, J. DeCicco, N. Elliott, H. Geller, M. Goldberg, R. Mowris, and S. Nadel, *Energy Efficiency and Economic Development in the Midwest*, American Council for an Energy-Efficient Economy, Washington, DC, 1995.

3. See, for example, D.N. Koplow, *Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*, Alliance to Save Energy, Washington, DC, 1993. According to this study, federal energy subsidies alone totaled $39 billion in 1989. Fossil and nuclear resources received 88 percent of this amount, while energy efficiency and renewable energy resources received only 12 percent of the benefit. Determining the actual benefits to Illinois from these subsidies is difficult and beyond the scope of this study. Nevertheless, the near total reliance on traditional energy resources in Illinois suggests that the cost to Illinois (absent these subsidies) would be significant.

efficiency or renewable energy and only one-third selected natural gas, other fossil fuels, or nuclear power.[4]

The purpose of this report is to better understand how additional investments in energy efficient technologies can contribute to lower energy expenditures, new employment opportunities for residents of Illinois, and generally strengthened economic activity and quality of life. Recognizing that energy consumption and expenditure patterns depend upon the social and economic makeup of a state or region, Appendix A provides a brief economic profile of Illinois and background information on the state's energy use patterns. It includes information on energy resources, expenditures, and electricity consumption in Illinois.

We see that energy expenditures play an important role in Illinois. Although energy intensity (i.e., energy use per dollar of Gross State Product) is lower in Illinois than the national average (10,779 Btu per $GSP versus 12,527 Btu per $GSP in 1995), energy prices are higher than the national average — 2.7 percent higher in 1995. Overall, Illinois spent a combined total of over $23 billion on energy in 1995. These energy expenditures represent the equivalent of almost 7 percent of the state's combined GSP. In 1995, Illinois' electricity bill was almost $9.7 billion, followed by $9.1 billion for petroleum, primarily for transportation uses.

Energy policies designed to increase energy efficiency can go a long way towards reducing these expenditures. These same policies can reduce economic leakages for imported fuels, foster a more competitive environment for the state's industries, and provide environmental benefits for all.

The balance of this report expands on these themes. Section II provides a profile of some of the manufacturers and suppliers of these energy efficiency technologies and services in Illinois. Section III develops both a business-as-usual (baseline scenario) and a series of two high-efficiency scenarios for the state through the year 2015. It provides an estimate of the investment needed to achieve the resulting energy bill savings in the high-efficiency scenario based upon detailed analysis of the energy efficiency potential in each end-use sector.

Section IV summarizes the analytical method used to identify the net employment gains and other net economic benefits from the high-efficiency scenario. Section V presents the results of the economic impact analysis. Section VI identifies some of the past and current policy initiatives designed to promote energy efficiency improvements. The report then offers specific policy recommendations to help Illinois secure the full benefits of greater energy

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4. R. Hinckley and V. Breglio, *America Speaks Out on Energy: A Survey of 1996 Post-Election Views*, Research/Strategy/Management Inc., Lantham MD and Sustainable Energy Coalition, Takoma Park, MD, Dec. 1996.

efficiency. Finally, Section VII draws some brief conclusions and summarizes the policy recommendations needed to capture the greater efficiency potential.

II. PROFILES OF MANUFACTURERS OF ENERGY EFFICIENCY TECHNOLOGIES IN ILLINOIS

Saving energy creates and helps retain jobs in a number of ways. First, jobs are directly created and retained from manufacturing, selling, and installing energy efficiency measures. In addition, many jobs are indirectly created and retained when consumers respend energy bill savings in sectors of the economy that are more labor-intensive then producing and supplying electricity and fossil fuels. There are a large number of companies in Illinois that manufacture and/or install energy efficiency technologies.

The following brief profiles demonstrate that energy efficiency technologies are a growth area for many manufacturers. In some instances, millions of dollars have been invested to design and produce high-efficiency products. In other cases, existing plants have been expanded to meet rising demand for high-efficiency products. The case studies presented below are only a small sampling of the many companies currently doing business in Illinois. These case studies include both Fortune 500 corporations and smaller entrepreneurial firms in order to give a flavor of the direct job creation and job retention potential from energy efficiency technologies and services.

Honeywell, Inc.

Honeywell's Microswitch Division is located in Freeport, Illinois. Microswitch is a leading manufacturer of component parts for ventilation, control, and security systems. Among a number of other products, Microswitch manufacturers thermostats for building control systems, switches and sensors for industrial control applications, turbidity sensors and switches for high efficiency dishwashers (to help reduce water usage and process times), and is moving into industrial controls for batch processes to improve productivity and efficiency in industries such as pulp and paper, gas and oil, and chemicals.

Components produced at Microswitch supply a number of other Honeywell divisions as well as other equipment manufacturers throughout the world. Combined, Honeywell now employs approximately 2,700 persons in Illinois, primarily at their Freeport plant, but also including employees at their nearby Galena branch plant and sales and service persons in other areas of the state.[5]

Motorola Corp.

Motorola Lighting Division, headquartered in Buffalo Grove, Illinois, is now a major manufacturer of high quality electronic ballasts. Motorola has approximately 300 employees

5. Personal communications with Paula Prahl, Honeywell, Inc., Minneapolis, MN, August 1998.

in manufacturing and engineering in the Buffalo Grove area. Motorola began manufacturing here in 1991. Employment rose slightly in recent years as a result of production of other energy-efficient lighting products.[6]

Maytag Corporation

Maytag—Galesburg Refrigeration Products, is located in Galesburg, Illinois. The plant's manufacturing operations are focused on producing top-mount and side-by-side refrigerators. Brand names produced at the plant include Maytag, Admiral, Jenn-air, and Magic Chef, and are sold in more than 160 countries. In 1993, Maytag Corporation announced the investment of $180 million in the Galesburg facility to design and produce a totally new line of super efficient refrigerators known as Advance Performance Design (APD). New advanced equipment was purchased and installed to build the new manufacturing line. With the upgrade and expansion complete, the new top-mount refrigerators were introduced in March 1997 and the new side-by-sides in 1998.

The Maytag plant is the single largest employer in the area. Maytag employment has grown in recent years and Maytag now employs more than 2,400 employees in Galesburg. The total plant payroll exceeds $70 million annually. Maytag also manufactures washers and dryers at their facility in Herrin, Illinois. The Herrin plant employs an additional 870 persons.[7]

Duray Fluorescent Mfg.

Duray Fluorescent has been manufacturing fluorescent light fixtures in Chicago since 1946. Duray purchases most of their parts and does all the fixture assembly on-site. Fixtures are primarily for residential and commercial applications. Duray now employees approximately 100 persons.[8]

Siemens and Furnas Controls

Siemens and Furnas manufacture motor controls primarily for the industrial sector. They have three locations in Illinois, including plants in Batavia, West Chicago, and Morrison. The Batavia plant manufactures starters, push buttons, and pressure switches, and employs over 500 persons. The West Chicago plant manufactures controls for large motors and employs

6. Personal communications with Regina Manitote, Motorola Lighting Division, Buffalo Grove, IL, July 1998.

7. Personal communications with Jacky Kronstad, Maytag Marketing Information Analyst, Galesburg, IL, July 1998.

8. Person communications with Robin Weissberger, Duray Fluorescent Mfg., Chicago, IL, August 1998.

another 450 persons. The Morison plant manufacturers coils and other controls for motors and employees approximately 200 persons.[9]

Cooper Lighting

Cooper Lighting is located in Elk Grove, Illinois. Cooper produces lighting fixtures and lamps for residential, commercial, and industrial applications. They have more than 500 employees.

Siebe Environmental Controls

Siebe Environmental Controls is located in Loves Park, Illinois. Siebe, a division of the English Company, manufactures heating, ventilation, and air conditioning controls primarily for commercial applications. Siebe also has a sales and service location for temperature controls in Mt. Prospect, IL. Combined, Siebe employs a total of more than 2,000 persons in Illinois.[10]

Energy Masters International, Inc.

Energy Masters International (EMI), a subsidiary of Northern States Power Company, is an energy services company (ESCO). EMI, based in St. Paul, Minn., has maintained offices in Illinois for almost 10 years. The company offers a full range of services including providing energy auditing and design engineering, project and construction management, customized energy services, professional engineering, asset management, and other services to businesses and government customers throughout the country.

EMI, through its Chicago area field office, was selected to improve the energy efficiency of the facilities at Governors State University (GSU) located in Chicago's south suburbs. EMI was awarded a contract (estimated to be roughly $2 million) by GSU to improve the energy efficiency of four buildings. The company will improve the heating, ventilating and air conditioning (HVAC) systems and install new lighting. Energy savings at the university are projected to exceed $2,85 million over a 10-year period. EMI was also recently awarded a $15 million energy services contract with the Chicago Public Schools. EMI will replace existing electric heating with high-efficiency natural gas units and install efficient lighting and energy controls at 11 elementary and high schools during the next year.

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9. Personal communications with Sue Weiler, Human Resources, Siemens & Furnas Controls, Energy and Automation Group, Batavia, IL, August 1998.

10. Personal communications with Siebe Environmental Controls, Loves Park, IL, August 1998.

In addition to these projects EMI has completed energy efficient upgrades at a number of other institutional and commercial sites in Illinois. Among others, these include; Menard Correctional Center, Eastern Illinois University, St. Mary's Hospital, and Trinity Hospital.

EMI has been increasing its number of employees annually and expects this trend to continue. Currently, EMI employs a total of approximately 110 persons in Illinois. This number includes: engineers, installers, construction managers, administrative staff, sales and marketing staff, as well as management personnel.[11]

11. Personal communications with Energy Masters International, St. Paul, MN, in August 1998; personal communications with Virginia Tate, Chicago Division Manager, in September 1998; and information contained in "EMI Selected For Governors State University Energy Improvement Program," *PRNews Wire*, May 13, 1998.

III. Energy Consumption Scenarios

This section of the study offers an insight into what an energy-efficient future might look like – both in terms of the needed investment to develop energy efficient technologies and in terms of the energy bill savings that might accrue from such investments.

The section begins by mapping out three energy scenarios: a baseline growth projection and two high-efficiency scenarios. The baseline projection of energy consumption in Illinois builds on historic energy use patterns and then adapts projections for residential, commercial, and industrial building growth trends as well as projections for vehicle fuel economy and miles traveled.

The first alternative scenario includes efficiency investments among all major energy resources in the period 1999-2015. The second examines efficiency investments only in electricity end-uses. It should be noted that the intent of the analysis is not to "forecast" energy trends but to "project" reasonable energy use patterns for purposes of evaluating the impact of a high-efficiency scenario.

A. Baseline Energy Consumption Scenario

We began by establishing a baseline projection of energy consumption patterns in the period 1995-2015, assuming current trends and policies are continued. A variety of Energy Information Administration (EIA) and Census data from the *City and County Data Book* were used for this purpose.[12] The starting point for the baseline projection was the actual primary energy use in Illinois in 1995. These statistics covered energy use in the residential, commercial, industrial, and transportation sectors.[13]

The projected changes in energy consumption in the residential and commercial sectors reflect an analysis of residential and commercial building prototypes. This analysis was developed by ACEEE using the DOE-2.1E building energy simulation computer program.[14] For each prototype, average 1995 energy use was estimated and then multiplied by the number of buildings of that type in Illinois.

12. *City and County Data Book*, U.S. Department of Commerce, U.S. Census Bureau, Washington, DC, 1995.

13. See *State Energy Data Report 1995*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1997.

14. Use of the DOE-2.1E model and the data assumptions that underpinned the analysis are documented in a June 1994 unpublished technical memorandum prepared for ACEEE by Robert Mowris, a consulting engineer based in Orinda, CA. More details of the buildings analysis are provided in Appendix B of this report.

In this analysis total energy use in the residential sector is forecast to grow at a rate of 0.44 percent annually in the period 1995-2015. These trends are significantly slower than the annual 0.97 percent national growth estimate for the residential sector projected in the Energy Information Administration's *Annual Energy Outlook 1998* (AEO98) and reflect Illinois-specific growth trends in homes over the 1980-92 period. The growth in housing stock was adjusted by a 0.6 percent demolition and replacement rate.[15]

The energy growth rate for the commercial sector was based on trends in new floor area in the region for 1990-95, taken from the *Commercial Building Energy Consumption and Expenditures 1995* (CBECS).[16] The energy growth rate for the commercial sector was forecast to increase approximately 0.89 percent annually. This rate is essentially the same as the national growth rate of 0.90 percent annually in the AEO98.

Based on an analysis of vehicle miles traveled and fuel efficiency improvements, transportation energy growth was forecast to grow approximately 2.3 percent annually in Illinois. This rate is somewhat higher than the 1.9 percent national growth rate in the AEO98, although in recent years the AEO has under forecast transportation energy use. Transportation uses of electricity were omitted in this analysis.

For electricity only, it was found that the annual growth rate for residential uses would increase approximately 0.74 percent. Commercial uses were forecast to increase approximately 0.92 percent annually. Our baseline estimates project that electricity consumption in both of these sectors will increase somewhat slower than the AEO98 forecasts for the nation of 0.96 and 1.03, respectively.

Because the industrial sector represents a group of end-users that is significantly different at the state level than at the national level, a different approach was used. As described in more detail below, the result was a projected annual industrial growth rate of 1.37 percent for total energy and 1.46 percent for electricity use. The AEO98 projects a slightly smaller increase of 1.21 percent annually for all end-uses in the industrial sector and a somewhat smaller 1.03 percent annual increase for electricity end-uses only.

Figures 1 through 3 highlight the overall trends for the baseline projections and alternative efficiency scenarios in the period 1995-2015. Figure 1 identifies total energy consumption,

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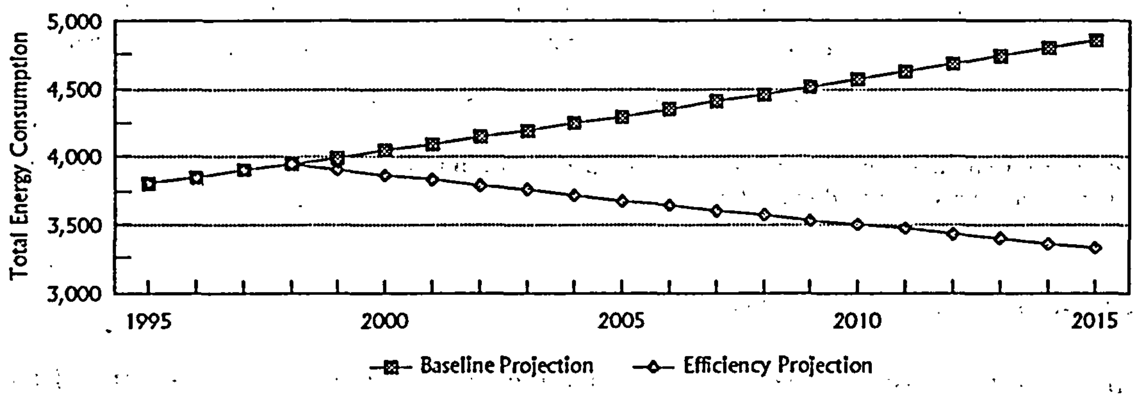
15. These rates are based on information contained in the *Annual Energy Outlook 1998*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1997, and S. Nadel and H. Tress, *The Achievable Electricity Conservation Potential: The Role of Utility and Non-Utility Programs*, American Council for an Energy-Efficient Economy, Washington, DC, 1990.

16. *Commercial Buildings Energy Consumption and Expenditures 1995*, Energy Information Administration, U.S. Department of Energy, Office of Energy Markets and End Use, Washington, DC, 1998.

Figure 2 shows electricity only consumption, and Figure 3 displays transportation fuels consumption.

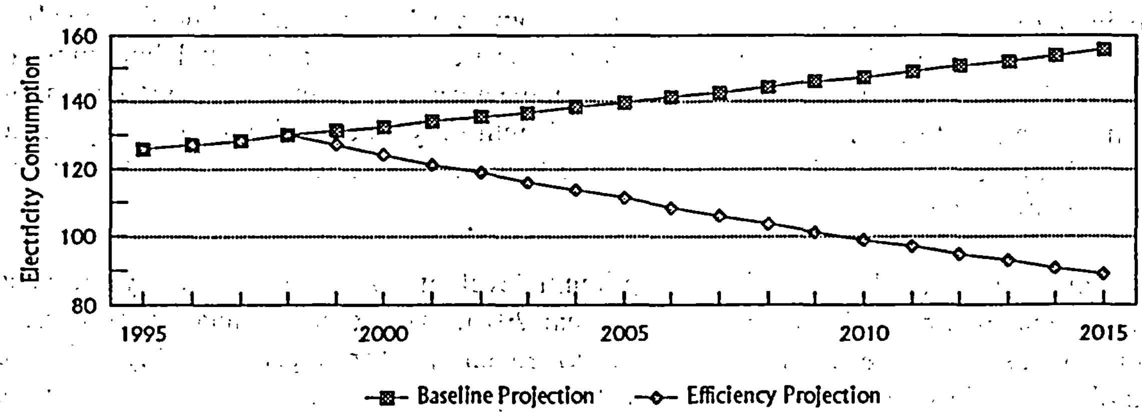
Using the sectoral growth assumptions, we project that total primary energy use will rise from 3,804 TBtu in 1995 to 4,853 TBtu in 2015, a 28 percent increase in consumption over that period. This trend is illustrated as the "Baseline Projection" in Figure 1 below.

FIGURE 1. ILLINOIS TOTAL ENERGY SCENARIO (IN TBTU)



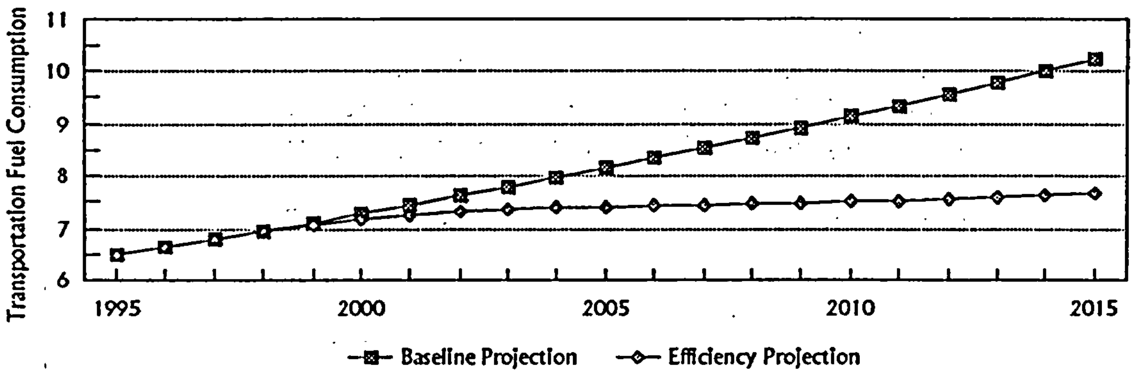
Electricity use is projected to rise from 126 billion kilowatt-hours (kWh) in 1995 to 155 billion kWh in 2015, a 23 percent increase in consumption over that same period. The baseline electricity trend is illustrated as the "Baseline Projection" in Figure 2 below.

FIGURE 2. ILLINOIS ELECTRICITY SCENARIO (IN BILLION KWH)



Finally, the growth of transportation fuels was projected to increase from 6.5 billion gallons in 1995 to 10.2 billion gallons in 2015, a 58 percent increase. The baseline growth in these transportation fuels is illustrated as the "Baseline Projection" in Figure 3 on the following page.

FIGURE 3. ILLINOIS TRANSPORTATION SCENARIO (IN BILLION GALLONS)



Source: Data for all three figures were developed by the American Council for an Energy-Efficient Economy based upon assumptions described in the text.

B. HIGH-EFFICIENCY SCENARIOS

The efficiency trends for both the total energy and the electricity-only scenarios were adapted from scenarios that build on assumptions about cost-effective energy efficiency investments. The data are taken from a variety of industry and other published sources. For the most part, the efficiency scenarios are based upon technologies that are now cost-effective and available in the marketplace. A few of the energy efficiency measures are advanced technologies that are expected to be available in the near future.

To build the energy efficiency scenarios, the economy was disaggregated into the four basic end-use sectors as in the baseline projections. These are: (1) residential buildings, (2) commercial buildings, (3) industrial applications in the agricultural, mining, construction, and manufacturing sectors; and (4) automobiles and light-duty trucks within the transportation sector. Analytical models unique to each of the four end-use sectors were used to construct the efficiency scenarios.

The analysis attempted to identify an optimum level of cost-effective energy efficiency improvements that could be obtained by the year 2015. The economic analysis (for energy efficiency) assumed the amortized cost of saved energy for a given energy efficiency technology would be less than or equal to the long-run retail cost of conventional energy resources. For the purpose of this analysis, long-run energy prices (with the exception of electricity prices) in real terms are assumed to be level with the 1995 price paid by each end-use sector in Illinois for each energy resource.

Electricity prices in the residential, commercial, and industrial sectors are assumed to decline approximately 10 percent below 1995 prices. These assumptions are broadly consistent with the latest Energy Information Administration forecast contained in AEO98, which forecasts that electricity prices in 2015 will be lower than 1995 levels, and rate reductions which are expected to take place in Illinois as a part of deregulation.[17]

Each efficiency investment is assumed to be amortized over its effective life using a 5 percent real discount rate. For example, installing more efficient lighting fixtures in an existing office building might reduce electricity consumption annually by about 4.73 kWh per square foot of occupied space at a cost of $0.50 per square foot. Once the change is made, the equipment can be expected to last 20 years.

At a 5 percent discount rate, the investment would be amortized at a rate of 8.02 percent annually.[18] Thus, the annualized cost is $0.50 times 0.0802, or $0.0401 per square foot. Saving 4.73 kWh implies a cost of saved energy (CSE) of $0.0401 divided by 4.73, or $0.0085 per kWh. Since the 1995 commercial cost of electricity in Illinois was approximately $0.073 per kWh, this particular measure would clearly be considered cost effective. All technology choices were treated in this manner. A more complete description of the end-use analyses and the assumptions that feed into that analysis follows.

An important caveat should be noted at this point. The intent of the high-efficiency scenario is to construct a reasonable profile of investments and energy use impacts, assuming that cost-effective efficiency measures are widely adopted over the 17-year period of the analysis (i.e., 1999-2015). Hence, this analysis is not a forecast of what will likely occur given current trends. The high-efficiency scenarios represent, however, a highly possible energy future and, as we will show, a desirable economic future for Illinois.

The "Efficiency Scenario" shown in Figure 1, suggests that consumption for total primary energy in the year 2015 could be lowered by just over 31 percent, from 4,957 TBtu to only 3,330. This would put Illinois' total energy consumption at almost 13 percent below its 1995 level. The "Efficiency Scenario" for electricity shown in Figure 2, suggests that electricity consumption could be reduced by 43 percent, or about 30 percent below the 1995 levels. The

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17. EIA's latest forecast estimates that electricity prices will decline by an average of 1.1 percent annually, natural gas prices will increase by an average of 0.1 percent annually, and petroleum product prices will increase by an average of 0.5 percent annually. See *Annual Energy Outlook 1998*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1997, Table 3. Current legislation for utility deregulation in Illinois mandates that residential electricity rates will decline by as much as 15 percent for many residential customers of regulated utilities with more than 12,500 customers. The 15 percent reduction currently applies to two of the state's utilities. Residential rates at four other utilities serving Illinois will also decline, but by a smaller percentage. For more information on deregulation legislation in Illinois see, House Bill 362, House Bill 1817, and Senate Bill 56. These bills are available for viewing on the Illinois Commerce Commission web site at http://icc.state.il.us/icc/dereg/.

18. This is based upon the standard amortization formula, $I/(1-(1/(1+I)^n))$, where I is the discount rate and n is the life of the measure.

transportation "Efficiency Scenario" shown in Figure 3, suggests that transportation fuels could be reduced by 25 percent, or about 18 percent above the 1995 levels.

Table 1, on the following page, summarizes both the cumulative investment required for each major end-use sector to achieve the 31 percent total energy savings, the 43 percent electricity savings, and the 25 percent savings in transportation fuels, over the 17-year period from 1999-2015. It also highlights the cumulative energy bill savings for the state as well as the benefit-cost ratios associated with each end-use sector. This ratio understates the overall cost-effectiveness (from the consumer perspective) of the energy efficiency investments in the region because energy savings will continue well beyond 2015.

1. Building Efficiency

ACEEE developed residential and commercial building prototypes using the DOE-2.1E building energy simulation program.[19] Building prototypes were developed using prototypes from a 1995 ACEEE study on the Midwestern states modified with data from the 1997 ACEEE study on the Mid-Atlantic states.[20] The residential prototypes were augmented by an ACEEE analysis of the costs and savings of a variety of appliance efficiency improvements pertaining to water heaters, clothes washers and dryers, refrigerators, freezers, dishwashers, and lighting. The appliance and efficiency measures analyzed in the residential and commercial building prototypes are not meant to be all inclusive, rather they are meant to capture a large portion of potential efficiency measures.

Four residential and eight commercial building prototypes were developed. The residential prototypes include Existing Multifamily Apartment, New Multifamily Apartment, Existing Single Family Detached, and New Single Family Detached. The commercial prototypes included Existing Medium Office, New Medium Office, Existing Medium Retail, New Medium Retail, Existing School, New School, Existing Warehouse, and New Warehouse.

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19. Use of the DOE-2.1E model and the data assumptions that underpinned the analysis are documented in Appendix B of this report.

20. See S. Laitner et al., *Energy Efficiency and Economic Development in the Midwest*, American Council for an Energy-Efficient Economy, Washington, DC, 1995; and S. Nadel et al., *Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania*, American Council for an Energy-Efficient Economy, Washington, DC, 1997.

TABLE 1. CUMULATIVE EFFICIENCY INVESTMENTS AND SAVINGS: 1999-2015 (IN BILLIONS OF 1995 DOLLARS)

	Residential	Commercial	Industrial	Transportation	Total
Full-Efficiency Scenario					
Investment	$11.3	$5.2	$12.7	$8.7	$37.8
Savings	$20.7	$13.3	$17.9	$24.4	$76.3
Benefit-Cost Ratio	1.84	2.57	1.41	2.80	2.02
Electricity Only Scenario					
Investment	$3.7	$4.5	$8.0	NA	$16.3
Savings	$9.2	$12.3	$12.7	NA	$34.3
Benefit-Cost Ratio	2.50	2.72	1.58	NA	2.11

Notes: Energy investments, savings, and benefit-cost ratios are based on the 17-year study period. Had the analysis been extended to include the savings over the life of the measures, rather than limited to the study period, the respective savings and benefit-cost ratios would have been greater

For weather-sensitive heating and cooling loads, weather patterns for the East North Central Census Region were used to adapt the DOE-2.1E model.

Each prototype incorporates average 1997 saturation levels of many energy efficiency measures. For each prototype we then applied a series of additional energy efficiency measures and estimated how much energy would be saved using DOE-2.1E. Aggregate energy savings potential is estimated by applying that measure in the proportion of the building stock for which that measure was appropriate (i.e., had not been installed yet, was technically feasible, and cost effective to consumers on a life-cycle cost basis).

Measures were applied sequentially in order of cost effectiveness (as measured by cost of saved energy) up to the cost-effectiveness limit (i.e., when cost of saved energy equals current retail energy prices adjusted for the 10 percent electricity rate reduction in the residential sector, noted earlier). Savings estimates for each measure are incremental savings not achieved by any previous measure. Tables reporting these results for each of the prototypes are contained in Appendix B. Key summary information for each of the prototypes are reported in Table 2, on the following page.

Table 2. Summary Data from Building Efficiency Analysis

Building Type	Baseline Electric kWh/unit	Baseline Gas kBtu/unit	Electric Saved kWh/unit	Gas Saved kBtu/unit	Electric Savings (percent)	Gas Savings (percent	Total Savings (percent	Effic. Invest ($/unit)	1st yr Savings ($/unit)	Simple Payback (years)	Cost of Svd Energy ($/MMBtu)
Residential (units = dwelling units)											
Existing											
Single family	10,213	215,800	3,264	147,421	32.0%	68.3%	56.2%	$7,134	$978	7.3	$2.69
Multifamily	6,066	93,089	2,141	51,708	35.3%	55.5%	47.3%	$3,295	$436	7.6	$2.05
New											
Single family	10,688	112,700	2,943	55,209	27.5%	49.0%	38.3%	$1,898	$527	3.6	$2.55
Townhouse	6,000	69,490	2,133	24,544	35.5%	35.3%	35.4%	$1,490	$311	4.8	$2.45
Commercial (units = sq. ft. of floor area)											
Existing											
Office	17.5	62.5	10.9	15.0	62.1%	24.0%	52.4%	$2.98	$0.82	3.6	$1.74
Retail	12.1	48.8	5.4	3.3	44.8%	6.8%	34.3%	$0.85	$0.39	2.2	$1.13
School	8.7	85.2	3.4	11.2	39.5%	13.2%	26.8%	$1.70	$0.29	5.9	$3.01
Warehouse	5.9	55.3	2.6	7.7	44.4%	13.8%	30.0%	$1.11	$0.21	5.2	$2.67
New											
Office	13.0	36.2	6.9	-3.2	53.1%	-8.8%	40.2%	$0.95	$0.46	2.1	$1.11
Retail	9.9	27.7	4.0	-0.2	39.9%	-0.8%	31.4%	$0.87	$0.27	3.2	$1.52
School	6.7	67.9	1.5	3.6	22.9%	5.4%	14.3%	$0.62	$0.12	5.1	$2.71
Warehouse	5.0	41.0	1.9	2.6	37.6%	6.4%	23.9%	$0.71	$0.14	5.0	$2.65

Notes: All energy values and prices reflect primary rather than end-use perspectives. Electricity was converted using the average heat rate in 1995 — 10,519 Btu/kWh. The simple payback periods are based on 1995 weighted average sectoral energy prices. The cost of saved energy reflects the cost of the efficiency investment (in dollars per million Btu) as amortized over the life of the investment, using a five percent real discount rate. Negative values for gas savings reflect additional fuel requirements due to implementation of electric efficiency measures.

Savings from these analyses of prototype buildings were then applied to projected energy use in Illinois, based on new construction trends (for the new building prototypes) and an ACEEE estimated implementation rate for each package of measures. The implementation rate assumes an aggressive set of policies is adopted to encourage implementation of cost-effective energy-saving measures. For the existing building prototypes, we assumed that measures would be gradually installed over the 1999-2015 period on a linear path, resulting in installation of 80 percent of the measures by 2015.

Thus, over the 17-year analysis period, nearly 5 percent of the measures are implemented each year (80 percent per 17 years). For the new building prototypes, we assumed that updated building codes that incorporate all of the measures become effective in 2003, with voluntary adoption of these efficiency levels growing from 22 percent of new buildings in 1999, 34 percent in 2000, 50 percent in 2001, and to 75 percent in 2002.

The result of all of these assumptions is that by the year 2015, residential energy consumption would be 40 percent lower than the baseline projections. In order to achieve these savings substantial investments will be required, primarily by energy users. These investments will be repaid with energy savings but the investments are significant none the less. For the residential sector, based on the average costs of saved energy reported in Table 1, investment over the 1999-2015 period will total $11.3 billion. However, cumulative energy bill savings from these measures, during the same period, will total $20.7 billion. Hence, the benefit-cost ratio to residents (i.e., savings divided by investment) for the high-efficiency scenario is 1.84.

For the commercial sector, by 2015 energy use will be just under 30 percent lower than the baseline projections. The savings are not as large (in percentage terms) as in the residential sector because savings opportunities in the commercial sector for natural gas are limited. Nevertheless, the commercial sector has a very large electricity saving potential — almost 39 percent.

Commercial sector investments are also large (although significantly lower than in the residential sector), totaling $5.2 billion over the 1999-2015 period. However, cumulative energy bill savings from these measures are estimated to be $13.3 billion, resulting in a commercial building benefit-cost ratio to businesses of 2.57.

2. Industrial Efficiency

The industrial sector represents a diverse grouping of entities including: farming, agricultural services, forestry, fisheries, mining, construction, and manufacturing. Because of this diversity and the fact that energy use is an integral part of many of the operations performed in this sector, a different approach was required from that used for buildings.

ACEEE has developed a methodology for the estimation of baseline energy consumption in the industrial sector at the state level and the potential for cost-effective energy efficiency improvements; this methodology is discussed in Appendix C.[21]

Information on energy consumption within the industrial sector at any level other than the national level has been difficult to obtain and is of varying quality. Energy end-use varies widely among the different industry groups, and even among industries within some of those groups, so the energy efficiency opportunities also vary substantially.[22] Therefore, it is important to have representative disaggregations of energy use within the industrial sector in order to make meaningful estimates of the potential for energy efficiency improvements and identify areas of greatest opportunity for energy savings. This study uses state employment data to apportion *State Energy Data Report*[23] estimates of industrial energy consumption at the state level to twelve industrial groupings.

As figure 4, on the following page, indicates, the petroleum refining industry is the state's largest industrial fuel user. This industry is closely followed by the primary metals and chemicals industries. Consistent with the overall high fuel use, figure 5, on the following page, illustrates, these same two industry groups, with the addition of the fabricated metals industry, represent the state's highest industrial electricity users as well. Combined, they account for 54 percent of industrial electricity consumption.

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21. This analysis methodology was developed for a previous study by S. Laitner et al., *Energy Efficiency and Economic Development in the Midwest*, American Council for an Energy-Efficient Economy, Washington, DC, 1995.

22. R. N. Elliott, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector*, American Council for an Energy-Efficient Economy, Washington, DC, 1994; M.H. Ross, P. Thimmapuram, R.E. Fisher, and W. Maciorowski, *Long Term Industrial Energy Forecasting (LIEF) Model (18 Sector Model)*, Argonne National Laboratory, Argonne, IL, 1993.

23. *State Energy Data Report 1995*, see note 13.

FIGURE 4. ESTIMATED 1995 INDUSTRIAL FUEL CONSUMPTION (IN TBTU)

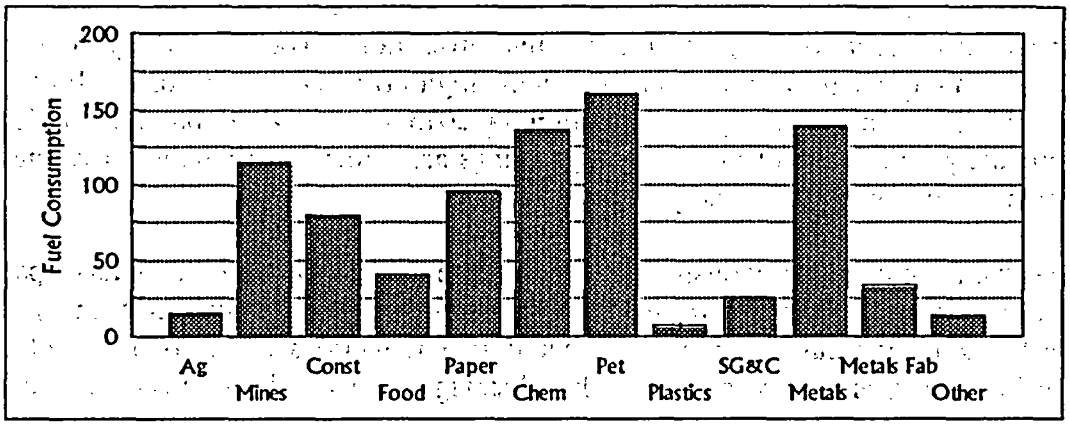
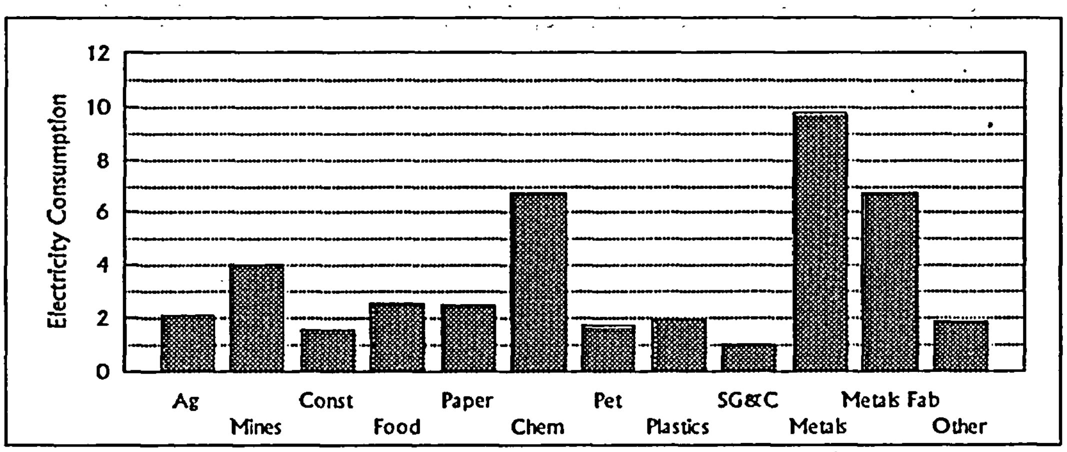


FIGURE 5. ESTIMATED 1995 INDUSTRIAL ELECTRICITY CONSUMPTION (IN BILLION KWH)



Source: Calculations by the American Council for an Energy-Efficient Economy based upon assumptions described in the text.

The energy efficiency potential in the industrial sector was estimated using conservation supply curves derived from the Long-Term Industrial Energy Forecasting (LIEF) model[24] and ACEEE estimates for additional savings from investments in combined heat and power generation. Most conservation supply curves have been developed by combining various characteristic measures for a particular market. Such an approach is impractical for the industrial sector because of the complexity and site-specific nature of many efficiency measures. The LIEF curves were developed from a historical analysis of sectoral energy intensities and prices.

24. Ross et al., see note 22.

Industrial sector energy savings estimates are based on the average industrial energy prices in Illinois in 1995. By 2015, primary energy consumption in the industrial sector is reduced by just under 32 percent compared to the baseline projections. Total electricity consumption decreases even more significantly over time in the high-efficiency scenario, resulting in a 60 percent reduction in electricity consumption in 2015 compared to baseline projections. Approximately 37 percent of the electricity savings are directly attributable to savings from investments in combined heat and power generation.

The potential for conserving industrial fuels is a more modest 17 percent. In large part, this is because average fuel prices are relatively low in key industries such as primary metals, chemicals, and petroleum refining. Potential fuel reductions are also impacted by the additional fuel requirements necessary to take advantage of electricity savings from combined heat and power generation.

The high-efficiency scenario requires $12.7 billion in energy efficiency investments over the period 1999-2015 (in constant 1995 dollars). Cumulative bill savings (based upon 1995 energy prices) would be $17.9 billion. Hence, the benefit-cost ratio for the industrial sector is 1.41.[25]

25. At first glance, the industrial benefit-cost ratio may appear to be unusually low. But we need to make a distinction between the benefit-cost ratio of a project and of a scenario. A single project with a payback of 4 years and a life of 10 years will have a benefit-cost ratio of 2.5. But a scenario with investments made annually over a 17-year period will always be incurring new investments, especially in the outlying years. Therefore, some of the benefits accrue outside of the scenario time frame. This is all the more important to understand within the industrial sector since many projects may have effective lives of less than 10 years (compared to commercial buildings, for example, which may last 20, 30, 40 or more years). This means that in the 11th year new investments are made to keep the same level of efficiency benefit.

TABLE 3. ESTIMATED CUMULATIVE ENERGY SAVING AND EFFICIENCY INVESTMENTS 1999-2015	
Category	**Industrial Sector**
Fuel Savings	16.6%
Electricity Savings	60.3%
Primary Energy Savings(1)	31.8%
Bill Savings (million$) (2)	$17,895
Efficiency Investments (million$)	$12,689
Benefit-Cost Ratio (3)	1.41

Notes: (1) Based on an electricity system heat rate of 10,519 Btu/kWh.
(2) Calculated using industry consumption-weighted, average fuel prices in 1995 and state average industrial electricity prices in 1995 reduced by 10 percent
(3) Ratio of cumulative bill savings to cumulative capital investment in efficiency improvements. Energy savings after 2015 that result from investments made before 2015 are not considered in this calculation.

3. Transportation Efficiency

As throughout the nation, the transportation sector accounts for major portions of energy use and energy-related emissions in Illinois. Moreover, the transportation sector is almost wholly dependent on petroleum. A breakdown of energy use by transportation mode is not available for Illinois; indeed, such a breakdown is difficult to define since a significant portion of the traffic, particularly freight, crosses state and national boundaries. Nevertheless, using national statistics as a guide, light duty vehicles (LDVs, i.e., cars and light trucks) account for the majority of transportation energy use. Thus, our analysis focuses on LDVs, taken here to include passenger cars and 2-axle, 4-tire, light trucks, as defined in the U.S. Department of Transportation's *Highway Statistics* (HS) report.[26] Nationally, LDVs account for 94 percent of highway vehicle miles of travel (VMT), about 80 percent of highway energy consumption, and 60 percent of overall transportation energy use.

26. *Highway Statistics, 1996*, FHWA-PL-98-003, Federal Highway Administration of the U.S. Department of Transportation, Washington, DC, 1997.

Transportation energy efficiency, particularly for light duty vehicles and aircraft, has improved substantially over the past two decades. Today, however, ongoing improvements are only being seen in aircraft, and even those improvements are insufficient to keep up with rising travel demand. Efficiency improvements have almost completely halted for the largest contributor to transportation energy use, cars and light trucks.[27] Thus, motor vehicle energy use is now rising in step with increased driving, which, as we note below, is expected to grow at an average rate of 2.3 percent per year in Illinois.

Previous work indicates a substantial energy savings opportunity for improving vehicle efficiency using technologies already available for conventional cars and light trucks.[28] Our analysis is based on estimating the potential energy savings obtainable through vehicle efficiency improvement. We do not examine the use of alternative fuels, such as natural gas, biofuels, hydrogen, or electricity, which have a long-term potential for displacing petroleum. These alternative technologies are still entering the early stages of commercialization and further research and development is needed for many of them. Battery-powered electric vehicles (EVs) are just now becoming commercially available but are still inhibited by battery technology limitations and associated price premiums. Therefore, we restrict our analysis to conventional vehicle technologies, which still have considerable unmet potential for low-cost energy savings and pollution reduction over the time horizon of this study.

Also critical for improving transportation system efficiency are measures to reduce VMT by shifting to more efficient modes, including higher vehicle occupancy, transit, walking, and bicycling; reducing the need to travel through more efficient planning or use of electronic communications; and reforming transportation pricing and spending policies that subsidize car and truck travel. These broader aspects of transportation planning transcend energy concerns and fall beyond the scope of this analysis; these issues are well covered in the study by Ketcham and Komanoff. [29]

A key factor underlying energy analysis for the transportation sector is expected growth in travel demand in the state. Figure 6 shows the recent history of VMT growth for Illinois along with the projected growth assumed for our analysis. Although this growth can, and for efficiency reasons, should be dampened through policy and planning reforms, for the purposes

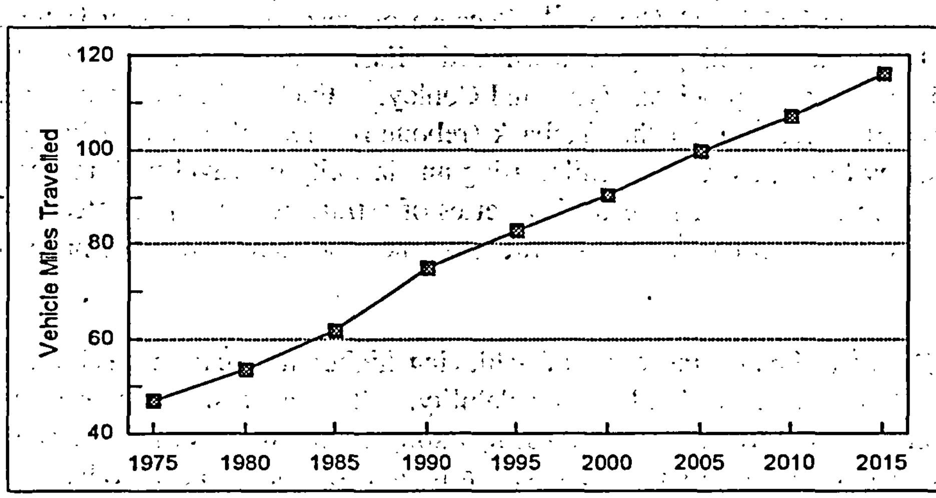
27. The motor vehicle and parts manufacturing industry (which will be affected by policies to improve vehicle efficiency) is well represented in Illinois. Among others, Chrysler, Ford, and Diamond Star each have manufacturing plants in Illinois. In addition, Navistar has its headquarters and engine and parts distribution in Illinois.

28. J.M. DeCicco and M. Ross, *An Updated Assessment of the Near-Term Potential for Improving Automotive Fuel Economy*, American Council for an Energy-Efficient Economy, Washington, DC, 1993.

29. B. Ketcham, and C. Komanoff., *Win-Win Transportation: A No-Losers Approach to Financing Transport in New York City and the Region*, Transportation Alternatives, New York, NY, 1992.

of estimating the potential energy savings from vehicle efficiency improvements we take it as a given that travel demand will increase.

FIGURE 6. PAST AND PROJECTED LIGHT DUTY VEHICLE TRAVEL IN ILLINOIS (IN BILLIONS OF MILES PER YEAR)



Notes: Vehicle miles traveled for 1975-1995 represents historical data. Data for 1996-2015 is projected based on descriptions in the text.

For projections of travel growth, we adopted national forecasts for VMT and adjusted these using Illinois specific VMT data obtained from HS.[30] The resulting forecast is for 1995-2015 VMT growth of 1.7 percent per year. Consistent with nationwide trends (largely influenced by demographic changes), the expected future growth rate is slower than over the past two decades, when the state's VMT growth rate averaged approximately 2.9 percent per year.

The transportation energy savings calculation involves combining projections of annual VMT, new car miles per gallon (mpg), the per unit cost to achieve that efficiency level, and annual new LDV sales. For our analysis, base year data were compiled for 1995 and vehicle efficiency improvements were assumed to begin in 1999. Base year car sales[31] were scaled up to estimate car and light truck sales by applying the ratio of LDV VMT to car VMT as reported in HS.[32] Estimates of annual new LDV sales for future years were made in

30. *Highway Statistics, 1996,* see note 26.

31. *AAMA Motor Vehicle Facts and Figures,* American Automobile Manufacturers Association, Washington, DC, 1994.

32. *Highway Statistics, 1996,* see note 26.

proportion to growth in VMT. The energy and fuel cost savings were calculated relative to a baseline assumption of frozen vehicle efficiency, accounting for the vehicle stock (all cars and trucks, new and used, in service within a given year) and its turnover.

The stock retirement model uses vehicle usage and scrappage statistics from Davis and Strang,[33] further described by DeCicco.[34] Because on-road fuel economy is lower than EPA-rated fuel economy, a 20 percent downward adjustment is made to account for the shortfall, based on estimates by Mintz, Vyas, and Conley.[35] Fuel savings estimates were also adjusted downward to account for the takeback (rebound) effect of greater driving because higher fuel economy lowers the cost per mile, using an elasticity of travel with respect to fuel cost of -0.1 based on Greene.[36] The result is a series of estimates of the projected real-world average fuel economy of all cars and light trucks on the road (new and used) in each future year.

DeCicco and Ross[37] estimated the costs of achieving higher new car fuel economy under varying assumptions about technology availability. The analysis examined a set of conventional car and light truck technologies, including engine improvements, transmission improvements, and measures to reduce mass, rolling resistance, and aerodynamic drag. Measures were screened for cost and ranked in a "cost curve" representing the slate of technical options for improving new vehicle efficiency without reducing average vehicle size and performance or compromising safety. (In fact, adjustments were made to account for potential safety improvements that might add some mass back to the vehicles.)

The DeCicco and Ross mid-range estimates indicate that a 65 percent improvement in new car fuel economy is achievable with about 10 years of lead time.[1] With additional time, further technology improvements would be possible, as indicated by a significantly higher ("Level 3") set of estimates developed by DeCicco and Ross. Based on this analysis, we adopt a higher improvement level as attainable by 2015. We estimate that by 2015 average new car fuel economy can improve to 50.3 mpg, just over double the 1995 level which averaged 24.6 mpg.

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33. S. Davis and S. Strang, *Transportation Energy Data Book: Edition 13*, ORNL-6743, Oak Ridge National Laboratory, Oak Ridge, TN, 1993.

34. J. DeCicco, "Projected Fuel Savings and Emissions Reductions from Light Duty Vehicle Fuel Economy Standards," *Transportation Research* 29A(3): 205-228, 1995.

35. M. Mintz, A. Vyas, and L. Conley, *Differences Between EPA-Test and In-Use Fuel Economy: Are the Correction Factors Correct?* 931104, Transportation Research Board, Washington, DC, 1993.

36. D. Greene, "Vehicle Use and Fuel Economy: How Big is the 'Rebound' Effect?" *Energy Journal* 13(1), 1992.

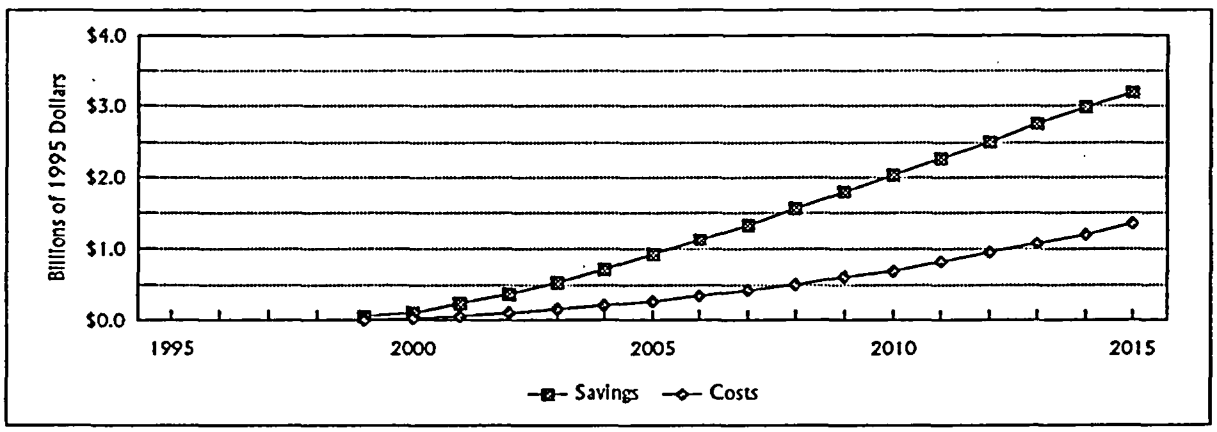
37. J.M. DeCicco and M. Ross, *An Updated Assessment of the Near-Term Potential for Improving Automotive Fuel Economy*, American Council for an Energy-Efficient Economy, Washington, DC, 1993.

Further, we estimate an average added retail cost of approximately $770 per car (1995$). Similar degrees of improvement are also achievable in light trucks (pickups, minivans, sport utilities), relative to their current (lower) average efficiency levels.

For our analysis, we assume the efficiency improvements are phased-in at an average rate of 1.5 mpg per year, relative to a combined new car and light truck average fuel economy of 25 mpg. Given the assumption of improvements starting in 1999, the result is average new light vehicle efficiency levels of 34.7 mpg by 2005, 42.2 mpg by 2010, and 50.3 mpg by 2015. The costs of achieving the phased-in higher fuel economy levels in each year were calculated using an analytic form of the DeCicco and Ross cost curve. Total annual costs are shown in Figure 7, below. Costs grow in accordance with our assumption of ongoing efficiency improvements through the horizon of analysis.

Improvements in new car and light truck efficiency take time to "trickle-down" throughout the total on-road stock of vehicles (new and used), since the average vehicle lifetime is about 12 years. Results from the stock model show that the 98 percent improvement in new light duty fleet efficiency by 2015, compared to the current level, will have induced a 62 percent improvement in stock average efficiency by that time. The result is a roughly one-quarter savings in light vehicle fuel use per mile of driving. The resulting savings stream is shown as the upper curve in Figure 7. Savings exceed investments from the start since the initial technological improvements have payback times of less than one year.

FIGURE 7. COSTS AND SAVINGS FOR LDV EFFICIENCY IMPROVEMENTS



The cumulative investment in vehicle technology improvements, realized as modest increases in the average price of new cars and light trucks, would amount to $8.7 billion over 1999-2015. The cumulative value of the resulting fuel savings would be much larger, at $24.4 billion over the same period. The resulting benefit/cost ratio is 2.80. This ratio would, moreover, continue to grow as years went on, since the overall consumer savings from higher vehicle efficiency will keep growing as improved vehicles continue to replace older, less efficient vehicles in the on-road stock in the post-2015 period.

IV. ECONOMIC IMPACT ANALYSIS

With both the baseline projection and the efficiency scenarios established, the question now posed by this analysis is: "What are the employment and other macroeconomic impacts for Illinois if the baseline energy use were reduced by just over 31 percent, or about 1,523 TBtus, by the year 2015?"

In effect, we are examining the benefits of lowering energy consumption from a projected average growth rate of about 1.2 percent annually to a growth rate of a negative 0.66 percent annually. One way to understand this issue is to think of it as increasing the productivity of the state's economy by reducing its overall energy costs. One tool that can assist in this type of macroeconomic evaluation is referred to as input-output modeling, sometimes called multiplier analysis.

A. INPUT-OUTPUT ANALYSIS

Input-output models initially were developed to trace supply linkages in the economy. For example, they show how purchases of lighting equipment not only benefit lighting manufacturers but also the fabricated metal industries and other businesses supplying inputs to those manufacturers.

The employment that is ultimately generated by expenditures for energy efficiency will depend on the structure of a local economy. States that produce fabricated metal products, for instance, will likely benefit from expanded sales of locally manufactured, high-efficiency ballasts; states without such production will not benefit in the same way.

Different expenditures support a different level of total employment. Table 4 compares the total number of jobs in Illinois that are directly and indirectly supported for each one million dollars of expenditures made by consumers and businesses. To capture the full economic impacts of the investment in energy efficiency technologies, three separate effects (i.e., direct, indirect, and induced) must be examined for each change in expenditure.[38]

Direct effect refers to the on-site or immediate effects created by an expenditure. In the case of installing the energy efficiency upgrades in a manufacturing plant, the direct effect would

38. In this study we have adapted the 1995 IMPLAN model for the analysis. See, for example, *Micro IMPLAN User's Guide*, Minnesota IMPLAN Group, Stillwater, MN, 1993. Table 7 presents what are referred to as Type I multipliers, incorporating only the direct and indirect effects of an expenditure. Adding the induced effect would generate what are known as the Type II multipliers (or Type III multipliers as referenced in the IMPLAN model).

be the on-site expenditures and jobs of the electrical or special trade contractors hired to carry out the work.

The indirect effect refers to the increase in economic activity that occurs when a contractor or vendor receives payment for goods or services delivered and he or she is able to pay others who support their own businesses. It includes the equipment manufacturer or wholesaler who provided the new technology. It also includes such people as the banker who finances the contractor, the accountant who keeps the books for the vendor, and the building owner where the contractor maintains its local offices.

The induced effect derives from the change in wealth that the energy efficiency investment program creates. Businesses and households are able to meet their power, heating, cooling, lighting, and transport needs at a lower total cost, due to efficiency investments. This lower cost of doing business and operating households makes available greater wealth for firms and families to spend or invest in the state economies.

The sum of these three effects yields a total effect that results from a single expenditure. However, since household spending is included as part of the final demand changes in the analysis, the employment and other macroeconomic impacts have been limited to the direct and indirect effects only. This will tend to understate the net effect of the efficiency scenario.[39] Table 4 provides employment multipliers for key sectors such as agriculture, construction, manufacturing, utility services, wholesale and retail trade, services, and government.

For purposes of this study, a job is defined as sufficient wages to employ one person full-time for one year. Of immediate interest in Table 4 is the relatively small number of jobs supported for each one million dollars spent on fuel production and utility services. As it turns out, much of the job creation from energy efficiency programs is derived by the difference between jobs within the utility supply sectors and jobs that are supported by the respending of energy bill savings in other sectors of the economy.

B. An Illustration: Jobs from Energy Improvements in Government

To illustrate how a job impact analysis might be done, we will use the simplified example of a state agency that installs $1.0 million of efficiency improvements. Government agencies, traditionally large users of energy due to heating and air-conditioning loads, significant use

39. For more information on this point, see R.E. Miller and P.D. Blair, *Input-Output Analysis: Foundations and Extensions*, Prentice-Hall, Inc., Englewood, NJ, 1985, pages 25-30.

Table 4. Illinois Employment Multipliers for Selected Economic Sectors

Sector	Employment Multipliers (Jobs per $1 Million of Expenditures)
Oil Refining	2.6
Natural Gas Utilities	3.7
Electric Utilities	4.2
Oil/Gas Mining	5.3
Insurance/Real Estate	6.9
Coal Mining	7.0
Motor Vehicles	7.4
Primary Metals	8.0
Food Processing	8.2
Other Mining	8.8
Pulp and Paper Mills	9.2
Metal Durables	9.6
Other Manufacturing	10.2
Stone, Glass, and Clay	10.8
Transportation, Communication, and Utilities	12.4
Finance	12.6
Wholesale Trade	12.6
Construction	15.1
Agriculture	20.1
Services	21.1
Government	22.3
Education	27.0
Retail Trade	29.6

Source: Adapted from the 1995 IMPLAN database for Illinois. The employment multipliers represent the direct and indirect jobs supported by a one million dollar expenditure for the goods and/or services purchased from a given sector.

of electronic office equipment, and the large numbers of persons employed and served, provide substantial opportunities for energy-saving investments. The results of this example are summarized in Table 5.

The assumption used in this example is that the investment has a positive benefit-cost ratio of 2.00. This ratio is comparable to those shown in Table 1. If we anticipate that the efficiency changes will have an expected life of 15 years or more, then we can establish a 15-year period of analysis. We further assume that the efficiency upgrades take place in the first year of the analysis, while the energy savings occur in years 1 through 15.

The analysis also assumes that we are interested in the *net effect* of employment and other economic changes. This means we must first examine all changes in business or consumer expenditures — both positive and negative — that result from a movement toward energy efficiency. Each change in expenditures must then be multiplied by the appropriate multiplier (taken from Table 4) for each sector affected by the change in expenditures. The sum of these products will then yield the net result for which we are looking.

In our example there are four separate changes in expenditures identified in Table 5, each with their separate multiplier effect. As Table 5 indicates, the net impact of the scenario suggests a gain of 29.0 job-years in the 15-year period of analysis. This translates into a net increase of 1.9 jobs each year for 15 years. In other words, the efficiency investment made in government facilities is projected to sustain an average of just under two jobs each year over a 15-year period compared to a baseline or "business-as-usual" scenario.[40]

C. Evaluating the Alternative Energy Scenario

The employment analysis of the alternative energy efficiency scenario was carried out in a very similar manner as the example described above. That is, the changes in energy expenditures brought about by investments in energy efficiency technologies were matched with their appropriate employment multipliers. There are several modifications to this technique, however.[41]

40. The estimate may be conservative when we recall that the commercial sector as a whole was shown to have a benefit-cost ratio of almost 3.0 (noted earlier in Table 1), which compares with the benefit-cost ratio assumption of 2.0 used in this example.

41. For a more complete review of how this type of analysis is carried out, see H. Geller, J. DeCicco, and S. Laitner, *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*, American Council for an Energy-Efficient Economy, Washington, DC, 1992.

Table 5. Job Impacts from Government Energy Efficiency Improvements

Expenditure Category	Amount ($ Million)	Job Multiplier	Job Impact
Government Efficiency Improvements in Year One	$1.0	15.1	15.1
Diverting Government Expenditures to Fund Efficiency Improvements	-$1.0	22.3	-22.3
Respending of Energy Bill Savings in Years One through Fifteen	$2.0	22.3	44.6
Lower Utility Revenues in Years One through Fifteen	-$2.0	4.2	-8.4
Net Fifteen-Year Change	$0.0		29.0

Note: The employment multipliers are derived from the appropriate sectors (average of the three states) found in Table 7. The jobs impact is the result of multiplying the row expenditure change by the row multiplier. For more details, see the text.

First, it was assumed that only 80 percent of the efficiency investments would be spent within Illinois. Interviews with personnel from various state agencies in the region suggest this to be a conservative value since almost all efficiency investments are carried out by local contractors and dealers.

As it turns out, the level of locally installed efficiency upgrades does matter, especially in the early years of the analysis; that is, before the energy bill savings begin to show a significant return. For example, in 2000 the employment benefits for the region would turn negative if more than 50 percent of the upgrades were performed by out-of-region contractors or other businesses. By 2015, however, this level would have to rise to more than 95 percent before the employment gains are fully eroded. Thus, to maximize employment within the region, investments in the early years should emphasize the use of locally based businesses as much as possible.

Second, we made an adjustment in the employment impacts to account for specific sector changes in labor productivity. As outlined in the Bureau of Labor Statistics *Outlook 1995-2005*, productivity rates are expected to vary widely among sectors, ranging from a 0.1 percent annual productivity gain in the service sectors (which will experience a large influx of employment as those sectors become more important to the economy) to a 4.0 percent annual productivity gain in coal mining (where such gains have already led to significant job losses).[42]

To illustrate the impact of productivity gains, let us assume a typical labor productivity increase of 1 percent per year in manufacturing. This means, for example, that compared to 1997 a one million dollar expenditure in the year 2015 will support only 85 percent of the number of jobs as in 1999.[43]

Third, for purposes of estimating energy bill savings it was assumed that fossil fuel energy prices would remain at their 1995 levels and electricity prices decline by 10 percent from 1995 prices (as noted earlier). This is, in part, to simplify the matching of energy prices with an input-output model based upon 1995 price relationships but also in line with the Energy Information Administration's new price forecasts. The new forecast is substantially lower than previous forecasts in order to recognize the price-lowering impacts associated with utility restructuring.[44]

There are two important exceptions to the presumption that fossil fuel energy prices would remain at 1995 levels: (1) that a decline in consumption would cause a downward pressure in the variable costs of supplying energy resources, and (2) that in the early years of the study the fixed costs associated with producing energy would prompt a small increase in energy prices.[45] While this might represent a "deadweight loss" in some respects, the effect will be overcome by a reduction in energy consumption that is larger than the very small energy price increase.

Fourth, it was assumed that approximately 80 percent of the investment upgrades would be financed by bank loans that carried an average 10 percent nominal interest rate over a five-year period. To limit the scope of the analysis, however, no parameters were established to account for any changes in interest rates as less capital-intensive technologies (i.e., efficiency investments) are substituted for conventional supply strategies, or in labor participation rates — all of which might affect overall spending patterns.

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42. The productivity trends were calculated by Economic Research Associates using data from the Bureau of Labor Statistics employment projections, *Outlook 1995-2005*, as downloaded from the BLS FTP site <ftp.bls.gov/pub/special.requests/ep>, U.S. Department of Labor, Washington, DC, February 1996.

43. The calculation is $1/(1.01)^{16} * 100$ which equals $1/1.173 * 100$, or 85 percent.

44. *Annual Energy Outlook 1998*, see note 15.

45. This is a working estimate by Economic Research Associates for use in this analysis. Based upon a 40 percent average fixed cost, energy prices would go up by an estimated 7 percent in the year 2010, for example. On the other hand, a 24 percent drop in consumption would put a similar downward pressure on energy prices that would likely offset this trend - particularly in later years as fixed costs are fully depreciated.

While the higher cost premiums associated with the energy efficiency investments might be expected to drive up the level of borrowing (in the short term) and, therefore, interest rates, this upward pressure would be offset to some degree by the investment avoided in new power plant capacity, exploratory well drilling, and new pipelines. Similarly, while an increase in demand for labor would tend to increase the overall level of wages (and thus lessen economic activity), the modest job benefits are small compared to the current level of unemployment or underemployment. Hence the effect would be negligible.

Fifth, for the buildings and industrial sectors it was assumed that a program and marketing expenditure would be required to promote market penetration of the efficiency improvements. This was set at 15 percent of the efficiency investment for those sectors.[46] For the transportation scenario it was assumed that, since the efficiency improvements would be an integral part of all new vehicle purchases, a "program" expenditure would not be necessary. Finally, it should again be noted that the full effects of the efficiency investments are not accounted for since the energy bill savings beyond 2015 are not incorporated in the analysis.

Nor does the analysis include other productivity benefits that are likely to stem from the efficiency investments. These can be substantial, especially in the industrial sector. Industrial investments that increase energy efficiency often result in achieving other economic goals such as improved product quality, lower capital and operating costs, increased employee productivity, or capturing specialized product markets.[47] To the extent these "co-benefits" are realized in addition to the energy savings, the economic impacts would be amplified beyond those reported here.

46. For example, this was the same value as used in *Energy Efficiency and Job Creation*, see note 2.

47. Office of Technology Assessment, *Industrial Energy Efficiency*, Congress of the United States, Washington, DC, 1993, page 65. For a more complete discussion on this point, see S. Laitner, *Energy Efficiency as a Productivity Strategy for the United States*, Economic Research Associates, Alexandria, VA, 1995; and J. J. Romm, *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution*, Kodansha American, Ltd., 1994.

V. MACROECONOMIC RESULTS

The investment and savings data from the efficiency scenario were used to estimate three sets of impacts for the five-year periods of 2005, 2010, and 2015. The procedure was similar to the steps outlined in Section IV(B) of this report, and as modified by the assumptions in Section IV(C). For each benchmark year, each change in a sector's spending pattern for a given year was matched to the appropriate sectoral multiplier. These negative and positive changes were summed to generate a net result shown in the tables that follow.

The first of the three impacts evaluated here is the net contribution to Gross State Product (GSP) measured in millions of 1995 dollars. In other words, once the gains and losses are sorted out in each scenario, the analysis provides the net benefit of a scenario in terms of the state's overall economy. The second impact is the net gain to the state's wage and salary compensation, also measured in millions of 1995 dollars. The final category of impact is the contribution to the state's employment base as measured by full-time jobs equivalent. The following parts of this section identify these impacts for the total energy efficiency scenario as well as for electricity only.

In addition, the final part of this section presents the estimated reductions in air emissions that result from the efficiency scenario.

An important caveat should again be noted at this point. The intent of the high-efficiency scenario is to construct a reasonable profile of investments and economic impacts, assuming that cost-effective efficiency measures are widely adopted over the 17-year period of the analysis (i.e., 1999-2015). Given future changes in the electric utility industry and potential changes in consumption patterns in the economy, this analysis is not intended to provide a precise forecast, but rather approximate estimates of overall impact.

A. FULL EFFICIENCY SCENARIO

Table 6 summarizes the economic impacts of the alternative energy scenario for selected benchmark years. It provides the estimated economic benefits of the accelerated use of energy efficiency technologies in all sectors. While these increases are significant, the impacts are relatively small in comparison to overall activity of the state economy. By the year 2015, for instance, Illinois' GSP might grow to $479 billion (in 1995 dollars). Thus, reducing the state's GSP by $700 million (the impact from the full efficiency scenario) in that year will keep the GSP essentially level. Similarly, the increases in wage and salary compensation and jobs in 2015, brought about by implementing the full efficiency scenario, represent an increase of only 0.4 percent in compensation and 0.7 percent in total jobs by 2015.[48]

On the other hand, if the impacts are small in relation to the larger economy, it is only because the scale of investment is also relatively small. The anticipated $37.8 billion in cumulative efficiency investments (from Table 1) are well under 1 percent of the region's cumulative GSP in the period 1999-2015.

Table 6. Impact of the Full Efficiency Scenario

Year	Net Jobs Gain	Change in Wage and Salary Compensation (Million$)	Change in Gross State Product (Million$)
2005	20,700	$540	($150)
2010	40,600	$1,090	($280)
2015	59,400	$1,620	($700)

Notes: Dollar figures are in millions of 1995 dollars while employment reflects the actual job total. The implied benefit-cost ratio across the 17-year period is 2.02. The calculations are based upon a working analysis by Economic Research Associates, November 1998. They assume a 31 percent reduction in energy use over the year 2015 forecasted values and a displacement of conventional electric-generating resources by the use of energy efficiency technologies and combined heat and power. Totals may not equal the sum of components (as shown) due to independent rounding.

There are a number of different aspects of Table 6 worth noting before commenting on the impacts in more detail. The first is that the impacts are largely positive. By the year 2015, wage and salary earnings as well as employment are positive in each of the years shown — reaching a net total of $1.62 billion (in 1995 dollars) and 59,400 jobs, respectively, in 2015. GSP, however, shows a small decline in each of the years.

This apparent contradiction (i.e., rising earnings with declining GSP) is the result of three different influences at work in the economy. First, many of the initial outlays for energy efficiency investments have not begun to pay for themselves in terms of energy bill savings.

48. These projections are taken from *BEA Regional Economic Projections to 2045: States*, U.S. Department of Commerce, Bureau of Economic Analysis, 1995. The projections were originally reported in 1987 dollar values by BEA but have been adjusted to reflect 1995 dollar values for our analysis.

This tends to dampen the growth of GSP. At the same time, changes in the production recipe of the economy — largely the turn toward more labor-intensive purchases in the efficiency scenario — increase the share of benefit enjoyed by working men and women. And finally, the emphasis on supply (i.e., investments in combined heat and power generation in the industrial sector) offset some of the gains from efficiency.

Wage and salary compensation is one of the elements that comprise GSP, constituting about 60 percent of the GSP total. Thus, while overall GSP can fall, wage and salary compensation can rise as labor payments are substituted for investment capital in the larger economy. Thus, the tradeoff between capital and labor continues.

The employment impacts start modestly in 2005 with net employment gains of 20,700 jobs. The annual totals continue to climb to a net gain of 40,600 in 2010, and 59,400 in 2015. We can think of the net job gains as if they were provided by the relocation of a series of small manufacturing plants to Illinois. In that case, we then can say that a 31 percent energy savings would produce new employment that is equivalent to the jobs supported by about 396 small manufacturing plants that might open in Illinois in the year 2015.[49]

Alternately, we can think of the additional wage and salary compensation from the energy savings as an equivalent amount of spending by tourists and visitors. In this instance, the 31 percent energy savings would provide the dollar equivalent of spending from over 10.8 million visitor days.[50]

Perhaps another way to look at this issue is to see how the alternative energy future would change the unemployment rate. In July 1998 Illinois' unemployment rate was estimated at 4.4 percent.[51] If that continues through the year 2015 when total non-farm employment is

49. This estimate is based on the net gain of 59,400 jobs in Illinois. It assumes that a small manufacturing plant would employ 50 persons directly. For each job in the manufacturing plant, a total of 3.0 (2 additional) jobs would be supported in the economy for a total impact of 150 jobs. Therefore, each 150 jobs created by the alternative energy scenario is equivalent to the output of one small manufacturing plant. Dividing the total jobs created by 150 suggests the equivalent of a total of 396 (59,400/150) small manufacturing plants equivalent within the economy.

50. This estimate is based on the net gain in wage and salary compensation of $1.62 billion in the year 2015. It assumes that tourists and visitors to Illinois spend approximately $150 per day per person on recreation, eating and drinking, and lodging. Dividing the gain in wage and salary compensation by 150 suggests the equivalent of 10.8 million visitor day expenditures within Illinois economy. Visitor expenditures are based on averages compiled by Economic Research Associates.

51. The unemployment statistics for July 1998 (the most recent available) were downloaded from the U.S. Department of Labor Bulletin Board, at http://stats.bls.gov/ro5econ1.htm in September, 1998.

estimated to rise to just under 8 million jobs,[52] then the state's unemployment level would be about 275 thousand persons. Adding another 59,400 jobs to the state economy would be sufficient to lower the average unemployment rate from 4.4 percent to 3.7 percent.

Table 7, on the following page, offers yet another insight into the projections. It shows how each of the major economic sectors are affected in the year 2015 in the alternative energy scenario. These are sorted according to the anticipated job impacts beginning with those sectors that have the largest employment gains.

As elsewhere, it should be noted that the results in this table are not intended to be precise forecasts but rather approximate estimates of overall impact. Indeed, while the aggregate totals offer reasonable insights into the benefits of energy efficiency, some of the individual

52. *BEA Regional Economic Projections*, see note 47. Illinois' total non-farm labor force in 2015 is estimated to be 7.99 million.

Table 7. Energy Efficiency Impacts in Illinois by Sector in 2015

Sectors	Jobs	Compensation (Million$)	GSP (Million$)
Services	23,400	$650	$880
Construction	14,500	$510	$680
Retail Trade	9,000	$190	$310
Government	4,700	$180	$200
Finance	4,700	$250	$450
Other Manufacturing	3,200	$210	$350
Motor Vehicles	2,200	$210	$290
Transportation, Communication, and Utilities	2,200	$150	$280
Education	1,600	$60	$60
Metal Durables	1,400	$140	$220
Agriculture	900	$10	$20
Insurance/Real Estate	800	$40	$250
Food Processing	600	$30	$60
Other Mining	200	$20	$40
Pulp and Paper Mills	200	$10	$20
Primary Metals	200	$10	$20
Stone, Glass, and Clay	100	$10	$10
Wholesale Trade	0	$0	($10)
Oil Refining	(100)	($10)	($30)
Coal Mining	(100)	($20)	($40)
Natural Gas Utilities	(2,000)	($230)	($770)
Oil/Gas Mining	(2,600)	($130)	($640)
Electric Utilities	(5,700)	($670)	($3,350)
Total	59,400	$1,620	($700)

Notes: The numbers in parentheses reflect losses that are projected to occur in that sector as a result of the alternative energy scenario. Jobs refer to the net jobs created or lost in each sector. Compensation refers to the net gain in wage and salary income by sector. GSP refers to the net gain or loss in Illinois' Gross State Product created in each sector. All dollar values are in millions of 1995 dollars.

sectors show impacts that are sufficiently small that the results may swing one way or the other depending upon even modest changes in the assumptions.

As might be expected, the energy industries incur overall losses in jobs, compensation, and GSP. But this result must be tempered somewhat as the industries themselves are undergoing internal restructuring. For example, as restructuring takes place and the electric utilities engage in more energy efficiency services and other alternative energy investment activities, they will undoubtedly employ more people from the business services and engineering sectors. Hence the negative employment impacts should not necessarily be seen as job losses; rather they might be more appropriately seen as a redistribution of jobs in the overall economy and future occupational tradeoffs.

Explained differently, while the electric utilities may lose an estimated 5,700 traditional jobs due to selling less energy, they could gain many of those jobs back if they move aggressively into the energy efficiency business, thereby absorbing some of the job gains assigned to other sectors such as the construction and service sectors. In effect, if they expand their participation in the energy efficiency market, their job totals could increase relative to the estimates based on a more conventional definition of an electric utility as an energy supplier.

Table 7 shows three big "winners" under the alternative energy scenario. These are the service sectors (23,400 jobs), construction (14,500), and retail trade (9,000 jobs). Retail trade and the service sectors are winners largely for two reasons. First, they benefit from the actual investments in energy efficiency programs and technologies made in the year 2015. Second, they benefit from the higher level of goods and services sold as ratepayers and businesses respend their energy bill savings elsewhere in the economy.

The construction sector is a winner primarily because it is the industry that benefits most directly as special trade contractors and others are hired to install the new technologies and make the requisite efficiency upgrades. The construction sector alone pulls in about 24 percent of the net job increases in the year 2015. Using the construction industry as a benchmark for evaluation, it might be noted that about 1 out of 4 net job impacts in 2015 are from the efficiency investments made in that year. The remaining impacts are the result of respending the energy bill savings by ratepayers and businesses.

B. Electricity-Only Scenario

This section reviews the impacts of energy efficiency investments made only to reduce electricity use within Illinois. In the high-efficiency scenario, electricity use in 2015 drops approximately 43 percent relative to electricity use in that year in the baseline scenario. The cumulative investment in energy efficiency measures during 1999 through 2015 is estimated at $16.3 billion while energy bill savings reach $34.3 billion in that same period of time.

Table 8, below, summarizes the results for the same five-year periods as in the total efficiency scenario.

Table 8. Impact of the Energy Efficiency Scenario — Electricity Only

Year	Net Jobs Gain	Change in Wage and Salary Compensation (Million$)	Change in Gross State Product (Million$)
2005	10,900	$230	($360)
2010	22,300	$440	($740)
2015	35,200	$690	($1,310)

Notes: Dollar figures are in millions of 1995 dollars while employment reflects the actual job total. The implied benefit-cost ratio across the 17-year period is 2.11. The calculations are based upon a working analysis by Economic Research Associates, September 1998. They assume a 43 percent reduction in electricity use over the year 2015 forecasted values and a displacement of conventional electric-generating resources by the use of energy efficiency technologies and combined heat and power generation in the industrial sector. Totals may not equal the sum of components (as shown) due to independent rounding.

Perhaps the most interesting result is the drop in GSP for each year that is reviewed. Similar to the total energy scenario, this reflects the capital-intensive nature of the electric utility industry. As the revenues of electric utilities decrease under an accelerated energy efficiency scenario, the amount of capital investment also decreases (i.e., fewer new power plants are built). This, in turn, lowers the overall value-added and GSP.

On the other hand, the wage and salary compensation share of GSP actually increases in all three periods evaluated here. This is for two reasons. First, new electric plants are displaced by more cost-effective efficiency investments that are also more labor intensive. Second, the respending of energy bill savings is used for consumer and business purchases that are also more labor intensive.

As a result of this change in the economic mix, net employment rises. We might note, for example, that while electricity efficiency investments account for about 43 percent of the total investment in energy efficiency (as shown in Table 1), by the year 2015, electricity efficiency improvements account for 60 percent of the net employment benefits. This is the result of greater savings in the later years and the respending of the bill savings (and the induced effects from these). The latter is shown by comparing the results in Tables 6 and 8.

As might be expected, the traditional electric utilities sector would lose the most jobs, similar to the results from the total efficiency scenario noted earlier. The loss of jobs assumes a traditional economic structure for electric utilities in 2015. Thus, as fewer conventional power plants are needed as a result of efficiency gains, fewer traditional utility jobs are sustained. Once again, this points to an important opportunity for utilities: if utilities become more proactive in the area of energy efficiency services and other similar programs, they could take on new employees to carry out these new responsibilities.[53] One might assume, therefore, that utilities could incorporate at least part of the jobs gained in the construction and service sectors.

It should also be remembered that these estimates are not job losses in the strict sense of the word. Rather, they reflect differences between a business-as-usual (baseline) projection of future employment and jobs made available from an accelerated energy efficiency scenario. In the aggregate, there is a significant positive gain in both employment and wage and salary compensation, and a drop in the unemployment rate.

C. AIR QUALITY IMPACTS

One of the benefits of the high-efficiency scenario will be the impacts on pollutant emissions and air quality in Illinois. This positive impact is the direct result of the reduced burning of fossil fuels (primarily coal for electricity generation) associated with improving the efficiency of energy consumption. The following analysis was undertaken to approximate carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_x) emission savings associated with the efficiency scenario. It is not meant to represent a comprehensive analysis of the emission reductions, but rather to identify the magnitude of emission savings available and provide a reasonable estimate. To accomplish this task the analysis incorporates average marginal emission coefficients (by fuel type) adapted for Illinois from a number of sources.[54]

53. As restructuring occurs, providing additional services may also help utilities to retain existing customers and potentially expand their customer base.

54. Emission coefficients for the respective fuel types and end-use sectors are adapted from a number of sources. These include: 1995 carbon values for electricity generation contained in *Annual Energy Outlook 1998*, see note 15; 1995 SO_2 and NO_x values for electricity generation from the *Electric Power Annual 1995, Volume II*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1996; and 1995 SO_2, NO_x, and Carbon values for fossil fuels from *National Air Pollution Emission Trends 1900-1995*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC, 1996. The emission estimates are based on the use of fuel-specific coefficients derived from national and state values that are multiplied by each of the major fuels consumed in each of the end-use sectors reviewed in this study. The emission coefficients are average coefficients, across all hours of the year, and do not differentiate by time of day or season.

As Table 9, on the following page, shows, projected energy savings from implementation of the high-efficiency scenario, described earlier, suggest that carbon dioxide emissions would be reduced by approximately 85.3 million short tons by the year 2015. Just over 40 percent of these would be emissions reductions from reduced electricity consumption. These savings represent a reduction of almost 30 percent over the baseline scenario for 2015. These same savings will reduce the total amount of carbon emissions reductions necessary to meet national carbon stabilization goals by 4.3 percent.[55]

The high efficiency scenario will also reduce emissions of sulfur dioxide by 352 thousand short tons and nitrogen oxides by 370 thousand short tons by the year 2015. Once again, electricity savings account for a significant percentage of the total savings, 94 percent of the SO_2 and 51 percent of the NO_x. These savings also represent a significant reduction over baseline emissions for 2015.

Table 9. Avoided Air Emissions in 2015 (in Thousand Short Tons)

	SO_2	NO_x	CO_2
Total Savings	352	370	85,270
Electricity Only Savings	330	187	34,494

Note: Emission reductions are derived from energy saving in the residential, commercial, industrial, and transportation sectors from implementation of the high-efficiency scenario.

55. According to the Climate Change Action Plan (CCAP) 1994, developed by the Clinton administration, the national goal is to stabilize carbon emissions at 1990 levels. For energy-related emissions this is 1,344 million metric tons (MMT). See *Emission of Greenhouse Gases in the United States 1987-1994*, Energy Information Administration, U.S. Department of energy, Washington, DC, 1995. According to the *Annual Energy Outlook 1998*, see note 15, carbon emissions in 2015 are projected to be 1,888 MMT. To meet the 1990 stabilization goals carbon emission will need to be reduced by 544 MMT. Converting the 85.3 million short tons of carbon dioxide emission savings (from the high-efficiency scenario) to carbon equivalent equals 23 MMT. Illinois' 23 MMT contribution would therefore represent 4.3 percent of the total needed (23/544 = 4.3 percent).

VI. POLICY REVIEW AND RECOMMENDATIONS

With an annual energy bill of over $23 billion, the economic costs of energy use in Illinois are clearly enormous. Moreover, if current business as usual trends continue, total energy consumption is projected to increase by 28 percent by the year 2015, bringing with it all the associated economic and environmental costs.

However, there is an alternate path to the future. As the analyses presented earlier in this report document, an aggressive yet cost-effective commitment to energy efficiency could generate huge savings for Illinois, reducing energy bills for residential and business customers by over $76 billion during the 1999 to 2015 period.

The remainder of this chapter is devoted to discussing seven major policy areas (utilities, building codes, additional measures to support building energy efficiency, industrial strategies, combined heat and power (CHP) technologies, transportation, and a state-level sustainable energy agency) where creative and aggressive actions are needed to achieve significant energy efficiency improvements. In each of those areas, specific policy recommendations are provided. It is understood that many of these recommendations face significant obstacles to implementation and may be politically difficult to achieve. However, the magnitude of potential economic and environmental benefits available should make these recommendations at least worthy of consideration. That is the spirit in which this discussion and these recommendations are offered.

A. UTILITY ENERGY EFFICIENCY PROGRAMS

History and Current Situation

The history of regulatory and utility company involvement in promoting energy efficiency in Illinois is largely a story of great potential gone unrealized. Public Act 84-617, effective January 1, 1986, contained excellent language supporting the use of energy efficiency. For example, Section 8-402(a) stated:

"The objective of this Section shall be ... to utilize, to the fullest extent practicable, all economical means of conservation, nonconventional technologies relying on renewable energy resources, cogeneration and improvements in energy efficiency as the initial sources of new energy supply."

The statute required the Department of Energy and Natural Resources to "analyze, prepare and recommend a comprehensive utility energy plan for the state" (Sec. 8-042(b)) and required each public utility to file, every 2 years, an "energy plan for its service territory consistent with the planning objectives and requirements described in the Article." (Sec. 8-042(c)) Furthermore, the legislation specified that these plans should include:

"a discussion of all existing and proposed programs and policies to promote and ensure the full utilization of all practical and economical energy conservation." (Sec. 8-042(d)(ii)(C))

and

"a demonstration that the plan fully considers and utilizes all available, practical and economical conservation, renewable resources, cogeneration and improvements in energy efficiency." (Sec. 8-042 (d)(iii)(B))

Yet in spite of this seemingly specific and clear legislative intent, little of substance actually materialized. It wasn't until two years after the effective date of the legislation that the Illinois Commerce Commission entered an Interim Order submitting its proposed rule responding to Section 8-402 to the Secretary of State, and it wasn't until three years after the effective date of the legislation that the proposed rule finally took effect. Utilities weren't actually required to file a plan until mid 1989, nearly four years after the effective date of the legislation. (ICC Order #87-0261, December 21, 1988)

Subsequently, very little was accomplished in terms of actually implementing the energy efficiency envisioned in the legislation. In the assessment of individuals close to the process, the ICC never really supported the process and the utilities used a number of tactics to create roadblocks and avoid any commitment to energy efficiency. Ultimately, the energy efficiency components of the legislation enacted in 1986 were eliminated as a part of Illinois' electric restructuring legislation in 1997 (the Electric Service Customer Choice and Rate Relief Law of 1997, P.A. 90-561).

Precise information on historical spending on energy efficiency by Illinois utility companies is difficult to obtain. Repeated inquiries with the Illinois Commerce Commission were unsuccessful, as the organizational unit that used to be responsible for least cost planning and DSM has been disbanded in response to electric utility restructuring in Illinois. Utilities are not required to report any such information now, and ICC staff were unable to locate any historical spending data. What is generally acknowledged by all parties, however, is that utility energy efficiency spending in Illinois has been minimal.

Perhaps the most illustrative information available comes from an analysis by ACEEE of 1996 utility energy efficiency spending data obtained from the U.S. Energy Information Administration, together with data from the U.S. Census Bureau. That analysis compared the fifty states in terms of energy efficiency spending per capita, and found that Illinois ranked among a group of eight states with the very lowest spending ratios in the nation. Illinois was tied with Alabama and Alaska with a spending level of only 20 cents per person in the state.

Only the states of Arkansas, Mississippi, Oklahoma, Nebraska and Kansas had lower spending levels. The national average utility energy efficiency spending level per capita was 20 times higher than in Illinois.

As for current plans, the recently passed restructuring legislation in Illinois (the "Electric Service Customer Choice and Rate Relief Law of 1997, P.A. 90-561) provides for $3 million per year for an "energy efficiency trust fund", paid for through assessments on utility companies, to support residential energy efficiency programs administered by the Illinois Department of Commerce and Community Affairs.[56] It is significant to note that this $3 million annual funding level for energy efficiency would only provide essentially the same level of spending seen in that 1996 analysis discussed above, i.e., approximately 20 cents per person in the state. This would appear to perpetuate Illinois' history of extremely low energy efficiency spending.[57]

Finally, in response to severe electric capacity shortage problems this past summer, it is noteworthy that two Illinois utilities announced voluntary energy efficiency programs (Commonwealth Edison announced a $5 million program targeting residential and commercial lighting efficiency and Illinois Power announced a small pilot test of a commercial lighting program). While tiny in the context of the overall capacity shortfall situation, they at least mark an important acknowledgment of the value of including energy efficiency in the package of responses to system capacity needs.

Recommendations

The good news about Illinois' historically low spending on electricity efficiency programs is that the remaining potential for efficiency savings should be enormous. A glimpse of this latent potential was seen in the response to a small commercial lighting pilot by Commonwealth Edison in 1994. What was intended to be a 6 month pilot was fully subscribed in a matter of days. Similarly, a small $3 million commercial lighting pilot announced by Comm Ed this past summer, in response to supply shortage concerns, was sold out in three weeks. The relative lack of any significant utility DSM efforts over the years means that

56. The legislation also establishes a "Supplemental Energy Assistance Fund" for low income customers. This fund is estimated to raise approximately $76 million annually, of which 10% would be allocated for weatherization and related conservation services for low income households. This fund essentially replaced existing funding mechanisms for weatherization and utility bill payments.

57. Of the nine states which have thus far specified energy efficiency spending levels in their restructuring legislation or regulatory orders, Illinois would rank last in energy efficiency spending per capita. The average required energy efficiency spending per capita in the other eight states is over 50 times higher than for Illinois. (See the ACEEE report "An Updated Status Report of Public Benefit Programs in an Evolving Electric Utility Industry", July 1998, for data on restructuring related spending for energy efficiency.)

there are tremendous opportunities to improve the energy efficiency of the building and equipment stock in Illinois.

In view of this great potential, and in recognition of the very strained electric supply situation in Illinois and the Midwest, this report identifies three key recommendations which are presented below.

Adopt A Significant System Benefits Charge (SBC) To Fund Energy Efficiency Programs On A Statewide Basis

P.A. 90-561 actually includes a funding mechanism for energy efficiency (the "Energy Efficiency Trust Fund") which is similar in concept to a System Benefit Charge[58]. Unfortunately, the amount of funding generated ($3 million/year) is clearly inadequate, both in terms of the tremendous untapped potential for energy efficiency in Illinois, and in terms of what other major states proceeding with restructuring have allocated to energy efficiency. Furthermore, the energy efficiency required in P.A. 90-561 is restricted to the residential sector, thereby missing the extremely cost-effective efficiency savings available in the commercial and industrial sectors.

While some believe that private energy service companies (ESCOs) will step in and serve those sectors, the history of the ESCO industry gives little reason to believe that will happen. Due to the high "transaction costs" of marketing, contracting, measurement and verification, etc., ESCO's have tended to pursue only the largest of commercial and industrial customers. Moreover, most work performed by ESCOs nationally continues to be done in connection with utility incentive programs of one type or another. A statewide System Benefits Charge placed on distribution service would provide Illinois with a competitively neutral way to help fund significant energy efficiency improvements in the state.

As for the appropriate amount, Illinois could easily spend 10 to 20 times the amount specified in P.A. 90-561 on cost-effective energy efficiency initiatives. As an example, in neighboring Michigan, a single utility spent over $40 million per year in the early to mid 1990's, achieving a very attractive cost of conserved energy of 2.6 cents per kWh.[59] Similar results should easily be obtainable in Illinois.

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58. A System Benefit Charge is a small surcharge (typically 1 or 2 mills, i.e., 1 or 2 tenths of a cent per kWh) put on electricity delivered through the distribution system, regardless of the generation supplier. This competitively neutral mechanism has been adopted in a number of states as a way to fund public benefit programs such as energy efficiency.

59. M. Kushler, "Testimony of Martin G. Kushler, Michigan Public Service Commission", Staff testimony in Case No. U-10554, Lansing, Michigan, November 18, 1994.

Programs supported by the energy efficiency systems benefits charge should include a comprehensive and complementary mix of direct savings acquisition programs featuring competitive procurement (e.g., through Energy Service Companies) and innovative "upstream" programs focused on capturing "lost opportunities" (e.g., emergency replacement of equipment, new construction, etc.) and transforming existing markets for buildings and equipment to better capture efficiency opportunities. This type of comprehensive approach is being pursued in several leading states (e.g., New York, Massachusetts, California, etc.). There are a number of references available that describe these types of program initiatives.[60]

Decouple Utility Company Profits From Sales

In establishing the new regulatory structure for electric utilities in Illinois, it will be critical to devise mechanisms to ensure that utilities are not financially averse toward energy efficiency. In particular, it is important to decouple distribution company profits from sales. Under the rate freeze which has been instituted in Illinois, the utilities will have a powerful incentive to increase sales, and conversely, to not wish their customers to pursue energy efficiency. This is because additional sales would increase revenues by a greater amount than needed to cover the incremental costs from those sales, thus resulting in greater profits. Similarly, reductions in sales from efficiency would lower revenues by more than they would lower costs, thus resulting in lower profits.

One example of a potential remedy to this situation is to modify the rate freeze requirement so that, at the end of the year, actual sales levels and forecasted sales levels are compared, and, if actual sales are greater than forecasted sales, the fixed cost portion of these excess sales are refunded to customers. Conversely, if actual sales are less than forecast, the fixed cost portion of below forecast sales are charged to customers. These adjustments would remove the otherwise embedded disincentive to the utility regarding having its customers pursue energy efficiency. Such a system was included in a recent settlement agreement in Oregon between PacifiCorp and interveners.[61] Similar approaches have been proposed in New York in a proceeding involving Niagara Mohawk Power Corp.[62]

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60. For example, see Eto, J., C. Goldman, and S. Nadel "Ratepayer-funded Energy-Efficiency Programs in a Restructured Electricity Industry: Issues and Options for Regulators and Legislators" ACEEE, Washington, D.C. May 1998.

61. "Oregon Alternative Regulation Settlement Proposal," Joint Parties, filing to Oregon Pubic Utilities Commission, Portland, OR, October 1996.

62. P. Centollela, "Testimony of Paul Centollela in Case 94-E-0098, Proceeding on Motion of the Commission as to Rates, Charges, Rules and Regulations of Niagara Mohawk Power Corporation," NYPSC, Albany, NY, 1996.

Adopt Least Cost Planning Principles For Restructured Utility Companies

During much of the past decade, integrated resource planning (IRP) was a planning technique in which a wide array of possible investments for meeting future load growth were examined and an optimum mix selected that minimized cost while providing good levels of reliability. In recent years, IRP has been extensively used by utilities to determine optimum new investments in generation, transmission, distribution, and DSM resources. With the restructuring of the utility industry, distribution companies in many areas will be primarily concerned with only distribution investments. However, utilities in Illinois are also required to be the electricity supplier of last resort for customers who do not choose an alternative supplier. For these generation services, utility companies should still be responsible for securing least cost electricity services, which could include the use of energy efficiency.

Furthermore, in some cases, energy efficiency investments can be a lower cost alternative than investments in new distribution facilities and equipment because efficiency induced load reductions can postpone the need to reinforce the distribution system in areas where growing loads threaten to make existing distribution capacity inadequate. For example, Con Ed and Rochester Gas & Electric have both targeted some of their energy efficiency programs in this manner. Similarly, energy efficiency investments that reduce loads can be an alternative to increased power purchases made by distribution companies to serve customers who elect not to choose alternative power providers. Illinois utilities should be required to use a least cost planning approach toward meeting their responsibilities as distribution utilities as well as their obligations as suppliers of last resort to Illinois customers.

Back when utilities were responsible for all generation, transmission, and distribution services, IRPs were large and complex undertakings. Now, if planning focuses on the distribution and power purchase roles, the planning processes can be significantly simplified. For example, instead of screening a wide array of potential generation resources, prices in the futures market can be used. Instead of planning for 20 year time horizons typical for generation, much shorter (5 to 10-year) time horizons used for distribution and power purchase planning can be used. In these ways, a distribution utility planning requirement can serve a useful purpose — optimization of investments — without becoming a major burden.

However, it is important to note that Illinois' utilities are unlikely to embrace least cost planning principles on their own initiative. If they are regulated in the old "cost of service" manner, they will have the traditional embedded incentive to increase the capital investment upon which they can earn a rate of return. If they are regulated through a simple price cap or rate freeze mechanism, they will have the previously discussed embedded incentive to maximize profits by maximizing sales levels. It will require a carefully designed regulatory least cost planning mechanism to provide the utility with the proper economic incentives to seek to lower total system costs through the incorporation of demand side measures.

B. Building Codes

History and Current Situation

In February 1991, the Illinois Department of Energy and Natural Resources (DENR) filed its second Statewide Electric Utility Plan with the Illinois Commerce Commission (ICC). Included as part of this plan was a recommendation that cost-effective improvements in building energy and end-use device efficiency be vigorously promoted throughout the State by developing and evaluating energy efficiency standards for commercial lighting, industrial motors, and residential and commercial buildings. The ICC approved this recommendation, and specified that DENR lead a collaborative effort to develop a detailed proposal including the state's electric utilities, ICC staff, and other interested and affected parties.

As a part of that effort, ACEEE was commissioned to perform a study to explore options for a statewide building code as well as statewide equipment efficiency standards, and to evaluate the cost-effectiveness of a statewide building energy code for reducing energy demand in Illinois. That study was completed and a comprehensive final report published in May 1994.

The results of that study demonstrated that upgrading the residential and commercial building codes in Illinois would be extremely cost-effective and produce significant energy savings. Quoting from the report:

"Based upon this review, we recommend that Illinois adopt the 1992 CABO Model Energy Code for low-rise residential buildings, and the ASHRAE 90.1 code for commercial and high-rise residential buildings with Illinois-specific modifications to increase lighting and chiller efficiencies. Cost and savings analyses show that these two codes will be extremely cost-effective from both building owner and societal perspectives. The codes will increase the energy-efficiency of buildings, over those being built today by 10 to 18% while not radically departing from current construction practices." (P. 2-1)

Unfortunately, no formal action was ever taken to implement the recommendations contained in that 1994 report. As of this writing, there is still no statewide building energy code for residential or commercial buildings.

Recommendations

Adopt Statewide Residential and Commercial Building Energy Codes To Improve The Efficiency Of New Buildings

Building energy codes are an effective and widely used strategy for ensuring that new buildings are constructed to be relatively energy efficient. Illinois should revisit the 1994 report and pursue actions to implement the recommendations contained in that report: i.e., to implement the residential 1992 Model Energy Code and the ASHRAE 90.1 code for commercial and high rise residential buildings, with the Illinois-specific increased lighting and chiller efficiencies described in the report. These would be modest and cost-effective steps to help ensure that newly constructed buildings in Illinois are reasonably energy efficient, and should produce significant energy savings for the state over time.

To help address the practical problems of trying to get a statewide residential energy code passed, it may be helpful to open discussions with home builders. Under the current situation in Illinois, many municipalities in the state have their own energy related code provisions, while many others have none. This patchwork quilt of code coverages presents difficulties for builders, who frequently construct homes in more than one municipality. They could be of assistance in securing a uniform statewide code. If opposition from the city of Chicago presents a special barrier, perhaps legislation could specify that cities above 1 million in population could be exempt, and a code could still cover the rest of the state. Admittedly, a statewide code is difficult in Illinois due to Home Rule limitations. However, other states such as Pennsylvania are pursuing a statewide code in spite of similar Home Rule constraints, and the benefits to be obtained from a good statewide code make it worthwhile to at least pursue the issue.

C. Additional Measures in Support of Building Energy Efficiency

History and Current Situation

In addition to the policies discussed in the previous two sections, there are a number of other miscellaneous policy areas which can support improved energy efficiency in buildings. These include: energy codes for state owned buildings; energy standards for equipment; home energy rating systems; and having a state energy office to pursue energy efficiency opportunities. Illinois' record in these areas is mixed, but better than the first two policy areas discussed in this chapter.

For example, Illinois has been able to maintain the functions of a state energy office, which were transferred to the Department of Commerce and Community affairs in 1995. That office has been active in supporting such policies as a home energy rating system (HERS) program and an Affordable Housing Program, and in facilitating some industrial energy initiatives. Also, Illinois does have a statewide building energy code for state owned buildings, and has undertaken a number of activities to pursue energy efficiency in state owned buildings. The State Buildings Energy Program did detailed energy surveys of state facilities and documented savings of one million dollars annually from 1987 until 1995. Efforts continue, at a reduced pace, involving such things as motor surveys and lighting surveys in state facilities. Nevertheless, there are a number of areas where the policy efforts in Illinois could be improved.

Recommendations

Consider Adopting Equipment Efficiency Standards

Although federal standards cover a number of appliances and types of equipment, there are still a number of mass-produced products for which a substantial amount of energy can be saved by establishing minimum efficiency standards. For these products, high-efficiency levels are very cost effective to consumers, but due to a variety of market barriers, low efficiency products still dominate the market. Among these products are dry-type distribution transformers (used in many commercial buildings) and packaged commercial refrigeration equipment (e.g., vending machines, ice makers, and water coolers). These and other opportunities for state efficiency standards are discussed in detail elsewhere.[63]

In addition, the earlier referenced ACEEE study on "Energy Efficiency Codes and Standards For Illinois" specifically examined the opportunities for improving the efficiency of equipment not covered by federal standards. The study found that there were nine product types for which state standards appeared to be justified. Illinois should re-visit and update that 1994 study and seriously explore the possibility of adopting targeted state equipment efficiency standards.

Continue To Improve The Energy Efficiency Of State Owned Buildings

Illinois has updated its statewide building energy code for state owned buildings. It is based upon ASHRAE 90.1-1989. The State Capitol Development Board has authority to approve code updates and should pursue this option when the new ASHRAE code becomes available (currently expected in 1999).

In addition, Illinois should consider establishing a revolving loan fund to finance energy-saving improvements in state and municipal facilities. A highly successful program of this type, the LoanStar program, is operating in Texas and to date has achieved measured energy cost savings of more than $19.9 million in public buildings and schools. A key feature of this program is that it devotes extensive attention to properly commissioning energy-saving measures (making sure they operate correctly) and to monitoring actual energy savings, both to catch problems that may develop and to make a compelling case that the program is providing a substantial return on the state's investment. Funding for the Texas program comes

63. Nadel and Suozzo, *The Need and Opportunities for State Action on Equipment Efficiency Standards*, American Council for an Energy-Efficient Economy, Washington, DC, 1996; Nadel, *Minimum Efficiency Standards: Options for Federal and State Action*, American Council for an Energy-Efficient Economy, Washington, DC, 1994.

from oil overcharge funds but programs in Illinois could just as well be funded through state bonds.[64]

D. Industrial Energy Efficiency

History and Current Situation

Several adjoining mid-western states have a history of effective industrial energy efficiency programs run either by utilities or directly by the state (Laitner et al, 1995, Elliott, Pye and Nadel 1996, Elliott and Pye 1997). Industrial energy efficiency activities in Illinois have been more limited, although the Department of Commerce and Community Affairs (DCCA), Division of Energy Conservation and Alternative Energy does have a small scale ongoing industrial effort. These efforts have included programs focused on specific industrial groups.

The first area addressed by DCCA was plastics, in which a survey of the industry was conducted and a solicitation was made to the industry for energy efficiency projects, with matching grants of a maximum $50,000 being provided. In all, 13 grants were provided, totaling $432,271. Over $1.2 million of total investment was achieved. Projected savings from this solicitation are over $600,000 annually. A similar program is now at the solicitation phase for the fastener industry, and plans are under consideration for a similar initiative for the food industry. In addition, DCCA has been working with the Energy Resource Center at the University of Illinois Chicago and the North American Diecasters Association to develop an energy efficiency workbook and one-day seminar. DCCA also funds energy efficiency programs at five Small Business Development centers, and two CEMOI centers in the southern part of the state that provide surveys to small business. DCCA also participates as a Motor Challenge Allied Partner, coordinating with utilities in the state and has assisted in 15 Motor Master workshops attended by almost 250 participants. (David Kramer 1998). DCCA is also a sponsor of the Compressed Air Challenge, a national partnership to develop and deliver compressed air efficiency information and training.

As can be seen from the earlier analysis in this report, significant cost-justified energy efficiency potential clearly remains within the industrial sector. However, energy savings alone have not proven sufficient to motivate industry to action. Fortunately, many energy efficiency opportunities have additional benefits in the areas of productivity, safety, product quality, and environmental compliance. In many cases it is these other benefits, which may far exceed the energy benefits, that determine whether a project is implemented. An integrated strategy is needed to capture this potential, focusing on a broad range of benefits and looking

64. J. Haberl, et al., *Measuring Energy-Savings Retrofits: Experiences from the Texas LoanStar Program*, Oak Ridge National Laboratory, Oak Ridge, TN, 1995; "LoanSTAR Program Saves Texas Taxpayers Millions in Energy Bills," *TEES Engineering Issues*, Texas A&M Univ.,Texas Engineering Experiment Station, College Station, TX, 1995.

at the manufacturing system, rather than focusing exclusively on its components, and the project must be presented in financial terms that are commonly used by industrial decision makers (Pye 1998; Elliott, Pye, and Laitner 1997).

Additional initiatives are needed to realize the full industrial energy efficiency opportunities in the State. Program opportunities fall into the six broad strategic categories listed below, and could be undertaken at the regional and state level.

Recommendations

Illinois Should Establish And Promote A Comprehensive Industrial Energy Efficiency Strategy

The industrial energy efficiency strategy should address all aspects of the opportunity implementation process:

- opportunity identification,
- technical and design assistance,
- financial analysis,
- financing,
- operation improvements, and
- promoting advanced technologies.

An example of a well-integrated approach can be seen in the experience of New York. In the past, the New York State Energy Office (NYSEO) conducted comprehensive industrial energy efficiency programs with these characteristics. NYSEO's *Flexible Technical Assistance Program* provided audit, design assistance, procurement and implementation services. The *Energy Investment Loan Program* provided financing with interest rate subsidies to commercial lenders for their customers' energy-efficiency projects, and the *Construction Services and Professional Training Programs* provided training, technical assistance and resources to all levels of industrial staff from engineers to operators. Also, utilities in New York have conducted industrial DSM programs complementing the state's activities. These combined programs have achieved impressive results, especially in encouraging industrial facilities to make process-related improvements (Elliott and Weidenbaum 1994). With the closing of NYSEO, the program has been continued successfully by the New York State Energy Research and Development Authority (NYSERDA) (Platt 1998).

Government and utility programs can help to reduce the cost and hassle of identifying efficiency improvements (e.g., through surveys and technical and purchasing assistance) and the cost of installing efficiency measures (e.g., through rebates, loans, and creative private market financing). While large companies can benefit from these programs, they are especially critical for many smaller companies that lack the financial and human resources available in many larger companies to implement these energy efficiency and process improvement projects (Elliott, Pye and Nadel 1996).

The following material discusses each of the six components of the industrial efficiency strategy listed above in more detail.

Opportunity Identification

Identification of energy efficiency opportunities is the first step in the process. Illinois should consider establishing a program similar to the NYSERDA FlexTech design. This could be housed within state agencies, but it would be preferable to establish a statewide nonprofit center to provide these services, as has occurred with the Energy Center of Wisconsin and Advanced Energy in North Carolina. Another option is to locate the center at an academic institution as has been done with the Iowa Energy Center. Initial operating funding for an industrial assessment initiative of $500,000 - $1,000,000 annually would allow hiring several experienced staff engineers, as well as establishing consulting relationships with technical experts. Funding should be expanded as the demand for the center's services grow.

The Industrial Assessment Centers (IACs) (formally known as the Energy Analysis and Diagnostic Centers) are an existing resource of technical assistance that could be augmented with funds from either state revenues or a utility systems benefit change. Illinois has an IAC at Bradley University, and there are five centers in adjoining states that service most of Illinois.[65] In addition, the University of Illinois-Chicago has applied to become an IAC. This successful program, which receives its core funding from the U.S. Department of Energy (DOE), provides low-cost audits to small- and medium-sized firms. Nationally, 29 IACs each conduct approximately 30 assessments annually. Assessments identify energy savings opportunities that can be pursued by other key players, such as gas and electric utilities, or by the companies themselves. The overall IAC program achieves an average of 10 percent implemented energy savings with the average measures at a facility having a simple payback of less than two years. In addition, the program trains engineers in industrial energy efficiency techniques and these individuals often seek employment as energy managers in local industries (DOE 1998; Woodruff et al. 1996). Although the five IACs mentioned above cover most of the state, the number of assessments they can offer represents a small fraction of the need of eligible firms.

Several opportunities exist to expand and enhance the IACs in the region. The state could follow the example of Texas, which is now using oil overcharge funds to expand the activities

65. The University of Missouri-Rolla serves the southwest part of the state while the southeast is served by the University of Louisville. The north and central sections are served by University of Notre Dame, University of Wisconsin, and Iowa State University (DOE 1998).

of the IAC at Texas A&M in support of the new Texas Industrial LoanStar program. In addition, the IAC at Texas A&M University College Station has created an affiliate relationship with Texas A&M University in Prairie View to expand the coverage in the state (Eggebrecht 1996).

Based upon the precedent in Texas, Illinois could expand the activities of the five IACs in order to increase their services to small- and medium-sized manufacturers, who have been shown to benefit the most from this type of assistance (Hopkins and Jones 1995). In addition, new state-supported IACs could be established at Illinois universities or community colleges, either as affiliates of existing IACs or as new, independent centers. By expanding the level of activity at existing IACs as well as the number of IACs, a larger fraction of the eligible firms could be served. Increasing the number of centers would also allow closer relationships to develop between the IACs and firms in their immediate area.

Another opportunity is for DCCA to partner with Illinois EPA's (IEPA) Partners in Pollution Prevention (PIPP) program. (DCCA currently operates the Recycling Industry Modernization (RIM) program that provides assessment and grants to sites to implement recycling and source reductions.) PIPP, which has 200 partners, is a voluntary program that encourages companies to prevent pollution, rather than using end-of-pipe pollution control approaches. Energy efficiency is an excellent example of pollution prevention, and while it is not currently included in PIPP, EPA is restructuring the program and seriously considering adding an energy efficiency component, making it an opportune time to consider partnering (Gerberding 1998). Experience shows that energy efficiency and non-energy forms of pollution prevention often occur simultaneously, expanding the benefits of such projects, and presenting an opportunity to leverage expertise, funding, and industrial contacts (Pye 1998).

Technical and Design Assistance

Industries' lack of access to specialized expertise and energy efficiency services can be barriers to implementing efficiency opportunities (Alliance et al. 1997). The NYSERDA FlexTech program is one example of the kind of resource that can be made available to a region. Other centers sponsored by the states, utilities, and industry could be developed, increasing the scope and availability of expertise to assist industry with energy efficiency and productivity enhancements.

Since development of this expertise is costly, it would be reasonable for state agencies and utilities in the region to pool their resources. A regional effort along these lines has been established in the southeastern United States, and could be copied in the Midwest. Advanced Energy (formerly the North Carolina Alternative Energy Corporation) established an Industrial Electrotechnology Laboratory (IEL), which now operates in South Carolina and Virginia as well as North Carolina. The IEL provides technical training, assistance, and testing services to industrial users in areas such as electric motor systems, product heating and drying, and low-emission coatings. The IEL allows industrial customers to develop and evaluate process technology changes in a near-production environment without disrupting the manufacturing operation (Koger 1996).

Electric motor systems offer one of the most attractive opportunities for energy efficiency improvements but the expertise necessary to support motor programs is in limited supply. A state or regional motor systems program could address this problem. Several national initiatives have emerged that are intended to be the foundation for local initiatives. The DOE Motor Challenge offers extensive resource to program implementors through their Allied Partners program (DOE 1997). The DCCA is currently making only limited use of the range of available resources. The Consortium for Energy Efficiency (CEE) has developed programs for premium efficiency motors, motor repair and energy efficient transformers (CEE 1998). Compressed Air Challenge (for which DCCA is a sponsor) has been formed by a unique group of government entities, utilities, private interest, and public interest groups to produce information and training on efficient compressed air system operation and design, and will offer operator certification in the future (CAC 1998).

An example of a successful motor program is the Electric League of Washington State (a coalition of electric utilities), which has retained a motor expert to coordinate motor programs among its members. The program uses brochures and efficiency levels developed by CEE. This effort to promote motor management and encourage efficient motor purchases has expanded to the entire Pacific Northwest under the new Northwest Energy Efficiency Alliance. The effort is being expanded to include compressed air and motor repair, both based on national initiatives (Zdebski 1998).

The Energy Center of Wisconsin (ECW) also offers two model motor-system programs: Responsible Power Management (RPM) and Performance Optimization Service (POS), which promote energy-efficient equipment and improved optimization of motor-driven systems. RPM offers a consistent motor-driven equipment incentive program for all the state's electric utilities, coupled with technical support that is coordinated with the CEE initiative. The POS program, which uses the systems approach to identify, assess, and optimize the performance of industrial motor systems, offers comprehensive technical training and support to end-users and motor system design engineers. The ECW was a founding sponsor of the Compressed Air Challenge and is now hosting the organization during its formative period (Meadows 1998).

Programs similar to the Washington and Wisconsin initiatives to improve motor system efficiency should be considered at the state or regional level in Illinois. A northeast regional utility motor initiative, led by the Northeast Energy Efficiency Partnership, Inc., has been formed (NEEP 1998). The opportunity exists to either start a broad Illinois state initiative or revive the Midwest motor consortium that was started in the early 1990s. It is important that utilities in the state be encouraged to support and participate in these initiatives, and that groups coordinate their efforts.

Financial Analysis

Many businesses operate with a tight constraint on their capital budgeting. Hence, the allocation of capital remains a significant barrier to achieving greater levels of energy efficiency. Given a choice between expanding existing production capability and introducing new products, and reducing energy bills, the production-related projects will invariably win out. Hence, presenting projects based on total benefits will likely be more effective than building a case on the energy savings alone because, as mentioned earlier, investments in energy efficiency often have significant non-energy "co-benefits." By quantifying both energy and non-energy benefits, energy efficiency investments can be elevated from being simply "cost justified" to becoming as attractive or more attractive than alternative capital investments.

The financial analysis of an efficiency project is the basis for making the investment decision. The financial analysis may range in sophistication from a simple payback (investment/annual net savings) or rate of return (average annual net savings/total investment) to more accurate calculations, such as net present value (NPV) or internal rate of return (IRR), which take into account the time value of money. Regardless of which calculation is used, *the most important part of a financial analysis is the comprehensive estimation of project costs and benefits.*

The financial analysis is not only an important part of a company's investment decision-making process, but is also critical to obtaining project financing. The more information that can be provided to a lender regarding the costs and benefits of a project, the easier it is for the lender to accurately determine the level of risk and appropriate interest rate. The more non-energy benefits can be quantified, the more attractive the investment is in terms of minimizing risk and interest rates.

Financing

Some industrial customers, particularly many small- to medium-sized companies, lack the capital to finance energy-saving improvements. The existing grants program at DCCA is a successful effort, but could benefit from substantial expansion. A financing program may offer a lower cost option for overcoming this barrier. Such a program could be: specifically for industry (e.g., NYSEO's Energy Investment Loan Program); part of the utility system benefit charge, discussed in the utility section; or operated in conjunction with loan programs for other sectors (e.g., Texas' LoanStar program). Based on the New York experience, we suggest a state total industrial loan pool of approximately$125 million.[66] Such a program could use private capital with interest-rate reductions for small- and medium-sized companies,

66. These levels are based on subsidizing the financing of an additional 3 percent of industrial capital investment in Illinois (as reported by the Census [1993]) for an average five 5-year term. The cost of the subsidy is 29 percent of the dollar value of the realized capital investments, as was achieved in the NYSEO program (Elliott and Weidenbaum, 1994).

financed with system-benefit charge monies, or state funds could be issued at interest rates somewhat below market rates.

Operation Improvements

Once energy efficiency measures and process improvements are installed, individual plant staff must learn how to operate this equipment correctly. FlexTech is unique in that it provides customized training as part of its energy services program (Elliott and Weidenbaum 1994). As the Energy Center of Wisconsin's POS program has discovered, an important aspect of process optimization frequently involves changes to the operating procedures. These can frequently be more important than the equipment changes (Meadows 1998). On-the-job training services in Illinois would help insure that industrial equipment is operated and maintained properly and that the energy savings potential of efficiency improvements is realized. Funding for these efforts is included in the recommended budgets for the industrial assistance center initiative discussed above.

Efficient operation requires properly trained engineers and technicians who are aware of the benefits of energy efficiency to the success of the company. Companies such as Dow and 3M have achieved impressive bottom-line benefits when they "empowered" their staffs to look for efficiency opportunities (Nelson 1993 and Schultz 1996). One opportunity to create trained and aware engineers is through IACs. In addition to providing immediate benefits to companies, IACs are creating a pool of engineers with energy efficiency expertise for companies to draw upon. Technicians are as important to the efficient operation of industrial process as engineers. The region's community college systems should be encouraged and funded to incorporate energy efficiency into the engineering technology curriculum, as has occurred with programs in North Carolina and Wisconsin. As mentioned above, the Compressed Air Challenge offers a nationally developed training program that can be deployed at state, local, and regional levels by a range of entities.

Promoting Advanced Technologies

In addition to promoting currently available energy efficiency measures, the state and utilities should encourage technological innovation in the industrial sector. This can lower energy intensity as well as create new opportunities for economic growth. Technological innovation is also critical for industrial competitiveness and environmental protection over the long run.

NYSERDA has an active state program supporting research and demonstration in industrial energy efficiency and pollution prevention technologies. NYSERDA's industrial research program funding is currently about $4 million annually. This represents about a quarter of the Authority's annual research budget. In recent years, the program has averaged about 35 active programs. NYSERDA documents annual benefits from industrial sector projects undertaken after 1990 of $8 million in 1995 and $9.4 million in 1996. These energy savings represent only a portion of the true benefits since benefits estimates are unavailable for a fraction of the projects. NYSERDA is attempting to make a more accurate projection and forecasted program benefits of more than $15 million for 1997 (Peter Douglas 1997).

The state of Illinois has already been actively involved with the DOE's National Industrial Competitiveness through Energy, Environment, and Economics (NICE^3) program (Kramer 1998), which can be viewed as a model effort in this area. NICE^3 provides matching grants to state government and industry partnerships that demonstrate innovative energy efficiency and waste-reducing technologies. Many projects have successfully demonstrated new techniques for reducing energy use, cutting emissions, and saving businesses money. The state and utilities should provide additional resources for NICE^3 or similar projects.

Another opportunity is to establish a state *Industries of the Future* (IOF) program. A state-level initiative would build on the successful U.S. DOE IOF program, which has developed industry-led initiatives for nine energy- and waste-intensive industries.[67] IOF creates partnerships among industry, government, and supporting laboratories and institutions to accelerate technology research, development, and deployment. The DOE Office of Industrial Technologies (OIT) has a program to assist states that develop industry-led initiatives for both national IOF industries and industries critical to individual states. These initiatives undertake cooperative programs to address specific needs of a state's industries (Quinn 1998).

Coordination Of Efforts

Because of the limited existing program framework, it is important that Illinois leverage available program resources at least initially. An expanded use of resources such as those developed by Motor Challenge, Compressed Air Challenge and CEE, could be coordinated with other potential players such as utilities and universities, and would represent an opportunity to expand industrial programs in the state. In addition, the state should consider initiating a formal state-level IOF program, since this effort will not only allow the State program to develop programs appropriate to the needs of the state's industries, but will also develop channels for program deployment. Partnering of DCCA and IEPA's PIPP presents yet another opportunity to leverage resources — both human and financial.

Moreover, the state would benefit from the establishment of a technology center similar to Advanced Energy's IEL, which would provide comprehensive assistance to industry on energy efficiency and the accompanying benefits of reduced production costs, improved product quality, and lower environmental emissions. This center might be part of a multi-sector center or could be specifically targeted at the industrial sector alone. Because of the costs associated

67. The IOF industries are Forest Products, Chemicals, Glass, Aluminum, Iron and Steel, Petroleum, Mining, Agriculture, and Metals Casting.

with establishing this type of center and retaining expert staff, regional joint efforts should be seriously considered. The state also might consider funding IAC assessments from one of the centers in adjoining states or establishment of a state-funded center, perhaps at Bradley University which has an IAC.

A comprehensive approach, such as the NYSERDA FlexTech approach, either housed within existing agencies, utilities or at an energy center should be the goal for the development of a program. Included in this should be a loan program for Illinois industrial companies, with an initial capitalization of $125 million, which could be structured using either the New York or Texas models. This funding could be provided by bonds, repaid with utility system benefit charge (SBC) funds.

With focused effort, the state can plot a more productive and secure future for its industrial sector with broad benefits from industrial process improvements and modernization, as have already been realized in New York and Texas.

E. Combined Heat and Power

History and Current Situation

Combined heat and power (CHP), also known as cogeneration, is a system configuration that generates electricity and thermal energy in a single, integrated system, rather than with separate electric power plant and heating and cooling equipment. Thermal energy recovered in CHP can be used for heating or cooling in industry or be distributed to buildings in the form of steam, hot water or chilled water via district energy systems. The total efficiency of these integrated systems is much greater than from separate systems.

CHP systems comprise a somewhat unique but very promising policy opportunity. Issues surrounding CHP bridge across several of the four policy categories discussed in this chapter. While the industrial sector is the prime candidate near-term for application of CHP, opportunities also exist in the institutional, commercial, and now even in the residential sectors.

Many manufacturing plants and district heating plants operated CHP facilities at the turn of the century. As a separate electric power industry emerged in the U.S., the electric generation capacity at most of these facilities was abandoned in favor of more convenient purchased electricity. However, some industries, such as pulp and paper and petroleum refining, have continued to operate their CHP facilities. In the past two decades, new interest has emerged in CHP, influenced significantly by the Public Utilities Regulatory Policies Act (PURPA) as discussed below.

PURPA played a critical role in moving cogeneration into the marketplace by addressing many barriers that were present in the early 1980s. These barriers included high standby charges from utilities and unwillingness to buy excess power. PURPA limited the standby charges and required utilities to purchase at their "avoided cost." Due to PURPA, many independent power producers found a use for some of their waste thermal energy. However, because PURPA allowed system as little as 5% useful thermal energy to qualify, many systems were optimized for electricity production and were not very efficient (Bluestein 1998).

The 1990s saw a change in the power market with the emergence of independent power producers (IPP) who did not need to find a use for waste heat. The barriers that PURPA was intended to address changed with the market, and a new set of barriers to efficient cogeneration emerged. "Avoided costs" were falling rapidly, driven by declining fuel cost and changes in generation mix. Rather than buying power at their avoided cost, utilities were purchasing power in wholesale markets based on market conditions. Concurrently, many utilities increased standby charges to cogenerators in part to discourage cogeneration and the resulting loss of sales revenue. These developments taken together slowed, but by no means eliminated, expansion of cogeneration capacity during the 1990s (Bluestein 1998).

These developments increased the attractiveness of generating power only for the wholesale markets, and discouraged independent power producers from seeking steam customers for their new plants.

Combined heat and power (CHP) systems initially consisted primarily of boilers that generated steam, some of which was used to turn steam turbines that generated electricity. Due to the cost and complexity of these systems, they were mostly confined to sizes of more than 50 MW_e,[68] precluding their installation at many manufacturing facilities or in commercial buildings. Recent advances in electricity generation technologies, in particular advanced combustion turbines and reciprocating engines, are reducing system costs, enabling much smaller CHP systems and increasing potential electricity output per unit of fuel input. Combustion turbines are now cost-effective in many applications down to 500 kW_e and reciprocating engines can be cost-effective down to 50 kW_e, with even smaller equipment on the horizon. This smaller equipment dramatically expands the number of sites where CHP can be installed. In fact, a turbine or engine can replace fuel burners in some existing boilers, adding electricity generation capability while reducing on-site emissions of pollutants (Interlaboratory Working Group 1997).

In addition to those operating cost and environmental benefits, CHP implementation could also have beneficial effects on the electric system in the state. Since new generation and transmission capacity will be needed to meet Illinois's growing energy requirements, and to

68. $_e$ signifies electricity.

replace aging existing facilities, one strategy is to address this need with electricity generated by combined heat and power systems. Conventional electricity generation is relatively inefficient, converting only about one-third of the fuel's potential energy into useful energy, with the remaining energy rejected to the environment in the form of heat. CHP systems reclaim most of this heat for use in industrial processes or conditioning buildings. Overall system efficiency of CHP systems can approach 85%. In addition, by locating the generation at the point of use (so-called distributed generation) the pressure to build additional electricity transmission capacity is reduced.

Although the technical performance and cost of CHP systems have greatly improved, significant barriers limit widespread use of CHP in the United States (Casten and Hall 1998). These barriers influence investments in capital equipment and tend to "lock-in" continued use of polluting and less-efficient utility infrastructure. The Sears Tower in Chicago is a typical example of the problems frequently encountered by CHP projects. The building owners sought to install a CHP system to deliver steam, chilled water and electricity to their tenants. They were unable to reach an agreement with their local utility on the issues of interconnecting their generation to the utility, which has already delayed the system's installation by several years.

If CHP is not considered for future generation, transmission, and distribution requirements, the new investments that must made in utility capacity to meet load growth may preclude future deployment of CHP. (Com Ed has acknowledged this opportunity, and is developing a list of suggested CHP locations.) The main barriers to CHP fall into two broad categories:

Permitting — Many current permitting regulations do not take into consideration the technology developments that have taken place with CHP, nor the environmental benefits inherent with CHP. Most air emissions regulations currently are based on emissions per unit of fuel used by the system. This approach does not take into account differences in the efficiency of energy using equipment. CHP systems make much more efficient use of the fuel used than do separate generation systems. Since a CHP system will use more fuel than a conventional boiler system, companies seeking to install CHP systems frequently encounter problems obtaining environmental permits, because they receive no credit for additional usable energy they produce.

Other regulations can unintentionally discourage CHP. Many communities are concerned that because many CHP systems use turbines or engines, there will be a local noise problem, in spite of fact that new turbines and engines are frequently quieter than existing equipment. In addition, local regulations may require full time operators for all engines, based upon past experiences with old style equipment in the days before computer controls. New systems have an excellent record in automated operation (Carroll 1998).

Utility Regulations — When new capacity is added at a customer facility, the customer is faced with a number of issues. Many utilities will require an "exit fee" to recover the cost of their investment in generation, transmission and distribution equipment that was made to satisfy the load. In addition, as part of restructuring, the customer may also be asked to pay a stranded-cost recovery fee to pay for past non-economic investment by the utility, as well as a competitive transition fee. Utilities can also charge fees to provide backup power, which have frequently been at artificially high levels. These fees can total to almost the cost of the electricity that is no longer being purchased.

In addition, utilities can erect barriers to connecting the customer's system to utility grid. These barriers include complicated and expensive technical interconnect requirements which exceed that which is required to insure safe and reliable operation of the grid.

Experts are confident that the declining trend in new projects can be reversed, and significant new CHP capacity could be installed if these barriers are removed (Casten and Hall 1998; Davidson 1998; Kaarsberg and Elliott 1998). While federal action may be the long-term solution to some barriers, changes in policy and regulations by states can overcome many of the barriers.

Recommendations

Set up expedited permitting for CHP systems

Permitting for CHP systems that use smaller, standardized packages, engines and turbines should be streamlined. The state should certify emissions from this equipment, in cooperation with manufacturers, and the state should issue permits expeditiously, based on this certification using a standard form.

Implement output-based air pollution regulations

CHP's efficient use of energy will be recognized if permitting is based on the emissions per unit of *usable energy out* rather than *per unit of fuel consumed.* EPA has recently begun to consider "output" based standards, which are based on the emissions per unit of usable energy delivered by the system. A new EPA rule gives credit for the greater efficiency of CHP systems with an electricity generating capacity of great than 25 MW_e (Lainter 1998). The state regulators should adopt output-based standards for NOx and other criteria pollutants accounting for both the useful heat and power produced by CHP systems.

Address issues of utility access and stranded-cost recovery through a national restructuring bill, FERC jurisdiction, and actions by individual states

Some states, such as Massachusetts, have already enacted restructuring plans that give favorable treatment to CHP by exempting owners of CHP systems from paying stranded cost recovery for new, efficient CHP system that are built in the state. However, other states, like Pennsylvania, have rejected such measures (Bluestein 1998). Likewise, some states allow their utilities to specify overly complex interconnection procedures as well as charge high rates for backup power. Illinois should provide for reduced exit and stranded cost recovery fees for new CHP capacity since it will allow the state to meet its future generation and transmission in a efficient, environmentally friendly and cost effective manner. In addition, the state should establish a standard for interconnect of all distributed generation systems.

Evaluate State Facilities for CHP Potential

State institutions, such as universities and hospitals, represent a promising candidate for conversion to CHP since many have an existing district energy system and centralized electrical distribution. Many of these facilities are faced with aging infrastructure, so the infusion of cost savings from CHP can help to rehabilitate these systems. CHP systems are currently installed at several state facilities (including the University of Illinois Urbana-Champaign, University of Illinois-Chicago, NEIU, SIU-Carbondale, and the Illinois Veterans Home in Quincy). The state should evaluate all state facilities to determine which others would be attractive candidates for CHP.

F. Transportation

History And Current Situation

As throughout the nation, the transportation sector accounts for major portions of energy use and energy-related emissions in Illinois. Moreover, the transportation sector is almost wholly dependent on petroleum, which presents additional air pollution, energy imports, and national security concerns. A breakdown of energy use by transportation mode is not available for Illinois. However, using national statistics as a guide, light duty vehicles (LDVs, i.e., cars and light trucks) account for the majority of transportation energy use. Nationally, LDVs account for 94 percent of highway vehicle miles of travel (VMT), about 80 percent of highway energy consumption, and 60 percent of overall transportation energy use.

Transportation energy efficiency has improved substantially over the past two decades. Today, however, efficiency improvements have almost completely halted for the largest contributor to transportation energy use: cars and light trucks. Thus motor vehicle energy use is now rising in step with increased driving, which, as we note earlier in this report, is expected to grow at an average rate of 2.3 percent per year in Illinois.

Unfortunately, while existing federal regulations are acting as a driver for lower vehicle emissions, and some federal and state programs exist to demonstrate and promote use of alternative fuels, no policy drivers are in place to advance automobile (both car and light truck) efficiency above the minimum levels required by the now 20-year old Corporate Average Fuel Economy (CAFE) standards.

It is important to recognize that a significant transformation of the automobile market, which is inherently a national market, is unlikely to follow from piecemeal efforts focusing on one or another aspect of vehicle energy use and emissions. Therefore, Illinois should begin a process to join with other states, municipalities, and the federal government in developing a broad-based Green Vehicle Strategy that can foster the introduction of advanced technologies while encouraging consumers to purchase the "greenest" (cleanest and most fuel-efficient) vehicles currently available. A Green Vehicle Strategy is essential for reducing both conventional air pollution, particularly in the Chicago region and other metropolitan areas, as well as for reducing greenhouse gas emissions and the economic risks of oil dependence.

An existing fleet strategy is already underway for alternative fuel vehicles, with national coordination by DOE's Clean Cities Program. These efforts are valuable for exploring and cultivating potential alternative fuel options. Among the most promising long-term options are biomass-based ethanol produced by advanced cellulosic conversion processes and biomass-based hydrogen produced by advanced gasification processes. It is too soon, however, to tell which of these will prove most competitive and cost-effective for meeting future needs. The scope for public participation in such efforts is limited by fuel infrastructure needs and high startup costs. Therefore, a state's green vehicle strategy should include campaigns to promote cleaner and more efficient gasoline vehicles, which can have a much broader scope and would be more likely to deliver measurable fuel conservation and emissions reduction benefits over the next decade.

Three types of state policy options are available for improving the energy efficiency and lowering the environmental damages due to cars and light trucks. One is state leadership, both in its own fleet procurement policies and by facilitating local government and private fleet programs within Illinois. Second, the state should enact vehicle purchase price incentives ("feebates") linked to higher efficiency and lower emissions. Finally, the region should provide concerted political support for stronger federal policies to advance vehicle efficiency nationwide, through stronger CAFE standards, nationwide incentives, and federal support for state incentive and fleet leadership programs. Illinois can pursue these options through legislation and resolutions to implement them in appropriate forms, given state fiscal policies and economic interests.

Recommendations

Establish State Procurement Policies To Obtain Efficient Vehicles

Illinois can lead the way to more efficient vehicles by establishing procurement policies for state fleets to buy the most efficient vehicles in a given class and make commitments to buy advanced technology vehicles as they become available. ACEEE has analyzed and outlined the potential for such a program, which we term the Green Machine Challenge.[69] To provide practical guidance for both consumer and fleet purchases, we publish an annual *Green Guide to Cars and Trucks*.[70] The state can use this publication to guide its own procurements and also promote the use of the guide by consumers throughout the state. The State and Territorial Air Pollution Program Administrators Association (STAPPA) are considering the development of a green vehicle education project, using ACEEE's *Guide* as a tool, and Illinois can support and participate in that initiative. The state can greatly leverage the effects of its own green vehicle procurement efforts by coordinating similar efforts by county and municipal fleets along with voluntary efforts by private fleets.

A Green Machine Challenge procurement strategy can be designed with two stages. One stage would be directed toward bulk purchases of current production vehicles that are "best in class" in terms of fuel efficiency and low emissions. ACEEE's *Green Guide to Cars and Trucks* identifies these models in each major class. The second stage would be directed to purchasing advanced, next-generation vehicles having substantially higher efficiencies, tied to a nationwide effort to provide a "Golden Carrot" for ultra-efficient vehicles. This "step-forward" efficiency challenge can accelerate the commercialization of promising advanced technologies. Such a program can be viewed as a market pull complement to the advanced efficient vehicle technology research and development efforts being pursued by U.S. automakers through the Partnership for a New Generation of Vehicles. It would also speed U.S. introduction of hybrid vehicles, such as the Toyota Prius, which is now in production and seeing strong sales in Japan, and encourage U.S. automakers to bring their own hybrid designs to market sooner rather than later.

ACEEE is now collaborating with U.S. DOE, EPA, state and local government organizations including STAPPA and the U.S. Cities for Climate Protection campaign (of which Chicago is a member), and other organizations to explore planning options for a Green Machine Challenge. Illinois should affirm its commitment to these efforts, update its state vehicle procurement guidelines with a strong "buy green" component, provide state official liaisons

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69. DeCicco, J.M., *Developing a Market Creation Program to Promote Efficient Cars and Light Trucks*, Washington, DC: American Council for an Energy-Efficient Economy. August 1997.

70. DeCicco, J., and M. Thomas, *Green Guide to Cars and Trucks: Model Year 1998*, Washington, DC: American Council for an Energy-Efficient Economy, 1998.

to the nascent green vehicle campaign efforts, and fund program planning and coordination work within the state.

Explore The Establishment Of A Feebate Policy To Encourage The Purchase Of Higher Efficiency Vehicles

Under current market conditions and those likely to prevail in the absence of a major oil supply disruption, there is low consumer and manufacturer interest in higher fuel economy. A state can create revenue neutral incentive for higher efficiency by establishing feebates.[71] Feebates involve rebates or lower taxes on vehicles that are more efficient than average. These rebates would be financed by higher taxes or fees on less efficient vehicles. In Illinois, there is an existing vehicle license fee as well as a vehicle sales tax which varies by county. These fees could be converted to a sliding scale based on efficiency and emissions, thus encouraging higher efficiency vehicles with no net increase in fees or taxes.

Support Strong Federal Policies To Encourage Vehicle Efficiency

Additionally, Illinois should support stronger federal vehicle efficiency policies, recognizing that cars and light trucks are produced for a national--and increasingly international--market, in which any one state holds only a relatively small share. All states will benefit from an overall improvement in car and light truck efficiency. While the leverage of any one state's market is limited, all bear a responsibility to help set the nationwide direction.

For this reason, federal policy plays a determining role in the types of vehicles consumers can buy. This role is particularly crucial in areas of public concern, such as safety, emissions, and efficiency. Since a state stands to greatly benefit from a nationwide effort for higher vehicle efficiency, states should play an active role in pressing for the full range of federal policies to induce greater vehicle efficiency, including stronger fuel economy standards, feebates linked to higher efficiency (in which state feebates can complement a more widespread federal program), and a nationwide Green Machine Challenge. States should also support federal policies that enable and encourage the states to have their own green vehicle programs. In this regard, Illinois should encourage expansion of DOE's Clean Cities program to incorporate promotion of efficient vehicles and the state should lobby for clarification and reform as needed of federal guidelines which may inhibit state efficient vehicle incentives on the basis of preemption concerns.

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71. DeCicco, J.M., H.S. Geller, and J.H. Morrill, *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles*, Washington, DC: American Council for an Energy-Efficient Economy, May 1993.

Take Steps To Implement Comprehensive Transportation Planning

Finally, vehicle efficiency improvement is just one -- albeit the largest -- of the opportunities for improving energy efficiency in a state and regional transportation system. Particularly in cities and in corridors connecting the state's many centers of economic activity, policies for reducing vehicle-miles traveled and providing better transit, intercity rail, and intermodal services are also important. While analyzing the potential role for such broader transport efficiency measures is beyond the scope of this study, these approaches can make an additional contribution to reducing energy and environmental costs in the state. This broader range of transportation energy efficiency options is addressed at the national level in the *Energy Innovations* study, on which the state can draw to help inform its own comprehensive transportation efficiency strategy. A model state study could be conducted along the lines of what was done for Texas.[72]

G. A Sustainable Energy Development Agency

History and Current Situation

Several states have developed agencies specifically devoted to promoting energy efficiency and sustainable energy development. As an example, New York has a highly effective agency, the New York State Energy Research and Development Authority (NYSERDA), which could serve as an excellent model (other potential models include sustainable energy development agencies in California, Florida, Iowa, North Carolina, and Wisconsin). These agencies support technology research and development, demonstrations, field monitoring, and (in some cases) education, training, and other implementation activities.[73] They can also be powerful tools for economic development. A sustainable energy development agency can be a useful complement to state energy offices and related state agencies (like DCCA) because sustainable energy development agencies tend to be less political and broader-based (government-representatives generally comprise only a portion of their board), which better enables them to obtain substantial private sector co-funding and to engage in multi-year projects. In fact, sustainable energy development agencies and state energy offices work closely together in most of the states listed above.

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72. CTR, *Texas Transportation Energy Savings*, Report prepared by the Center for Transportation Research, University of Texas, Austin, and the Tellus Institute, Boston. Austin, TX: Texas Sustainable Energy Development Council, April 1995.

73. For more information on these state energy RD&D agencies, see M. Pye et al., *Energy Technology Innovation at the State Level: Review of State Energy Research, Development, and Demonstration ((RD&D) Programs*, Washington, DC: American Council for an Energy-Efficient Economy. July 1997.

For example, NYSERDA's research and development (R&D) program encourages economic development by promoting energy efficiency and environmental products manufactured in New York. It accomplishes this through five program areas — Applications, Buildings, Energy Resources, Transportation, and Environmental Research. NYSERDA's R&D projects develop new technologies, create and retain jobs, reduce energy imports (which promotes economic development by allowing more discretionary money to be spent in-state), and mitigate environmental effects of energy production and use.

NYSERDA has more than 300 projects aimed at helping the state's businesses and municipalities, of which 185 are developing new products.[74] One of these projects improved turbine efficiency, which saves New York up to $12 million per year in energy costs and could save $108 million a year nationwide. Another example of NYSERDA's contribution to the state's economic development is its support for the development of an energy-efficient window-insulation system that can be operated automatically using a photovoltaic power source. Over a few years time, this product helped a New York company grow from two people to 200 people, with $12 million in annual sales.[75]

Funding for state energy development agencies has often come through utility contributions or small utility surcharges. In some cases an independent organization performs these types of functions as a compliment to their state energy office. Among others, Wisconsin and Iowa each have independent energy organizations of this type as well as a state energy office. With the utility industry restructuring, a systems benefit charge is often a funding source. This is the approach being used in both California and New York.

Recommendation

Our final policy recommendation is for Illinois to establish some type of a Sustainable Energy Development Agency. A Sustainable Energy Development Agency in Illinois could provide a number of functions in working with manufactures and consumers in their state, including: (1) applied R&D and demonstrations of advanced energy efficiency and renewable energy technologies; (2) technology and market assessments; and (3) support for technology transfer and commercialization. Such an agency could also help the state's utilities and state agencies in the design and evaluation of energy efficiency and renewable energy programs, and possibly assist with training or technical assistance concerning building code implementation or improving industrial energy efficiency. In many respects, a Sustainable Energy Development Agency could be of great value in helping Illinois achieve the economic and environmental benefits outlined in this report.

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74. *1995-96 Annual Report*, New York State Energy Research and Development Authority, Albany, NY, 1996.

75. *Top 75 NYSERDA R&D Program Achievements*, New York State Energy Research and Development Authority, Albany, NY, 1996.

H. SUMMARY

This chapter has identified a number of recommendations for policies to increase energy efficiency in Illinois. The questions may arise as to which of these options are most important and in what order might they be pursued. While it is not possible to rank these recommendations in terms of importance for action, it may be reasonable to indicate some type of relative rating of the recommendations along certain relevant dimensions. For that purpose, Table 10 (on the following pages) provides a rating (low, medium, or high) of each recommendation in terms of three factors: the magnitude of impact in terms of energy savings; the technical difficulty of implementation; and the political difficulty of implementation. The table also provides a brief listing of the key agencies or entities that would need to address the recommendation.

Such ratings are, of course, subjective in nature, and others may well have a different assessment of any individual recommendation. The use of such ratings is also subjective. Some may believe that options with high savings should be pursued even if the difficulty is high. Others may prefer to pursue options with lower difficulty of implementation, even if the savings impact is relatively low. The intent of this table is merely to provide a starting point assessment of the relative impact and potential difficulty of implementation of these various recommendations. Moving forward in any of these areas is obviously up to the judgement of citizens and decision makers within Illinois.

I. CONCLUSION

Based on the analyses presented in the earlier chapters of this report, it is clear that Illinois has the opportunity to achieve substantial cost savings and reductions in air pollutants through the pursuit of a high-efficiency policy scenario. An aggressive yet cost-effective commitment to energy efficiency could significantly reduce energy bills for residential and business customers during the 1999 to 2015 period, with further savings continuing beyond 2015.

However, large benefits do not come without large effort. In that spirit, this chapter has presented a number of ambitious policy initiatives that Illinois could consider as options in pursuing substantial energy efficiency improvements. While some simpler steps which might be achieved by administrative action are also included in the text, many of the major recommendations are admittedly challenging and would require significant commitment and leadership from both the executive branch and the legislature. Those major recommendations included the following areas:

Table 10. Relative Impact and Feasibility Assessment

Recommendation	Magnitude of Impact	Technical Difficulty	Political Difficulty	Key Players
Regulatory				
SBC for Efficiency	High	Low	Medium	Legislature/ ICC/Utilities
Decoupling	Low	Medium	Medium to High	
IRP for Distribution Utilities	Medium	Medium	Medium	
Statewide Building Codes				
Residential	High	Low to Medium	High	Legislature/ Code Officials/ Municipalities/ Builders
Commercial	High	Low to Medium	High	
Additional Building Measures				
Equipment Standards	Medium to High	Medium to High	Medium to High	Legislature/ DCCA
State Buildings Strategies	Low to Medium	Low	Low	State Capital Development Board
Industrial				
Opportunity Identification	Medium	Medium	Low	IAC/DCCA/ Utilities
Technical and Design Assistance	High	High	Low	DCCA/Utilities Universities
Financial Assistance	High	Medium	Medium	DCCA/ICC/ Utilities
Financing	High	Medium	High	DCCA/Banks/ Legislature
Operation Improvement	Medium	Medium	Medium	IAC/Utilities
Advanced Technologies	Medium	High	Low	DCCA/Utilities Universities

Table 10. Relative Impact and Feasibility Assessment(Continued)

Recommendation	Magnitude of Impact	Technical Difficulty	Political Difficulty	Key Players
CHP				
Expedited Permitting	Medium	Medium	Medium	IEPA
Output-based Air Regulations	High	High	High	IEPA
Stranded Cost/Hookup Regulations	High	Low	High	Legislature/ICC
Evaluate State Facilities	High	High	Medium	Legislature/ DCCA/Utilities /State Facilities Office
Transportation				
State Procurement	Low	Low	Low	Legislature/ State Purchasing
Feebate Policy	Medium	Low	High	Legislature
Federal Policy	Low	Low	Low	Legislature/ Govenor
Comprehensive Transportation Planning	High	Medium to High	High	Legislature/ Govenor
Sustainable Energy Development Agency	Medium to High	Low to Medium	Medium to High	Legislature/ Govenor/DCCA

- Key regulatory strategies of establishing of a substantial "system benefits charge" to fund energy efficiency, and developing carefully structured regulatory mechanisms for distribution utilities to make sure that these utilities have incentives to pursue cost-effective energy efficiency.

- Implementing strong statewide building energy codes for residential and commercial buildings.

- Developing and instituting an expanded and systematic set of policies to encourage industrial energy efficiency.

- Promoting a number of innovative policies to improve transportation energy efficiency.

- Creating or designating a dedicated Sustainable Energy Development Agency in Illinois to coordinate ambitious statewide energy efficiency R&D and implementation efforts.

These policies, together with other actions which could be developed by experts within the state, would help move Illinois forward toward realizing the substantial economic and environmental benefits available through increased energy efficiency. While no-one should under-estimate the challenges involved in accomplishing these strategies, the good news is that (as described earlier in the chapter) these types of policy options have been successfully implemented in other states.

VII. CONCLUSION

Based on the analysis of the high-efficiency scenarios, it is clear that accelerated energy efficiency improvements can help ensure that citizens and businesses in Illinois obtain energy-related services at the lowest possible overall cost. Total expenditures for energy services (including energy efficiency expenditures) in 2015 are projected to be about 25 percent lower in the high-efficiency scenario relative to the baseline projections.

Moreover, accelerated energy efficiency investments would provide significant macroeconomic and environmental benefits. For example, we estimate a net increase of 59,400 jobs by 2015 as a result of pursuing the high-efficiency scenario. Those jobs are equivalent to the employment supported directly and indirectly by about 400 small manufacturing plants throughout the state. This would represent a reduction in the state-wide unemployment rate of about 0.7 percent in 2015.

On the environmental side, we estimate that the energy savings projected in this analysis will reduce carbon dioxide emissions by 85.3 million short tons by the year 2015 (a projected reduction of 30 percent). The high-efficiency scenario will also reduce sulfur dioxide emissions by 352 thousand short tons, and nitrogen oxides by 370 thousand short tons by the year 2015. In this way, energy efficiency will help utilities and the state of Illinois meet their Clean Air Act requirements and national carbon stabilization goals defined in the Climate Change Action Plan.

Hence, energy efficiency investments are more than mere cost-cutting measures. They yield both positive environmental benefits and net employment gains. Given the additional net employment and income that would be generated, energy efficiency investments should be viewed as an important economic development strategy for Illinois.[76]

One important aspect of the high-efficiency scenario is that "it takes money to make money." In order to achieve the level of economic benefits illustrated in Table 6, policies must be adopted and effectively implemented to encourage a $37.8 billion investment in the period 1999-2015. Averaged out over the 17-year period, this implies an average annual investment of $2.2 billion – about 10 percent of the state's current annual energy bill.

76. A recent report analyzing a balanced national strategy to put the United States on an innovative, economically and environmentally sound energy path reached a similar conclusion. The authors note that the plan could lead to over 770,000 more jobs for the United States in the year 2010. See *Energy Innovations*, note 2.

Overcoming institutional barriers and redirecting financial investments away from conventional energy resources and towards energy efficiency measures will not occur without concerted action by policy makers, along with critical support from the federal government.

If Illinois wishes to capture the full economic benefits of the high-efficiency scenario, we suggest that a number of policies be adopted, including:

- Developing strong and well designed policies to ensure that energy efficiency services play a major role in Illinois' restructured utility industry. These include the establishment of a substantial "system benefits charge" to fund energy efficiency, and carefully structured regulatory mechanisms for distribution utilities to make sure that these utilities have incentives to pursue cost-effective energy efficiency.

- Implementing strong building energy codes for residential and commercial buildings, including adoption of BOCA 1996 (including the residential Model Energy Code and the ASHRAE 90.1 code for commercial and high rise residential buildings), with the Illinois-specific increased lighting and chiller efficiencies described in the report.

- Developing and instituting a comprehensive and systematic set of policies to encourage industrial energy efficiency. These would include mechanisms and techniques for: opportunity identification, technical and design assistance, financial analysis, financing, operation improvements, promoting advanced technologies, and facilitating the adoption of combined heat and power (CHP) technologies.

- Promoting wherever possible policies which would improve the fuel economy of cars and light trucks operated in Illinois. These include incorporating "best in class" vehicle efficiency as an important criterion in state and municipal fleet decisions, and exploring creative policies such as "feebates" to encourage the purchase of fuel efficient vehicles.

- Creating a Sustainable Energy Development Agency in Illinois that would fund applied R&D and demonstrations of advanced energy efficiency and renewable energy technologies; fund technology and market assessments; and provide support for technology transfer and commercialization. Such an agency could also help the state's utilities and state agencies in the design and evaluation of energy efficiency and renewable energy programs, and possibly assist with training or technical assistance concerning building code implementation or improving industrial energy efficiency.

These initiatives, along with other actions that can be taken to increase energy efficiency and economic productivity, can help to ensure a healthier economy and a cleaner environment in Illinois in the coming decades.

APPENDIX A

I. ECONOMIC PROFILE OF ILLINOIS

A. Population and Income

The population of Illinois has increased less than 1 percent in the last 26 years. Since 1970, Illinois' population has increased from 11.1 million people to over 11.8 million people in 1996. By comparison, the U.S. population rose by just over 30 percent in that same period (1970-1996). A slower growth in population might generally be taken as an indication of a smaller level of growth in energy use. As we will see, this turns out to be true in Illinois for a variety of reasons.

As Table A-1 indicates, less than 16 percent of the state's population lives in rural areas. This is significantly lower than the U.S. average of just under 25 percent.

Table A-1. Selected 1996 Economic and Demographic Data

Category	US	Illinois
Population (000s)	265,284	11,847
Rural Population (1990 percent of total)	24.8%	15.4%
Population Density (per square mile)	75.0	213.1
Persons Per Household	2.62	2.65
Per Capita Personal Income (current $)	$24,426	$26,848

Source: The population data contained in this table is based on calculations from census data found in various tables in the *Statistical Abstract of the United States 1997*. The per capita personal income values are derived from data found in the Bureau of Economic Analysis *Regional Economic Information System*.

When the total population is viewed in terms of density per square mile, the state's average density of just more than 213 persons per square mile is almost three times greater than that of the United States as a whole.

The average number of persons per household however, is similar for the United States and Illinois. In spite of the similar household size, the more densely populated nature of Illinois suggests that the state may consume less energy for its transportation uses than does the United

States as a whole. Indeed, the per capita transportation energy consumption in the region is 75 percent of that for the nation as a whole.

In 1990, the Illinois' average per capita personal income of $20,533 was approximately 7 percent above the average per capita income in the United States. By 1996, the state's per capita income increased to almost 10 percent more than the U.S. average. This increase is the result of slower population growth and sustainable growth in personal income (the two factors used to estimate per capita personal income) in Illinois.

In an overall comparison with other states, Illinois ranked seventh in per capita income in 1996.[1] Higher income usually suggests that a state consumes more energy per capita than the national average. As it turns out, this is not true for the state of Illinois. In fact, as we see later in this appendix (see Table A-4), when all end-use sectors are considered, the state of Illinois consumed approximately six percent less energy per capita than the U.S. as a whole.

B. Employment

The state economy supported a total of just under 7 million jobs in 1996.[2] Measured on a per capita basis, the state employment level was 102 percent of the national average, with the state's businesses providing 0.59 jobs per resident compared with a U.S. total of 0.57 jobs per resident.

Figure A-1, on the following page, illustrates the employment intensities (i.e., a measure of the number of persons employed) in selected economic sectors within the state. The figure indexes the state's per capita employment in each sector to that of the United States as a whole.

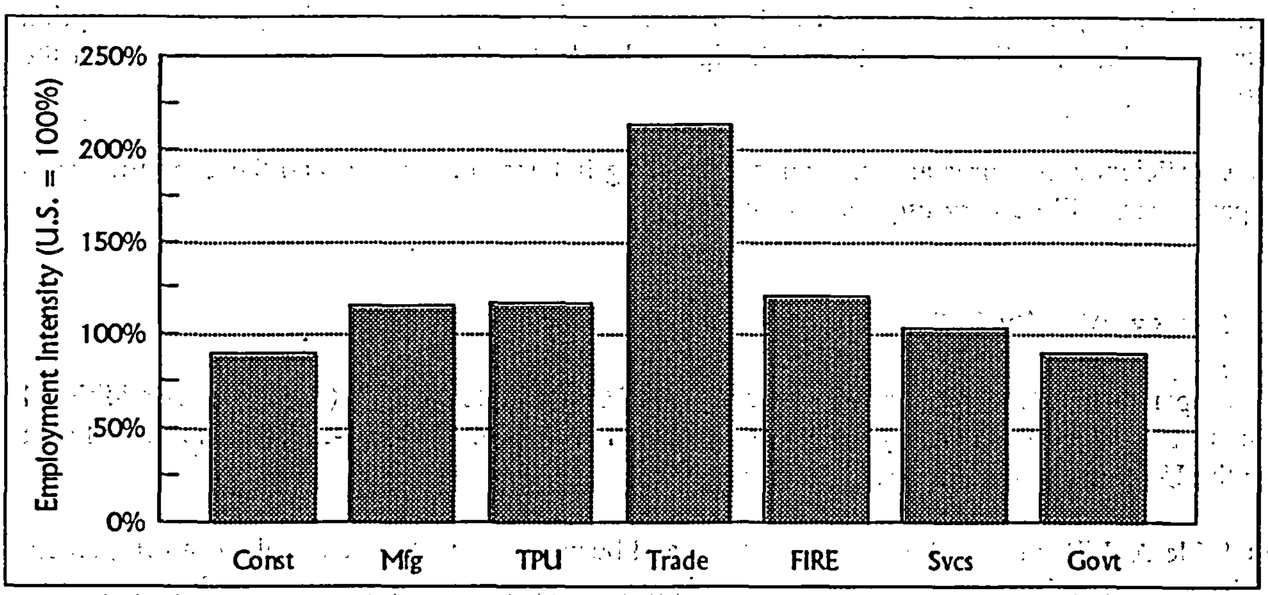
Sectors having an employment intensity greater than 100 percent are those which provide more jobs per capita compared to the same sectors within the United States. Similarly, those sectors with an employment intensity less than 100 percent provide fewer jobs per capita compared to those same sectors for the nation as a whole.

As shown in Figure A-1, the state has a strong and relatively diverse economic base. Five of the seven employment sectors analyzed have an employment intensity that is greater than that

1. This ranking is based on analysis of personal income and population data derived from the Bureau of Economic Analysis *Regional Economic Information System.*

2. The employment data that follows are provided by the Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC, 1997. The data include wage and salaried employees as well as proprietors, self-employed, farm workers, unpaid family workers, private household workers, and members of the Armed Forces.

Figure A-1. 1996 Sectoral Employment Intensities For Illinois



Notes: The economic sectors noted include: (1) construction (referenced as "Const") — businesses/contractors involved in general building, heavy construction, special trades and other construction activities; (2) businesses involved in wholesale and retail trade ("Trade"); (3) manufacturing ("Mfg") — businesses producing nondurable goods such as food products, textile products, chemicals, etc., and durable goods such as lumber and wood products, glass products, machinery, motor vehicles, etc.; (4) finance, insurance, and real estate ("FIRE") — businesses involved in banking, investment services, insurance and real estate; (5) transportation and public utilities ("TPU") — businesses involved in rail, air and bus transportation, trucking and warehousing, pipelines, communications, and electric, gas and sanitary services among others; (6) services ("Svcs") — businesses providing any number of services including: business, auto repair, recreational, household, health, legal, education, etc.; and (7) government ("Govt") — federal, state and local government including civilian and military enterprises. For more details on the specific type of business, products, or services within each of the respective sectors refer to the *Standard Industrial Classification Manual*, Office of Management and Budget, Washington, DC, 1987. Sectoral employment intensities are calculated from data published by the Bureau of Economic Analysis.

of the nation as a whole. The combined retail and wholesale trade industries (Trade) however, have the highest intensity — 213 percent of the national average. Other industries with high employment intensities include the combined finance, insurance, and real estate industries (FIRE) at just under 121 percent, transportation and public utilities (TPU) and manufacturing, both at just under 116 percent, and services at 102 percent. The remaining two economic sectors reviewed — construction and government — are below the U.S. levels, both at 90 percent.

Stated differently, the combined number of employees in the more energy-intensive industries is significantly higher than for the U.S. average. According to the U.S. Department of Energy, just six industries account for almost 90 percent of total energy use in the manufacturing sector. These include: food processing, chemicals, petroleum refining, pulp and paper, primary metals, and stone, glass and clay products.[3] The state's employment intensity in these six industries is approximately 125 percent of the U.S. average. Normally, this suggests a higher level of industrial energy use in the state. In fact, in 1995 (the latest year for which energy consumption data is available), Illinois had the sixth highest level of industrial energy consumption in the nation.

Thus, efficiency measures and programs addressing industry in general, and these six industries in particular, will be very important in Illinois.

C. Energy Intensity Indicators

A comparison of data on energy use per dollar of Gross State Product (GSP)[4] offers additional insights about the role of energy as part of the Illinois economy. Table A-2 contains relevant data for the United States and the state of Illinois.

As Table A-2 illustrates, the state's residents and businesses spent the equivalent of 6.6 percent of the state's combined GSP on energy.[5] This ratio of energy expenditures to GSP compares to the U.S. ratio of 7.1 percent. This lower ratio for Illinois is due in part to the lower energy use in the industrial sector and the relatively low energy consumption in the state overall.

Likewise, the level of energy intensity for the state (measured as the number of Btus[6] consumed per dollar of GSP) is also significantly lower - about 14 percent lower than the U.S. level. In other words, every dollar of valued-added products generated in Illinois requires less energy and a lower level of spending for energy than the U.S. average.

Although the measure of energy used to produce economic output is not a direct indicator of energy efficiency (i.e., industries can be inefficient users of energy but still consume small amounts of energy relative to other economic activities), it is interesting to note that Illinois uses

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3. See *Manufacturing Consumption of Energy 1994*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1997.

4. This refers to the total value of goods and services at market prices produced by the state's economy in a given year. It includes the total purchases of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade.

5. This includes total expenditures for coal, natural gas, petroleum and electricity in the residential, commercial, industrial, and transportation sectors.

6. Btu, or British Thermal Units, refers to the energy or heat value per unit quantity of fuel. One Btu is the quantity of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit at or near 39.2 degrees Fahrenheit; or roughly equivalent to the amount of heat given off by one wooden kitchen match.

less energy per dollar of output than the national average. Illinois accounts for approximately 4.9 percent of the nation's combined GSP and utilizes only 4.2 percent of the total energy consumed nationwide.

Table A-2. 1995 Energy Consumption Per Dollar of GSP

	GSP (Billion $)	Energy Expenditures (Billion $)	Energy Expenditures As % of GSP	Energy Consumption (Trillion Btu)	Btus Per Dollar GSP
United States	$7,228	$515.8	7.1%	90,547	12,527
Illinois	$353	$23.3	6.6%	3,804	10,779

Source: The data in this table are adapted from the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) economic data, the Energy Information Administration's (EIA) *State Energy Price and Expenditure Report 1995*, and the *State Energy Data Report 1995*. All dollar values used in this table reflect current year totals.

II. Regional Energy Use Patterns

A. An Overview

Overall, total energy consumption in Illinois increased approximately 3.9 percent between 1970 and 1995. As Table A-3 indicates, the largest portion of this increase in energy consumption occurred primarily in the 1970s and then again in the 1990s.

Energy consumption in each of the sectors, except the industrial, increased during the 25 year period. Contrary to this trend of increasing energy consumption, consumption in the industrial sector decreased 8.6 percent between 1970 and 1995. Table A-3 shows that the decline in energy consumption in the industrial sector offset much of the increases in the other sectors. This impact on the state's total consumption is not surprising when we consider that the industrial sector has consistently accounted for between 34 and 40 percent of the state's energy consumption for the years noted.

When viewed on a per capita basis we see that total energy consumption in Illinois decreased 2.1 percent during this same period. Consumption increased in the early 1970s from 330 million Btu (MBtu) per capita in 1970 to a high of 339 MBtu in 1975, and then decreased to 296 MBtu in 1985. In spite of this brief decline during the late 1970s and early 1980s, per capita consumption increased once again during the next 10 years, reaching 323 MBtu in 1995 (still slightly lower than in 1970).

Table A-3. Illinois Energy Consumption 1970-1995
(in Trillion Btu)

							Percentage Change		
Sector	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**1970-80**	**1980-90**	**1990-95**
Residential	841.0	917.1	877.1	838.2	862.6	955.5	4.3%	-1.7%	10.8%
Commercial	572.4	623.3	642.5	629.6	648.4	703.3	12.2%	0.9%	8.5%
Industrial	1,459.0	1,411.0	1,402.3	1,179.4	1,217.1	1,333.6	-3.9%	-13.2%	9.6%
Transportation	790.3	883.9	821.3	726.2	857.8	811.9	3.9%	4.4%	-5.4%
Total	3,663.0	3,836.1	3,743.3	3,373.4	3,586.0	3,804.3	2.2%	-4.2%	6.1%
Per capita (MBtu)	330	339	328	296	314	323	-0.6%	-4.2%	2.9%
Population (000s)	11,110	11321	11,427	11,400	11,431	11,790	2.9%	0.0%	3.1%

Source: The information contained in this table is derived from data in the *State Energy Data Report 1995* and data from the *Statistical Abstract of the United States 1997.*

Consistent with this decline in per capita energy consumption, Illinois consumed approximately 6 percent less energy per capita in 1995, compared with the national average. As Table A-4 indicates, the region consumed 322.7 MBtu per person in 1995 compared to the U.S. total of 344.4 MBtu. If we were to translate this energy into an equivalent amount of gasoline, it turns out that Illinois requires 2,581 gallons of gasoline equivalent per capita per year compared with a nationwide requirement of 2,755 gallons. Even with the declines noted above, the state's residential and commercial sectors consumed more energy per capita than the U.S. averages.

Taking the major end-use sectors one at a time, the Illinois residential sector requires 81 MBtu per capita. This compares with the national average of 68.7 MBtus. This may signify more modest implementation of energy efficiency measures and/or greater use of heating and air conditioning compared with the nation as whole.

Commercial sector per capita energy use in Illinois (59.7 MBtu) is also higher than the national average at 112 percent of the U.S. per capita consumption. This is the result of both higher heating requirements than the country as a whole, the use of air conditioning in most commercial buildings, and the large number of commercial buildings.

Unlike the commercial sector, per capita energy consumption in the industrial sector (113.1 MBtu) is only 86 percent of the U.S. average per capita energy use. It is interesting to note however, that while industrial energy use per capita is 14 percent lower than the national average, manufacturing employment is almost 16 percent higher than the national average.

Similar to the lower energy consumption in the industrial sectors (compared with the U.S. average), Illinois' transportation sector (as a whole) is also lower, at 75 percent of the U.S. average. This appears to be due primarily to significantly greater population densities in the state (as noted earlier) and the use of mass transit.

Table 4-A. A Comparison of 1995 Per Capita Energy Consumption (in Million Btu)

Category	Residential	Commercial	Industrial	Transportation	Total
Illinois	81.0	59.7	113.1	68.9	322.7
United States	68.7	53.0	131.1	91.6	344.4
Illinois as Percent of U.S.	118%	113%	86%	75%	93.7%

Source: Information for this table is derived from data in the *State Energy Data Report 1995* and the *Statistical Abstract of the United States 1997.*

B. Energy Expenditures

In 1995, the state of Illinois used about 6 percent less energy per capita than did the United States as a whole. As Table A-5 shows, the average energy price in Illinois was only 2.4 percent higher than the U.S. average. Electricity prices in Illinois were the thirteenth highest in the nation, approximately 11 percent above the national average.

Similarly, prices for natural gas, coal, and motor gasoline were also above the national averages. These higher prices probably contribute to the lower energy consumption in Illinois relative to national averages. As a result of these generally higher prices and lower consumption levels, the state's per capita energy bill in 1995 was $1,980, approximately 0.9 percent higher than the national average of $1,962.

Table A-5. 1995 State Energy Prices
(In Dollars per Million Btu)

	Coal	Natural Gas	Motor Gasoline	Petroleum	Electricity	Average
Illinois	$1.62	$4.10	$9.42	7.96	$22.61	$8.48
United States	$1.37	$3.81	$9.14	7.23	$20.30	$8.28

Notes: Data derived from the *State Energy Price and Expenditure Report 1995*. Average price refers to all fuels for all end-use sectors (i.e., residential, commercial, industrial, and transportation).

Per capita GSP in Illinois was 9 percent higher than the national average. The end result is that families and businesses in Illinois spent the equivalent of approximately 7 percent less of the the state's GSP for energy than did the average U.S. resident or business.[7] Illinois' total energy expenditure was $23.3 billion in 1995. This is 40 percent larger than the state's combined collection of state income and sales taxes in 1995.[8]

Table A-6 provides a breakdown of total energy expenditures by fuel type and end-use sector. The expenditures are divided between coal, natural gas, petroleum, biofuels, and electricity.[9] The data indicate that the residents and businesses in Illinois spent between 80 percent of their total energy expenditures on petroleum and electricity.

The transportation sector was by far the largest energy user in dollar terms. These expenditures, primarily for petroleum, accounted for almost one-third of the state's 1995 total energy expenditures, $7.1 billion and $23.3 billion, respectively. This was followed by the industrial sector, the state's largest energy user in TBtu, which spent almost $5.3 billion (accounting for approximately 23 percent of the state's total energy expenditures). More than half of these expenditures were for petroleum. This is in part due to the large industrial sector and high petroleum prices noted earlier.

7. The state's total energy expenditures for 1995 are based on the *State Energy Price and Expenditure Report 1995*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1998. The population and income data are taken from the *Statistical Abstract of the United States 1997*, U.S. Bureau of the Census, Washington, DC, 1997.

8. According to the published data, the state of Illinois collected $16.6 billion in state income and sales taxes in 1995. See *Statistical Abstract of the United States 1997*, Table 493, see note 7.

9. Utility expenditures for coal, natural gas, and petroleum, along with other costs of providing electricity, are included in the electricity column.

Following the industrial sector, the commercial sector spent just under $4.5 billion, almost 20 percent of total state energy expenditures. Almost 80 percent of these expenditures were for electricity. The residential sector was the smallest energy user in dollar terms, accounting for just under $4 billion or approximately 17 percent of the state's total energy expenditures. These were split primarily between natural gas and electricity expenditures.

A-6. 1995 End-Use Expenditures by Sector and Fuel (in Millions of 1995 Dollars)

Sector	Coal	Natural Gas	Petroleum	Biofuels	Electricity	Total
Residential	$4.1	$2,337.7	$150.8	$22.2	$2,510.8	$6,492.5
Commercial	$4.1	$900.8	$84.3	NA	$3,482.5	$4,471.8
Industrial	$226.5	$1,095.3	$3,123.3	$7.9	$2,171.8	$5,295.1
Transportation	$0.0	$0.1	$7,063.1	NA	$20.7	$7,083.9
Total Expenditures	$234.7	$4,333.9	$10,421.5	$30.1	$8,185.8	$23,343.3

Source: This information is based on data contained in the Energy Information Administration's *State Energy Price and Expenditure Report 1995*. Based on this EIA reporting format agricultural uses are included in the industrial class together with mining, construction and manufacturing. Government uses are included with the commercial uses, together with trade and service industries. Commercial biofuels are included in residential. Columns may not add up due to independent rounding.

APPENDIX B

Residential and non residential building prototypes were developed using the DOE-2.1E building energy simulation computer program. The DOE-2.1E prototypes were used to evaluate energy savings estimates for a number of energy efficiency measures. The following measures could not be evaluated using DOE-2: steam distribution package; furnace fan/thermostat adjustment; duct sealing; and duct insulation. Energy savings for these measures are extrapolated from measured data.

Non-residential building prototypes were based on data from the Gas Research Institute (GRI 1991), Lawrence Berkeley Laboratory, Union Electric (UE 1993), and PSI Energy (PSI 1992). Residential building prototypes were based on data from a number of sources summarized in *Energy Efficiency Codes and Standards for Illinois* (ACEEE 1993). Minor modifications were made to the prototypes to reflect the unique characteristics of buildings and building practices in the region and to derive the energy use (i.e., Btu) per square foot values used in the analysis.

To the extent the residential or commercial prototypes reflect any inaccuracies in energy use the analysis incorporates an adjustment factor for end-use energy consumption. This correlates the base or current derived energy use to actual energy use in the region. The adjustments are made using data from the *Residential Energy Consumption Survey* (RECS 1995 and RECS 1997), the *Commercial Buildings Energy Consumption Survey* (CBECS 1995), and the *State Energy Data Report* (SEDR 1995). Eight non residential and four residential building prototypes were developed.

<u>Non Residential</u>

1. Existing Medium Office
2. New Medium Office
3. Existing Medium Retail
4. New Medium Retail
5. Existing School
6. New School
7. Existing Warehouse
8. New Warehouse

<u>Residential</u>

1. Existing Multifamily Apartment
2. New Multifamily Townhouse
3. Existing Single Family Detached
4. New Single Family Detached

Section B-1 provides a brief description of each building prototype used. In reality, the actual sizes of buildings varies greatly. Thus, the square footage noted for the respective prototypes is not necessarily an average but rather a value used to derive energy use and costs per square foot. Section B-2 provides a description of each energy efficiency measure. At the end of this appendix are a set of tables that provide for each building prototype percentage gas and electric energy savings, total specific gas and electric use (kWh/sf, KBtu/sf), energy efficiency measure costs per unit, units per square foot of floor area, marginal cost of saved energy (CSE, $/MMBtu), average CSE, and estimated measure life.

Also attached is a table summarizing the analysis of potential efficiency improvements for appliances. The efficiency measures analyzed in the residential and commercial prototypes are not meant to be all inclusive, rather they are meant to capture a large portion of potential effciency measures.

B-1. DOE-2.1E BUILDING PROTOTYPES

Existing Medium Office

The existing medium office prototype is a three-story building with 60,000 square feet of conditioned floor area. The base case has no insulation in the walls and an average of R-7.1 insulation in the roof. Peak lighting intensity is 2.0 W/sf and the peak equipment intensity is 1.2 W/sf. Windows are metal frame single-pane with a U-value of 1.0 Btu/hr-ft^2-F and a shading coefficient of 0.85. The window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft, and floors are medium weight (70 lb/cf). Peak occupancy level is 275 sf/person. The HVAC system is a reheat fan system serving two zones per floor (perimeter and core) with a 70 hp fan supply fan and a 23 hp return fan. Chilled water is provided by two 75 ton hermetic reciprocating chillers (3.82 COP, 150 tons total). Heat rejection is accomplished with two induced-draft cooling towers with a total capacity of 190 tons. Space heating is provided by two 75 percent efficient hot water boilers with a total capacity of 3,510 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

New Medium Office

The new medium office prototype is a three-story building with 60,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-19 insulation in the ceiling. Peak lighting intensity is 1.76 W/sf and the peak equipment intensity is 1.2 W/sf. Windows are metal frame double-pane with a U-value of 0.62 Btu/hr-ft^2-F and a shading coefficient of 0.65. The window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft, and floors are medium weight (70 lb/cf). Peak occupancy level is 275 sf/person. The HVAC system is a variable air volume (VAV) system serving two zones per floor (perimeter and core) with a 55 hp fan supply fan and a 18 hp return fan. Chilled water is provided by two 65 ton hermetic centrifugal chillers (4.23 COP, 130 tons total). Heat rejection is accomplished with two induced-draft cooling towers with a total capacity of 165 tons. Space heating is provided by two 80 percent efficient hot water boilers with a total capacity of 3,874 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

Existing Medium Retail

The existing retail prototype is a one story building with 10,000 square feet of conditioned floor area. The base case has R-4.2 insulation in the walls and R-6 insulation in the roof. Peak lighting intensity is 2.1 W/sf and peak equipment intensity is 0.25 W/sf. The windows are metal frame single-pane with a U-value of 1.0 Btu/hr-ft^2-F and a shading coefficient of 0.87. Window-to-wall area ratio is 0.19, floor to ceiling height is 15 ft, floor weight is medium (60 lb/cf). Peak occupancy level is 300 sf/person. The HVAC system consists of two (2) packaged single-zone (PSZ) systems with cooling capacity of 12.5 ton and 240 kBtu/hr gas furnace. The PSZ system serving the northeast zone has a 2.6 hp fan and the PSZ system serving the southwest zone has a 3.3 hp fan. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

New Medium Retail

The new retail prototype is a one story building with 10,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-19 insulation in the ceiling. Peak lighting intensity is 1.76 W/sf and peak equipment intensity is 0.25 W/sf. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a shading coefficient of 0.65. Window-to-wall area ratio is 0.19, floor to ceiling height is 15 ft, floor weight is medium (60 lb/cf). Peak occupancy level is 300 sf/person. The HVAC system consists of two (2) packaged single-zone (PSZ) systems with cooling capacity of 10 ton and 195 kBtu/hr gas furnace. The PSZ system serving the northeast zone has a 1.9 hp fan and the PSZ system serving the southwest zone has a 2.5 hp fan. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

Existing School

The existing school prototype is a two story building with 240,000 square feet of conditioned floor area. The base case has no insulation in the walls and R-3.3 insulation in the roof. Peak lighting intensity is 2.4 W/sf in the classrooms, library, kitchen, and dining areas, 0.65 W/sf in the gym, and 0.8 W/sf in the auditorium. Peak electric equipment intensity is 0.05 W/sf in the classrooms, 0.025 W/sf in the library and auditorium, 0.02 W/sf in the gym, 0.04 W/sf in the dining room and 5 W/sf in the kitchen. Peak gas equipment intensity is 148 Btu/hr-sf in the kitchen. The windows are metal frame single-pane with a U-value of 1.0 Btu/hr-ft^2-F and a shading coefficient of 0.89. Window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft in all rooms except the gym and auditorium that have 32 ft ceiling height. Floor weight is medium (60 lb/cf). Average peak occupancy level is 86.5 sf/person. The library, auditorium, gym, kitchen, and dining rooms are served by a reheat fan system with a 110 hp supply fan and a 37 hp return fan. Classrooms are served by a four-pipe fan coil system. Chilled water is provided by two 390 ton hermetic reciprocating chillers (3.82 COP, 780 tons total). Heat rejection is accomplished with four induced-draft cooling towers with a total capacity of 976 tons. Space heating is provided by two 75 percent efficient hot water boilers with a total capacity of 12,000 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

New School

The new school prototype is a two story building with 240,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-19 insulation in the ceiling. Peak lighting intensity is 2.1 W/sf in the classrooms, library, kitchen, and dining areas, 0.65 W/sf in the gym, and 0.8 W/sf in the auditorium. Peak electric equipment intensity is 0.05 W/sf in the classrooms, 0.025 W/sf in the library and auditorium, 0.02 W/sf in the gym, 0.04 W/sf in the dining room and 5 W/sf in the kitchen. Peak gas equipment intensity is 148 Btu/hr-sf in the kitchen. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a shading coefficient of 0.60. Window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft in all rooms except the gym and auditorium that have 32 ft ceiling height. Floor weight is medium (60 lb/cf). Average peak occupancy level is 86.5 sf/person. The library, auditorium, gym, kitchen, and dining rooms are served by a reheat fan system with a 110 hp supply fan and a 37 hp return fan. Classrooms are served by a four-pipe fan coil system. Chilled water is provided by two 310 ton hermetic centrifugal chillers (4.23 COP, 620 tons total). Heat rejection is accomplished with four induced-draft cooling towers with a total capacity of 775 tons. Space heating is provided by two 80 percent efficient hot water boilers with a total capacity of 11,680 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

Existing Warehouse

The existing warehouse prototype is a one story building with 25,000 total square feet of conditioned floor area (22,875 warehouse and 2,125 office). The base case has no insulation in the walls and R-4.2 insulation in the roof. Peak lighting intensity is 1.59 W/sf in the warehouse area and 1.76 W/sf in the office area. Peak equipment intensity is 0.10 W/sf in the warehouse area and 0.75 W/sf in the office area. The windows are metal frame single-pane with a U-value of 1.0 Btu/hr-ft^2-F and a shading coefficient of 0.87. There are no windows in the warehouse and the window-to-wall area ratio in the office is 0.26. Floor to ceiling height is 25 ft in the warehouse and 10 ft in the office, floor weight is medium (60 lb/cf). Peak occupancy is 15,000 sf/person in the warehouse and 275 sf/person in the office.

The HVAC system consists of two (2) packaged single-zone (PSZ) systems one for the warehouse and one for the office. The warehouse PSZ has 50 tons cooling capacity and 1100 kBtu/hr gas furnace. The office PSZ has 7.5 ton cooling capacity and a 140 kBtu/hr gas furnace. Base cooling EER is 8.1 and furnace efficiency is 75%. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

New Warehouse

The new warehouse prototype is a one story building with 25,000 total square feet of conditioned floor area (22,875 warehouse and 2,125 office). The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-11 insulation in the ceiling. Peak lighting intensity is 1.59 W/sf in the warehouse area and 1.76 W/sf in the office area. Peak equipment intensity is 0.10 W/sf in the warehouse area and 0.75 W/sf in the office area. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a shading coefficient of 0.65. There are no windows in the warehouse and the window-to-wall area ratio in the office is 0.26. Floor to ceiling height is 25 ft in the warehouse and 10 ft in the office, floor weight is medium (60 lb/cf). Peak occupancy is 15,000 sf/person in the warehouse and 275 sf/person in the office. The HVAC system consists of two (2) packaged single-zone (PSZ) systems one for the warehouse and one for the office. The warehouse PSZ has 37 tons cooling capacity and 800 kBtu/hr gas furnace. The office PSZ has 5.5 ton cooling capacity and a 100 kBtu/hr gas furnace. Base cooling EER is 8.5 and furnace efficiency is 80%. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

Existing Multifamily Apartment

The existing multifamily apartment prototype is a three-story building with eighteen apartments. Each apartment is 900 sf with a total of 18,216 square feet of conditioned floor area. Construction is masonry veneer over wood frame. The base case has no insulation in the walls and R-19 ceiling insulation in the roof. Peak lighting intensity is 0.9 W/sf and the peak internal loads are 2 Btu/hr-ft^2. Windows are wood frame with storms having a U-value of 0.625 Btu/hr-ft^2-F and a shading coefficient of 0.65. The window-to-floor area ratio is 0.10, floor to ceiling height is 8 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.7 ACH. The heating system is a 60 percent efficient steam boiler with 1,000 kBtu/hr capacity. Each unit has a 2 ton 8 EER room air conditioner. Occupancy, lighting, miscellaneous equipment, and domestic hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

New Multifamily Townhouse

The new multifamily townhouse apartment prototype has ten two-story units and each unit is 1200 sf. Construction is wood frame. The base case has R-13 wall insulation and R-30 ceiling insulation. Peak lighting intensity is 0.9 W/sf and the peak internal loads are 2 Btu/hr-ft^2. Windows are wood frame with storms having a U-value of 0.5 Btu/hr-ft^2-F and a shading coefficient of 0.60. The window-to-floor area ratio is 0.10, floor to ceiling height is 8 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.6 ACH. Each unit has a separate central air conditioner and heating system. The heating system is an 80 percent efficient gas furnace with 60 kBtu/hr capacity. The central A/C unit is 3 tons with a 10.3 EER. Occupancy, lighting, miscellaneous equipment, and domestic hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989, ASHRAE 1989a).

Existing Single Family Detached

The existing single family detached prototype is a two-story building with 2,085 square feet of conditioned floor area. Construction is wood frame with a basement. The base case has R-2 insulation in the walls and R-19 ceiling insulation in the roof. Peak lighting intensity is 0.9 W/sf and the peak internal loads are 1.15 Btu/hr-ft^2. Windows are wood frame with storms having a U-value of 0.62 Btu/hr-ft^2-F and a shading coefficient of 0.65. The window-to-floor area ratio is 0.19, floor to ceiling height is 8 ft. Peak occupancy level is 3 persons. Infiltration is 0.7 ACH. The heating system is a 75 percent efficient gas furnace 120 kBtu/hr capacity, and the 7.8 EER central air conditioning system has a capacity of 5 tons. Heating setback is from 10 PM to 6 AM, set point is 69 F and setback is 64 F. Cooling set-forward is from 9 AM to 5 PM, setpoint is 76 F and setforward is 84 F.

New Single Family Detached

The new single family detached prototype is a two-story building with 2,085 square feet of conditioned floor area. Construction is wood frame with a basement. The base case has R-14 wall insulation and R-30 ceiling insulation. Peak lighting intensity is 0.9 W/sf and the peak internal loads are 2 Btu/hr-ft^2. Windows are wood frame with storms having a U-value of 0.5 Btu/hr-ft^2-F and a shading coefficient of 0.60. The window-to-floor area ratio is 0.19, floor to ceiling height is 8 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.6 ACH. The heating system is a 82 percent efficient gas furnace 120 kBtu/hr capacity, and the 9.48 EER central air conditioning system has a capacity of 5 tons. Heating setback is from 10 PM to 6 AM, set point is 69 F and setback is 64 F. Cooling set-forward is from 9 AM to 5 PM, set point is 76 F and set-forward is 84 F.

B-2. MEASURE DESCRIPTION

Efficient Office Equipment

Measure Description. The energy efficient office equipment measure consists of replacing inefficient computers, video display terminals (Vats), and printers with high-efficiency products. EPA's Energy Star program in cooperation with major electronic manufacturers is hastening the evolution towards more energy efficient electronic office equipment. Apple, IBM, Compaq, and Hewlett Packard have already introduced a line of EPA certified Energy Star products. These products include portable laptops that plug into desktop "docking" systems, and Vats, desktop computers and printers that have a low-energy "sleep" mode (when inactive for a predetermined period of time). When the market is saturated (in 2-4 years), these innovative products will reduce office equipment energy use by approximately 63% compared to average components used today.

Base Case Equipment Power Density Levels. Baseline prototypical office equipment power density levels (1.2 W/sf) for new and existing buildings are based on *America's Energy Choices* (UCS 1992). The tables provide base case office equipment power density levels for each building prototype and vintage.

Incremental Cost. Incremental cost for efficient office equipment is assumed negligible due to EPA's cooperative Energy Star program and the general trend towards more energy efficient office technologies (E-Source 1990).

Efficient Lighting

Measure Description. The energy efficient lighting measure consists of replacing the standard fluorescent fixtures, lamps, and ballasts with high efficiency components. The high efficiency components are typically fixtures with specular reflectors, tri-phosphor T-8 lamps (32 W), and electronic ballasts. Incandescent lighting fixtures are replaced with IR halogen lamps or compact fluorescent lamps where appropriate. Efficient lighting power density (W/sf) is based on *America's Energy Choices* (UCS 1992).

Base Case Lighting Levels. Baseline prototypical lighting levels (W/sf) for new and existing buildings are based on *America's Energy Choices* (UCS 1992). The tables provide base case lighting levels for each building prototype and vintage.

Incremental Cost. The average incremental cost for efficient lighting is $37 per fixture for existing construction and $29 per fixture for new construction (XEN 1992).

Wall, Ceiling/Roof Insulation

Measure Description. Installing fiberglass or cellulose insulation material in floor, wall or roof cavities will reduce heat transfer across these surfaces. The type of building construction limits insulation possibilities. Choice of insulation material will vary depending on the wall or roof construction type. Wall construction types include, but are not limited to, mass walls, metal frame walls, wood frame walls, curtain walls, precast concrete panels, and tilt-duct concrete panels. Nominal R-values are used as the performance factor for insulation levels. For each commercial building prototype, the assumed overall wall or ceiling R-value are given followed by the nominal R-value for cavities (given in parentheses). The overall R-values include the thermal resistances of construction layers (gypsum, air gaps, framing, sheathing, concrete, roofing, etc.).

Base Case Insulation Levels. Assumed prototypical insulation levels for existing buildings are based on survey data. The tables provide base case insulation levels for each building prototype and vintage.

Wall Insulation in Metal Frame Walls. Insulation installed in metal frame walls will have an effective R-value that is about 50% less than the nominal R-value of the insulation (CEC 1992). This is due to the high thermal conductance of metal framing relative to wood framing. In our analysis we conservatively assumed metal frame walls exist in all new non residential construction.

Incremental Cost. Insulation costs are greater for retrofit installations where blown-in insulation is typically the only option. Assumed costs for insulation are shown below (XEN 1992).

Table B1. Insulation Costs.

Type of Insulation	Retrofit Cost $/sf	New Cost $/sf
Wall Insulation		
R-8 (R-4 for metal frame)	0.91	0.23
R-11 (R-5.5 for metal frame)	1.00	0.25
R-19 (R-9.5 metal frame)	1.25	0.35
Ceiling Insulation		
R-4	0.21	0.19
R-8	0.25	0.23
R-11	0.27	0.25
R-19	0.37	0.35
R-30	0.48	0.46

Windows

Measure Description. The important energy performance parameters for windows are U-value, shading coefficient, visible light transmission and air leakage. The window U-value will vary as a function of the number of panes, gap thickness, gap fill (air or inert gas), presence of low-emissivity (low-e) coatings, and frame type. The shading coefficient and visible transmission will vary as a function of glass type and low-e coatings. Air leakage will depend on the type of frame and window design (casement vs. slider).

Base Case Windows. For Non residential prototypes, base case windows are assumed to be single-pane with metal frames. For residential prototypes, base case windows are assumed to be single-pane wood windows with storm windows. U-values and shading coefficients for each prototype are given in the tables.

Double Pane, No Thermal Break (NTB). Replacing single pane with double pane windows reduces the U-value and heat transfer by 40%. This also reduces the shading coefficient, solar heat gain and the cooling load.

Double Pane, Thermal Break (TB). A metal window frame acts like a short circuit to heat transfer. Adding a thermal break to the metal frame will reduce the overall U-value by about 20%.

Double Pane Low-e, NTB and TB. Adding a low-e coating will improve the U-value by about 15%. The low-e coating will also provide a better shading coefficient than standard double pane glass while maintaining good visible light transmission. High performance low-e coatings cost more but provide much more flexibility and savings potential. Window manufacturers have different techniques of adding the low-e coating. Some manufacturers use low-e coated thin film plastic suspended between the double panes, some use "soft" low-e sputter coatings added to the inside of the outside lite, some use "hard" low-e pyrolytic coatings that can be added to either the inside or outside lite. Adding a thermal break provides even more savings at a slightly higher cost.

Incremental Costs and Window Performance Characteristics. The U-values, shading coefficients and costs for all window types evaluated in the study are shown below along with assumed costs per square foot. The U-values and shading coefficients were calculated using the WINDOW 4.0 computer program (LBL 1992). Costs are based on Eley 1990 and the XENERGY Measure Cost Study (XEN 1992). Retrofit costs include labor which is roughly equal to the cost of the window, effectively doubling the retrofit cost compared to new construction.

Table B2. Window Costs and Performance Data.

Window Description	U-value Btu/hr-sf	Shading Coefficient	Retrofit Cost $/sf	New Cost $/sf
Base Case; single pane, metal frame	1.000	0.850	-	-
Double pane, no thermal break	0.650	0.650	9.42	4.71
Double pane, thermal break	0.425	0.500	13.32	6.66
Double pane Low-e, no thermal break	0.453	0.287	14.30	7.15
Double pane, Low-e, thermal break	0.356	0.287	18.20	9.10

Efficient HVAC Retrofit

Measure Description. The efficient HVAC retrofit consists of the following three measures.

1. Variable speed drive (VSD) fan control; VSD fan control provides a method to vary the amount of constant temperature air delivered to the space. Other less efficient methods to create a variable air volume (VAV) system involve the use of fan inlet (vortex) dampers or discharge damper control. Terminal sections may be single duct variable volume units with or without reheat, controlled by space thermostats. VAV systems reduce energy use by reducing the volume of air handled by the entire system as a function of the air required to meet the needs of the warmest or coolest zone. When the space demands peak cooling the fan operates at full speed (and/or VAV dampers are fully opened). When less cooling is required the fan operates at low speed and the primary air flow to the space is reduced to the minimum flow rate. When in space heating mode, the supply air flow is held at the minimum flow rate reducing the heating energy use.

   There are many VAV system variations, such as VAV with reheat, VAV dual duct, VAV dual fan/dual duct, VAV with fan-powered boxes, etc. All of these are multiple zone systems. It is not generally practical nor desirable to use VAV for a single zone building such as a supermarket or warehouse. These types of buildings typically have constant-volume variable-temperature packaged single zone HVAC systems.

2. High efficiency fans; Overall fan efficiency is the multiplicative product of the fan motor and fan blade efficiencies. This study assumes that overall fan efficiency can be improved from 55 percent to 70 percent.

3. High efficiency chiller; This study assumes the high efficiency chiller is 6.3 COP (0.56 kW/ton). California's Title 24 Energy Efficiency Standards (CEC 1992) and the ASHRAE Standard 90.1-1989 (ASHRAE 1989) require minimum chiller efficiency of 0.75 kW/ton for non-ozone depleting refrigerants. Efficiency of 0.55 kW/ton represents the best available efficiency for hermetic centrifugal chillers using non-ozone depleting refrigerants. Higher efficiency is achieved by increasing condenser and evaporator area.

Base Case Air Handling System. VAV retrofit is only considered for existing large buildings having multi-zone systems. We assume that VAV systems are standard for new buildings having multiple zone systems. For this study only the existing medium office and school prototypes were considered for the VAV retrofit measure.

Incremental Cost. Incremental cost for VSD fan control is 125 $/hp (XEN 1992) and involve adding an electronic variable-speed controller to the fan motor. Incremental cost for the high efficiency fan motor is 8 $/hp (XEN 1992). Incremental cost for the high efficiency hermetic centrifugal chiller is assumed to be $56/ton based on 245 $/ton for the high efficiency hermetic centrifugal chiller and 189 $/ton for the 4.7 COP (0.75 kW/ton) chiller. Costs for existing and new construction are assumed to be the same since the existing cost is for replace-on-burnout (ROB).

High-Efficiency Condensing Furnace

Measure Description. High-efficiency gas furnaces have AFUEs of about 82% or higher. Condensing gas furnaces have AFUEs of greater than 90%. As efficiencies are increased, vaporized by-products of combustion may condense in the heat exchanger and vent system, forming an acidic liquid. Furnaces with moderate efficiencies (78 to 82%) do not produce any condensate. Furnaces with intermediate efficiencies (82% to 89%) may form condensate and have high flue gas temperatures which require costly, corrosion-resistant metals for the venting system. Consequently, furnaces in the latter efficiency range are being phased out by most manufacturers. If the efficiency is raised to 90% or higher, although condensate is formed, the flue gas temperatures are low enough that low-cost corrosion-resistant plastic materials can be used for venting. Efficiencies above 90% can be achieved with a number of technologies, pulse combustion and condenser being among the design approaches.

High-efficiency gas furnaces can be installed in new construction or can be retrofitted to existing commercial structures which have other heating systems. In most cases, a condensate drain must be added and a new or modified venting system must be installed.
Incremental Cost. Incremental cost for the high-efficiency furnace (75 to 82% AFUE) is 1.59 $/kBtuh and the incremental cost of the condensing furnace is 4.54 $/kBtuh (XEN 1992).

High Efficiency Boiler

Measure Description. Standard atmospheric boilers, in both fire-tube and water-tube designs, have combustion efficiencies of about 75%. Forced draft boilers with electronic ignition have higher full load combustion efficiencies of ~80%. At part load, they perform more efficiently due to reduced stack losses during off-cycles and better fuel/air ratios. Modular design allows for higher part-load efficiency since short cycling is eliminated.

Incremental Cost. High efficiency boiler cost is 14 $/kBtuh. The incremental cost is 3 $/kBtuh (XEN 1992) based on comparison to base case atmospheric boiler cost of 11 $/kBtuh ($14 - $11 = $3).

Condensing Boiler

Measure Description. Condensing boilers are the most efficient boilers available with combustion efficiencies of ~90%. Modular design allows for higher part-load efficiency since short cycling is eliminated. The pulse combustion technology is described below.

1. The boiler burns only a small amount of gas (0.8 cf) per cycle. A small amount of outdoor air is drawn into the combustion chamber and the mixture is ignited by a spark only on the initial cycle. Each subsequent air-gas mixture is ignited by residual heat from the previous cycle.

2. Pressure resulting from the combustion process forces hot gases down the heat exchanger tubes inside the boiler. Heat is then transferred to the surrounding boiler water.

3. As the hot gasses are cooled below the dew point, water vapor in the flue gases condenses, releasing the latent heat of vaporization. The condensate is removed by a drain at the boiler's base and the low-temperature exhaust is safely vented outside through plastic pipe.

Incremental Cost. Condensing boiler cost is 17 $/kBtuh. The incremental cost of 3 $/kBtuh (XEN 1992) is based on comparison to high efficiency boiler cost of 14 $/kBtuh ($17 - $14 = $3).

Duct Sealing plus Duct Insulation

Measure Description. Recent studies indicate that duct leakage and conduction losses in forced-air distribution systems are among the biggest energy consumers in typical residential buildings (Modera 1993). Duct leakage and conduction losses can add 20-30% to heating and cooling energy use. Houses with basement foundations typically have losses of about 20% and houses with crawl space foundations have losses of about 30%. Research shows that duct leakage and conduction through poorly insulated ducts account for about an equal 50-50 share of the losses. Duct sealing involves the use of a duct pressurization system that is used to detect the leaks. Leaks are then sealed using mastic. This measure cannot be simulated using DOE-2.1E.

Savings are therefore, based on measured data. Savings estimates used for duct insulation are based on insulating with R-8 foil skrim cracked (FSC) insulation.[1]

Incremental Cost. Incremental costs per square foot of floor area, average losses, savings, post-installation losses are shown below.

Table B3. Duct Sealing Plus Insulation: Costs and Savings Data

Description	Loss %	Savings %	Post Installation Loss %	Cost $/sf
Basement Foundation				
Single Family New Construction				
Duct Sealing + R-8 Insulation	20	10	10	0.23
Multi-Family New Construction				
Duct Sealing + R-8 Insulation	20	10	10	0.23
Single Family Existing Construction				
Duct Sealing + R-8 Insulation	20	9	11	0.38
Crawl Space Foundation				
Single Family New Construction				
Duct Sealing + R-8 Insulation	30	21	9	0.23
Multi-Family New Construction				
Duct Sealing + R-8 Insulation	30	21	9	0.23
Single Family Existing Construction				
Duct Sealing + R-8 Insulation	30	18	12	0.38

Reduce Infiltration

Measure Description. Natural infiltration is caused by temperature and wind induced pressure differences between the building shell and outdoors. Cracks and crevices in the building shell allow outdoor air to infiltrate the building based on indoor-outdoor pressure differences. Weatherstripping doors and windows and caulking cracks and crevices in the building shell will reduce infiltration. This study assumes that infiltration can be reduced from 0.7 to 0.4 air changes per hour (ACH) in existing construction and 0.6 to 0.4 ACH for new construction.

1. FSC R-8 insulation costs about 2.13 $/ft installed, 0.76 $/ft for the insulation and 1.37 $/ft for installation (Modera 1993).

Incremental Cost. The cost to reduce infiltration for existing construction is 0.46 $/sf and the cost for new construction is 0.24 $/sf (XEN 1992). It is easier to reduce infiltration in new construction than in existing construction and the costs reflect this fact.

High Efficiency 3.5 COP Air-Cooled Package Air Conditioner

Measure Description. Over 50% of current commercial air conditioning capacity is provided by packaged units with air handler, compressor, and compressor mounted in a metal box (Houghton et al. 1992). These units are typically roof-mounted to save interior space and have capacities ranging from 1 to 100 tons (5-20 tons are typical). Packaged units are attractive to builders and developers, especially those that build on speculation, because of their low first cost (often less than 500 $/ton). This emphasis fosters inefficiency. for example, packaged units monitored by PG&E in San Ramon had an overall efficiency of 1.75 COP (6 EER). California's Title 24 standards set minimum efficiency of 8.9 EER at 95F (1.34 kW/ton). Actual operating efficiencies can be even less, due to such factors as thin uninsulated cases which can leak substantial amounts of hot rooftop air; constricted high velocity, high-pressure duct work, and undersized, low-performance heat exchangers.

Much higher efficiencies are obtainable at reasonable cost through better design, materials, and controls, but have not yet been realized due to emphasis on first cost. To address this problem, a collaboration of energy groups and utilities known as the Consortium for Energy Efficiency (CEE) is implementing a program similar to the Super Efficient Refrigerator Program ("Golden Carrot") for residential refrigerators. CEE's plan will offer a coordinated rebate designed to create a market for high-efficiency packaged equipment, eventually making efficient equipment the norm. Efficiency goals of the program are a 3.5 COP (12 to 12.5 EER, 1 kW/ton at 95 F). Initial production is anticipated in 1995 (Nadel 1993).

Incremental Cost. The incremental cost for a high efficiency 3.5 COP air-cooled packaged air conditioner is expected to be 250 $/ton more than a 2.5 COP unit (Nadel 1993).

High Efficiency Central Air Conditioner

Measure Description. The 1992 Energy Policy act (1992 EPACT) established minimum appliance efficiency standards for residential central air conditioners (CACs) with capacity less than 65,000 Btuh. The EPACT requires a minimum 10 Seasonal Energy Efficiency Ratio (SEER). High efficiency CACs with SEER of 12 are available at a reasonable cost from most suppliers. Very high efficiency CACs with variable speed drive (VSD) compressors have SEERs of 16.9. VSD CACs have better part-load performance than constant speed CACs, but their peak efficiency is not as good as high efficiency CACs. Typical CACs are split systems with an outdoor section housing the compressor and condenser and an indoor section housing the evaporator. The indoor and outdoor (split) systems are connected by a pair of refrigerant lines and control wiring. High efficiency CACs can be installed in new construction or retrofit into existing construction.

Incremental Cost. The cost for a 3 to 5 ton high efficiency SEER 12 CAC is 161 $/ton more than a SEER 10 unit (XEN 1994). The incremental cost for a 3 to 5 ton SEER 16.9 VSD CAC is 608 $/ton more than an SEER 10 unit (XEN 1992). Our analysis showed that for new construction, the constant speed SEER 12 unit was more cost-effective than the VSD CAC SEER 16.9 unit.

High Efficiency Room Air Conditioner

Measure Description. The 1990 national appliance efficiency standards for residential room air conditioners (RAC) require minimum EER of 8.6. High efficiency RACs with SEER of 11 are available at a reasonable cost from most manufacturers. RACs are housed in a single assembly that will fit into a standard window opening. RACs run on 115 volt or 230/208 volt power. High efficiency RACs can be installed in new construction or retrofit into existing construction.

Incremental Cost. The cost for a 2-ton EER 11 RAC for costs 115 $/ton more than an EER 8.9 unit (XEN 1994).

Furnace Fan and Thermostat Adjustment

Measure Description. This measure is applicable to forced air heating systems in single family residences. Several studies have found that furnace thermostats are often set too high and thus useful heat in the furnace plenum is wasted and not moved to the living space (Proctor 1987). In addition, the anticipator on thermostats is often improperly set, which leads to overshooting the desired set point on each furnace cycle. Proper adjustment of these controls as well as basic furnace maintenance can produce energy savings of approximately 8 percent according to several Colorado field studies (Proctor 1987). These savings cannot be simulated using DOE-2.1E. As stated above, savings are assumed to be 8% of space heating energy (Proctor 1987).

Incremental Cost. The installed cost for the furnace fan/thermostat adjustment measure is $150 per home (Proctor 1984).

Steam Distribution Package

Measure Description. This measure is applicable to single pipe steam (SPS) distribution systems in multi-family buildings. This measure cannot be simulated using DOE-2.1E. Savings are therefore, based on measured data. Savings are assumed to 20% of space heating energy use. The package consists of three measures (Peterson 1985).

1. Main Line Air Vents (MLAVs); MLAVs allow more even flow of steam down the main distribution pipes at the expense of flow up into the radiators close to the boiler. Radiators farther from the boiler receive steam more quickly and close radiators receive steam more slowly. These are large thermostatic steam traps installed on the main distribution lines in the basement after the last riser and before the dry return drops into the wet return. The valve is open until heated by steam, at which point it quickly closes preventing steam from escaping. MLAV's cost about $90 each ($125 to $200 installed).

2. Thermostatic Steam Valves (TRVs); Normally there will always be some temperature variation between apartments. To compensate for this, the building can be divided into a number of different zones, each with some degree of separate thermostatic control. TRVs respond to temperature changes near the radiator. They are filled with fluid which expands and closes the air vent if the temperature goes above the set point. When the TRV is closed no air can be released and thus no steam can enter the radiator. TRVs cost about $45 each ($80 to $95 installed).

3. Pipe insulation; Insulating steam distribution pipes in the boiler room and/or basement area will allow more useful heat from the boiler to reach the radiators. Insulation costs about $3.20 per linear foot of pipe (XEN 1992).

Incremental Cost. The installed cost for the steam distribution package is $150 per apartment (Katrakis 1993).

White Surface Roof

Measure Description. Light or white colored exterior surfaces will reduce solar absorption and increase emittance thereby reducing cooling loads. This measure is most appropriate to roof applications. In addition to reducing cooling loads, a white surface roof should last longer than a dark roof since reducing absorbed solar radiation will prolong the integrity of the roof membrane. The extended life of white roof surfaces is not accounted for in this study.

Incremental Cost. In new construction a white surface roof is primarily a design measure, and therefore, cost is negligible. For existing construction, the cost is also assumed to be negligible since the roof color can be selected at time of replacement. If an existing roof were painted white as a retrofit measure the cost would be 0.50 $/sf (XEN 1992). The high cost of painting an existing roof surface white before it needs to be resurfaced (due to leaks and/or failure) is prohibitive.

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Existing Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Gas Savings	Primary Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life
Base Existing (R-7.1 roof, R-1 wall)	n/a	n/a	n/a	17.36	62.51	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Eff. Office Equip. (1.2 W/sf to 0.45 W	14.82	-4.31	10.12	14.79	65.20	$0.00	I	0.01	workstation	$0.09	$0.09	5
White Surface (ABS = 0.7 to 0.3)	16.48	-4.98	11.21	14.50	65.62	$0.00	I	0.333	roof area	$0.00	$0.03	20
R-18.1 roof (add R-11)	17.79	0.85	13.63	14.28	61.98	$0.27	F	0.333	roof area	$0.98	$0.20	30
Efficient Lighting (2 W/sf to 0.83 W/sf	45.03	-7.52	32.13	9.55	67.20	$37.00	I	0.014	fixtures	$1.08	$0.75	15
Eff. HVAC (Eff. Fans, VSD, COP=6.	58.00	-7.52	41.92	7.29	67.20	$194.11	I	0.003	chiller tons	$1.64	$0.86	20
Condensing Boiler (75% to 90%)	58.00	10.17	46.26	7.29	56.15	$6.00	I	0.059	boiler kBtu	$2.55	$1.03	20
Window, TB-Low-e (SC=0.3, u=0.35	62.11	24.02	52.76	6.58	47.49	$18.20	F	0.085	window area	$6.23	$1.51	30

New Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Gas Savings	Primary Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	12.88	36.18	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Eff. Office Equip. (1.2 W/sf to 0.45 W	0.18	-0.12	0.12	10.61	40.51	$0.00	I	0.01	workstation	$0.00	$0.00	5
White Surface (ABS = 0.7 to 0.3)	0.18	-0.13	0.12	10.56	40.77	$0.00	I	0.333	roof area	$0.00	$0.00	20
R-30 roof, R-9.5 wall (R-19)	0.19	-0.02	0.15	10.44	36.96	$0.11	I	0.531	roof+wall area	$0.75	$0.15	30
Efficient Lighting (1.76 W/sf to 0.7 W/	0.47	-0.21	0.33	6.87	43.72	$29.00	I	0.014	# fixtures	$1.23	$0.78	15
Window, TB-Low-e (SC=0.3, u=0.35	0.51	-0.09	0.39	6.36	39.35	$4.39	I	0.085	window area	$2.49	$0.82	30
Eff. HVAC (Eff. Fans, Herm. Cent. C	0.53	-0.09	0.41	6.04	39.35	$60.53	I	0.002	chiller tons	$3.13	$1.11	20
Condensing Boiler (80% to 90%)	0.53	0.03	0.43	6.04	35.07	$6.00	I	0.065	kBtu	$7.26	$1.47	20

Note:
1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Existing Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-6 roof, R-4.2 wall)	n/a	n/a	n/a	12.19	48.78	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	3.99	-5.31	1.52	11.71	51.37	$0.00	I	1.000	roof area	$0.00	$0.00	5
Efficient Lighting (2.1 to 0.93 W/sf)	43.34	-26.99	24.66	6.91	61.95	$37.00	I	0.006	fixtures	$0.54	$0.51	15
R-17 roof (add R-11)	44.77	-10.31	30.14	6.73	53.81	$0.27	F	1.000	roof area	$1.75	$0.61	30
Condensing Furnace (75% to 90%)	44.77	6.77	34.68	6.73	45.48	$9.00	I	0.039	furnace kBtu	$3.38	$1.12	20
Window, TB-Low-e (SC=0.3, u=0.35	51.21	17.06	42.14	5.95	40.46	$18.20	F	0.114	window area	$10.21	$2.57	30
Eff. HVAC (COP=2.37 to 3.5)	54.01	17.06	44.20	5.61	40.46	$250.00	I	0.003	A/C tons	$16.84	$4.41	15

New Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	9.97	27.74	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	2.00	-3.60	0.87	9.77	28.74	$0.00	I	1.000	roof area	$0.00	$0.00	5
Efficient Lighting (1.76 to 0.93 W/sf)	34.55	-25.63	22.46	6.53	34.85	$29.00	I	0.007	# fixtures	$0.71	$0.69	15
R-30 roof, R-9.5 wall (R-19)	35.44	-8.97	26.52	6.44	30.23	$0.11	I	1.486	roof+wall area	$1.91	$0.70	30
Window, TB-Low-e (SC=0.3, u=0.35	39.92	-0.75	31.75	5.99	27.95	$4.39	I	0.114	window area	$4.64	$1.36	30
Condensing Furnace (80% to 90%)	39.92	9.17	33.74	5.99	25.19	$9.00	I	0.039	furnace kBtu	$10.20	$2.21	20
Eff. HVAC (COP=2.5 to 3.5)	42.78	9.17	36.03	5.71	25.19	$250.00	I	0.002	A/C tons	$16.36	$3.50	15

Note:

1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Existing School - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric kWh/sf	Total Gas kBtu/sf	Energy Efficiency Measure Cost: $/unit	Cost Code	unit/sf-floor	unit	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-3.3 roof, R-1 wall)	n/a	n/a	n/a	8.69	85.21	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	3.66	-3.21	0.43	8.37	87.95	$0.00	I	0.551	roof area	$0.00	$0.00	5
Condensing Boiler (75% to 90%)	3.66	11.96	7.56	8.37	75.02	$3.00	I	0.050	boiler kBtu	$0.93	$0.89	20
R-22.3 roof (add R-19)	6.73	19.16	12.57	8.10	68.88	$0.37	F	0.551	roof area	$1.48	$1.02	30
Efficient Lighting (2.04 to 1.07 W/sf)	26.90	13.80	20.75	6.35	73.45	$37.00	I	0.015	fixtures	$3.84	$2.40	15
Eff. HVAC (Eff. Fans, VSD, COP=6.	39.50	13.17	27.13	5.26	73.98	$244.11	I	0.003	chiller tons	$5.82	$2.88	20
Window, TB-Low-e (SC=0.3, u=0.35	42.46	15.85	29.95	5.00	71.70	$18.20	F	0.060	window area	$14.26	$3.48	30

New School - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric kWh/sf	Total Gas kBtu/sf	Energy Efficiency Measure Cost: $/unit	Cost Code	unit/sf-floor	unit	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	6.73	72.96	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	1.21	-1.33	-0.05	6.65	73.93	$0.00	I	0.551	roof area	$0.00	$0.00	5
Condensing Boiler (80% to 90%)	1.21	8.38	4.76	6.65	66.84	$3.00	I	-0.049	boiler kBtu	$1.65	$1.68	20
R-30 roof, R-9.5 wall (R-19)	2.03	10.93	6.44	6.59	64.98	$0.11	I	0.865	roof+wall area	$2.48	$1.66	30
Efficient Lighting (1.81 to 1.03 W/sf)	22.87	5.36	14.20	5.19	69.05	$29.00	I	0.013	# fixtures	$3.44	$2.98	15
Eff. HVAC (Eff. Fans, COP=6.3)	25.90	5.05	15.58	4.99	69.27	$65.17	I	0.003	chiller tons	$7.17	$2.88	20
Window, TB-Low-e (SC=0.3, u=0.35	27.87	6.30	17.19	4.86	68.36	$4.39	I	0.060	window area	$7.57	$2.83	30

Note:

1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Existing Warehouse - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-4.2 roof, R-1.0 wall)	n/a	n/a	n/a	6.02	55.26	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	5.78	-5.45	0.69	5.68	58.28	$0.00	I	1.000	roof area	$0.00	$0.00	5
Efficient Lighting (1.6 W/sf to 0.82 W/	37.37	-12.67	14.69	3.77	62.27	$37.00	I	0.011	fixtures	$2.46	$2.38	15
Condensing Furnace (75% to 90%)	37.37	5.64	22.99	3.77	52.14	$9.00	I	0.036	furnace kBtu	$2.57	$2.20	20
R-23.2 roof (add R-19)	44.36	13.84	30.53	3.35	47.61	$0.37	F	1.000	roof area	$3.32	$2.48	20
Window, TB-Low-e (SC=0.3, u=0.35	45.05	13.92	30.94	3.31	47.57	$18.20	F	0.012	window area	$29.60	$2.36	30
Eff. HVAC (COP=2.37 to 3.5)	46.14	13.92	31.53	3.24	47.57	$250.00	I	0.002	A/C tons	$75.23	$4.93	15

New Warehouse - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	5.11	40.94	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	1.01	-2.13	-0.31	5.06	41.82	$0.00	I	1.000	roof area	$0.00	$0.00	5
Efficient Lighting (1.6 W/sf to 0.82 W/	35.36	-10.39	16.15	3.31	45.20	$29.00	I	0.007	# fixtures	$1.34	$1.37	15
R-30 roof, R-9.5 wall (R-19)	37.67	-5.03	19.74	3.19	43.00	$0.11	I	1.630	roof+wall area	$4.16	$1.72	20
Condensing Furnace (80% to 90%)	37.67	6.46	24.57	3.19	38.30	$9.00	I	0.036	furnace kBtu	$5.53	$2.50	20
Window, TB-Low-e (SC=0.3, u=0.35	38.28	6.35	24.87	3.16	38.34	$4.39	I	0.012	window area	$11.94	$2.15	30
Eff. HVAC (COP=2.5 to 3.5)	38.81	6.35	25.18	3.13	38.34	$250.00	I	0.002	A/C tons	$129.75	$4.88	15

Note:
1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Existing Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-19 roof, R-2 wall)	n/a	n/a	n/a	5.62	103.50	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	0.01	0.01	0.01	5.56	102.11	$0.00	I	0.500	roof area	$0.00	$0.00	20
Furnace Fan/Thermostat Adjustment	0.01	0.09	0.06	5.56	94.56	$0.07	F	1.000	floor area	$0.76	$0.61	20
Ducts, Sealing + R-8 Insulation	0.05	0.24	0.17	5.35	78.43	$0.38	F	1.000	floor area	$1.36	$1.06	30
R-38 roof, R-13 wall, R-19 floor	0.07	0.47	0.32	5.22	55.02	$1.14	F	1.000	floor area	$3.00	$1.97	30
Condensing Furnace (75% to 92%)	0.07	0.55	0.37	5.22	46.43	$9.17	I	0.058	furnace kBtu	$3.25	$2.55	20
Infiltration Reduction (0.7 to 0.4 ACH)	0.07	0.60	0.40	5.22	41.87	$0.30	F	1.000	floor area	$5.35	$2.74	20
Efficient Central A/C (8.1 to 12 SEER)	0.14	0.59	0.42	4.84	41.96	$145.00	I	0.002	chiller tons	$7.18	$2.99	20
Window, Low-e + argon (u=0.323, S	0.14	0.65	0.46	4.82	35.82	$1.71	F	0.200	window area	$3.50	$2.51	30

New Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost *$/unit*	*Cost Code*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-19 roof, R-2 wall)	n/a	n/a	n/a	5.83	54.05	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	0.01	0.00	0.01	5.78	53.91	$0.00	I	0.500	roof area	$0.00	$0.00	20
Ducts, Sealing + R-8 Insulation	0.07	0.18	0.12	5.45	44.49	$0.23	F	1.000	floor area	$1.18	$1.12	30
Furnace Fan/Thermostat Adjustment	0.07	0.23	0.14	5.45	41.55	$0.07	F	1.000	floor area	$1.96	$1.48	20
Infiltration Reduction (0.6 to 0.4 ACH)	0.06	0.33	0.18	5.49	36.02	$0.24	F	1.000	floor area	$3.76	$2.02	20
Window, Low-e + argon (u=0.323, S	0.06	0.43	0.23	5.48	30.60	$1.71	I	0.200	window area	$3.99	$2.12	30
Condensing Furnace (82% to 92%)	0.06	0.48	0.25	5.48	28.13	$9.17	I	0.058	furnace kBtu	$8.60	$3.11	20
R-38 roof, R-19 wall, R-19 floor	0.06	0.51	0.27	5.46	26.72	$0.56	I	1.000	floor area	$22.74	$3.56	30
Efficient Central A/C (10 to 12 SEER)	0.10	0.51	0.29	5.23	26.72	$145.00	I	0.002	chiller tons	$7.03	$4.58	20

Note:
1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Existing Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric kWh/sf	Total Gas kBtu/sf	Energy Efficiency Measure Cost $/unit	Cost Code	unit/sf-floor	unit	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base Existing (R-19 roof, R-1 wall)	n/a	n/a	n/a	4.25	91.99	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	0.76	-0.51	-0.08	4.22	92.45	$0.00	I	0.333	roof area	$0.00	$0.00	20
Efficient Boiler (60% to 82%)	0.76	23.85	16.04	4.22	70.05	$4.00	I	0.055	boiler kBtu	$0.79	$0.79	20
Steam Dist. Pkg. (vents, pipe insul., t-s	1.25	34.79	23.44	4.20	59.99	$0.15	F	1.000	floor area	$1.39	$1.09	15
Roof Insulation (R-19 to R-30)	1.53	35.75	24.17	4.18	59.10	$0.04	F	1.000	floor area	$2.37	$0.78	30
Infiltration Reduction (0.7 to 0.4 ACH)	1.75	43.23	29.20	4.18	52.22	$0.41	F	1.000	floor area	$5.64	$1.93	15
Window, Low-e + argon (u=0.323, S	5.83	47.93	33.69	4.00	47.89	$1.71	F	0.100	window area	$1.81	$1.37	30
High Efficiency RAC (8 to 11 EER)	10.26	47.93	35.19	3.81	47.89	$115.00	I	0.002	A/C tons	$11.04	$2.40	15

New Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Gas Savings %	Primary Savings %	Total Electric kWh/sf	Total Gas kBtu/sf	Energy Efficiency Measure Cost $/unit	Cost Code	unit/sf-floor	unit	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life
Base New (R-30 roof, R-13 wall)	n/a	n/a	n/a	2.82	37.85	n/a	n/a	n/a	n/a	n/a	n/a	n/a
White Surface (ABS = 0.7 to 0.3)	1.08	-0.65	0.13	2.79	38.10	$0.00	I	0.500	roof area	$0.00	$0.00	20
Window, Low-e + argon (u=0.323, S	6.45	10.74	8.80	2.64	33.78	$1.71	I	0.100	window area	$1.88	$1.86	30
Condensing Furnace (80% to 92%)	6.45	21.44	14.66	2.64	29.73	$4.54	I	0.050	furnace kBtu	$4.50	$3.18	20
Ducts, Sealing + R-8 Insulation	8.84	26.70	18.62	2.57	27.74	$0.23	F	1.000	floor area	$6.93	$3.98	20
Roof Insulation (R-30 to R-38)	8.95	27.58	19.16	2.57	27.41	$0.10	I	0.500	roof area	$8.83	$3.38	30
Infiltration Reduction (0.6 to 0.4 ACH)	8.87	33.83	22.54	2.57	25.05	$0.24	F	1.000	floor area	$9.89	$5.75	15
Efficient Central A/C (10 to 12 SEER)	11.60	33.83	23.77	2.50	25.05	$145.00	I	0.003	A/C tons	$43.07	$7.61	15

Note:

1. Percentage savings are with respect to the stock and new base buildings.
2. Cost code: I = Incremental cost, F = Full cost.

Potential Efficiency Improvements for Appliances

Appliance	Fuel	Measure	Base Use (per unit, per year) (kWh)	Savings (kWh)	Incremental Cost (per unit)	Measure Life (years)	CSE ($/kWh)	CSE $/MMBtu Primary	Percent Implement By 2015	Footnote
Electric										
Water heater	elec	Horizontal-axis clothes washer	2,823	356	$150	14	($0.02)	($1.56)	77%	1
Water heater	elec	Low water use dishwasher	2,467	140	$0	13	$0.00	$0.00	92%	2
Water heater	elec	Low-cost package	2,327	465	$46	10	$0.01	$1.22	100%	3
Water heater	elec	EF .93 tank	1,861	100	$17	12	$0.02	$1.82	100%	4
Water heater	elec	Heat pump water heater	1,761	895	$600	15	$0.06	$6.14	50%	5
Refrigerator	elec	2001 standard	704	208	$69	19	$0.03	$2.61	75%	6
Refrigerator	elec	Advanced refrigerator	496	246	$110	19	$0.04	$3.52	42%	7
Freezer	elec	2001 standard	510	70	$13	19	$0.02	$1.46	75%	8
Freezer	elec	Advanced freezer	440	132	$57	19	$0.04	$3.40	42%	9
Clothes dryer	elec	High spin-speed clothes washe	521	121	$25	14	$0.02	$1.98	77%	10
Lighting	elec	Energy-saver lamps	844	76	$3	2	$0.02	$2.02	100%	11
Lighting	elec	Compact fluorescent lamps	768	332	$72	8	$0.03	$3.19	100%	12
Gas			(therms)	(therms)			($/therm)			
Water heater	gas	Horizontal-axis clothes washer	269	16	$150	14	($0.37)	($3.65)	77%	13
Water heater	gas	Low water use dishwasher	253	15	$0	13	$0.00	$0.00	92%	14
Water heater	gas	Low-cost package	238	48	$46	10	$0.13	$1.25	100%	15
Water heater	gas	EF .62 tank	190	21	$44	12	$0.23	$2.31	100%	16
Clothes dryer	gas	High spin-speed clothes washe	33	5	$25	14	$0.51	$5.05	81%	17

Notes:

* Base use is for new units -- existing units will generally be less efficient.
* 5% real discount rate assumed.
* Measure lives are published estimates by DOE from appliance efficiency standard dockets.
* Appliances analyzed are not meant to be all inclusive, rather the analysis attempts to capture a large portion of potential efficiency measures.

1 Base use from EIA 1993, adjusted for recent improvements in water heater efficiency. Savings from CEE 1996. Costs from ACEEE 1998. Cost allocated to this measure and line 10.
2 Savings and cost from ACEEE 1998.
3 Savings and cost from Alliance to Save Energy et al. 1992.
4 Savings assume typical new water heater has an EF of .88 (from DOE 1993). Cost from ACEEE 1998.
5 Savings based on increasing EF from 0.88 to 1.89. Costs from ACEEE 1998.
6 Base use, costs and savings from DOE 1995.
7 EPA 1993 discusses five different options for reducing refrigerator energy use down to approximately 250 kWh/year. Average incremental manufacturer cost of these options, relative to the previous measure, was estimated to be $73. To this we add 50% to account for markups between the manufacturer and the consumer.
8 Base use, costs and savings from DOE 1995.
9 Base use, costs and savings from DOE 1995. This is for minimum-lifecycle cost model.
10 Baseline and savings from CEE 1996 and reflect reducing remaining moisture content to 50%. Costs are discussed above under measure 1.
11 Base use from EIA 1993. 90% of lamps assumed to be incandescent (Geller et al. 1986). Analysis based on 10% energy savings, an incremental cost of $0.10/lamp, and 30 lamps/house. Average lamp life estimated from Geller et al. 1986.
12 Analysis based on 75% energy savings in 6 heavily used lamps which operate an average of 3 hours/day. Analysis assumed 67 Watt lamps are displaced. A lamp life of 9000 hours and a lamp cost of $12 (see ACEEE 1998) are assumed.
13 See line 1.
14 See line 2.
15 See line 3.
16 See line 4.
17 See line 10.

References:
ACEEE - CEE screening study
CEE 1996 - Analysis of CEE tier savings
DOE 1995 -- Refrigerator TSD
EIA 1998 -- RECS 1997 Preliminary Energy Consumption and Expenditures
EPA 1993 -- Multiple Pathways report
Geller et al. 1986 -- Residential Conservation Power Plant Study -- Phase I.

APPENDIX C

ESTIMATION OF INDUSTRIAL SECTOR CONSERVATION POTENTIAL

DESCRIPTION OF MODEL

ACEEE has developed a methodology for the estimation of base case energy consumption in the industrial sector at the state level and the potential for cost-effective energy-efficiency improvements.[1] This analysis requires four steps: (1) project a baseline consumption for the industry groups in each state and then aggregate to the region; (2) estimate the economically viable savings potential from efficiency measures for each industry group in the region; (3) estimate the investment necessary to achieve and maintain that savings; and (4) analyze the potential for combined heat and power installations.

The method uses national and state data for energy use and employment to project baseline energy consumption. Sector energy growth is projected based upon energy and employment growth projections. The energy efficiency potential was estimated using conservation supply curves derived from the Long-Term Industrial Energy Forecasting (LIEF) model.[2] Most conservation supply curves have been developed by combining various characteristic measures for a particular market. Such an approach is impractical for the industrial sector because of the complexity and site-specific nature of many efficiency measures. The LIEF curves were developed from a historical analysis of sectoral energy intensities and prices over the 1958-1985 period. The model segregates industries into 18 categories that have similar energy use characteristics based on their historical energy use data, and treats electricity and all other fuels use separately.

This appendix describes in detail the various aspects of the methodology and assumptions made, and reports much of the data used to perform the analysis.

Data Sources

The U.S. Department of Commerce, Bureau of the Census (Census) and U.S. DOE Energy Information Administration (EIA) classify the industrial sector as those industries with

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1. This analysis methodology was developed for a previous study by S. Laitner et al., *Energy Efficiency and Economic Development in the Midwest*, see note 2 in the main report.

2. M.H. Ross et al., see note 22 in the main report.

Standard Industrial Classification (SIC) codes 01 through 39. These SIC codes include agriculture, forestry, fisheries, mining, construction and manufacturing.[3]

Excellent disaggregated data are available at the national level for the manufacturing sector (the manufacturing sector is normally defined as industries with SIC codes 20 through 39) from the EIA's Manufacturing Energy Consumption Survey (MECS).[4] MECS includes data on energy consumption by fuel type for all two-digit manufacturing SIC codes, as well as data for several of the most energy intensive four-digit manufacturing codes.

Similar data are not readily available for the other industry sectors. A Congressional Office of Technology Assessment study[5] derived estimates of 1985 consumption for these non-manufacturing sectors from the National Energy Accounts Data Base. The data upon which these estimates are based are no longer collected, so more recent estimates are not available.

Only limited data are available on industrial energy consumption at the state level. The EIA's State Energy Data System estimates industrial energy consumption by state and reports the estimates annually in the State Energy Data Report (SEDR).[6] These estimates report consumption by fuel type at the aggregated industry level, but are not desegregated by industry group. Though data are not available for individual states, MECS reports data for U.S. Census regions. Consumption data for some industry groups at the regional level are not available or are withheld to avoid disclosing data for individual establishments. The missing data reduces the value of MECS to regional energy planning.

The SEDR and MECS feature two different types of surveys conducted by EIA. The surveys used to produce the SEDR are targeted at suppliers and marketers of specific fuels, while those used in the MECS collect consumption data directly from end-use consumers. Differences in methodology result in important differences in the results. One area of difference is irregularities in the definition of "industry." While the standard definition of the industry sector includes SIC 01 through 39, the supply survey does not "map" directly these SIC codes. For example, SEDR documentation indicates that ". . . data on agricultural use of

3. J.L. Preston, "Comparability of Supply- and Consumption-Derived Estimates of Manufacturing Energy Consumption," *Monthly Energy Review*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1994.

4. *Manufacturing Energy Consumption Survey: Consumption of Energy 1991*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1994.

5. *Industrial Energy Efficiency*, Office of Technology Assessment, Congress of the United States, Washington, DC, 1993.

6. *State Energy Data Report 1995*, see note 13 in the main report.

natural gas are collected and reported in the commercial sector rather than the industrial sector, (b)ecause agricultural use of natural gas cannot be identified separately . . . " [7].

The U.S. Department of Commerce, Bureau of Economic Analysis (BEA) estimates employment at the two-digit SIC level for states along with projections of employment growth through 2040.[8] In addition, Census conducts an Annual Survey of Manufactures (ASM) that reports value of shipments, value added, capital expenditures, and employment by state at the three-digit level.[9]

Estimation of Baseline Energy Consumption

Using all the data sources previously mentioned, this study develops a methodology to estimate disaggregated state industrial energy consumption based on energy intensity per employee, derived from estimates of 1991 national energy consumption and employment data.[10] The state consumption estimate involves the following steps: 1) developing estimates of 1991 national energy consumption by industry, 2) identifying projections of national energy and employment growth by industry, 3) apportioning state industrial energy consumption using employment and energy intensity measurements, and 4) projecting future energy use by industry in the state using weighted industry growth projections.

1991 National Industrial Energy Consumption Estimates

The 1991 MECS[11] is used as the initial source for estimating energy consumption in the manufacturing sector for electricity and for all other fuels. Since many industrial firms switch among fuels other than electricity and most thermal efficiency measures considered in this study are fuel blind, no attempt was made to disaggregate by fuel type.

Since 1985 is the most recent year for which non-manufacturing data are available, these estimates are used as the starting point for estimating 1991 energy consumption in non-

7. Preston, see note 3.

8. Bureau of Economic Analysis, *Regional Employment Database*, U.S. Dept. of Commerce, Washington, DC, 1994.

9. Bureau of the Census, *1991 Annual Survey of Manufacturers: Geographic Area Statistics*, U.S. Dept. of Commerce, Washington, DC, 1993.

10. Extensive data from 1991 was incorporated into the original model used to derive industrial sector energy consumption and fuel usage. For this reason the current analysis continues to utilize the 1991 data and relationships with more current employment and energy data to derive 1995 and future years estimates.

11. *Manufacturing Energy Consumption Survey: Consumption of Energy 1994*, see note 4.

Table C-1.
Factors Used In Extrapolation of 1985 Energy Consumption to 1991 for Non-Manufacturing Sectors

Industry Group	Employment (Thousands)		Employment Change	1985 Consumption Fractions		Employment Weighting Factors	
	1985	1991		Elec.	Fuel	Elec.	Fuel
Agriculture	4,616	4,551	99%	24.2%	6.1%	27.2%	7.4%
Mining	1,376	984					
Coal Mining	198	139	70%	12.1%	3.3%	9.7%	2.9%
Metal Mining	53	59	112%	11.9%	2.2%	15.1%	3.1%
Oil and Gas	1,008	670	66%	29.9%	56.7%	22.6%	46.5%
Non-Metal Mining	117	116	98%	8.4%	7.3%	9.5%	8.8%
Construction	6,425	6,681	104%	13.4%	24.3%	15.9%	31.3%

Sources: see text

manufacturing sectors. It is assumed that the difference between the 1991 MECS estimate of manufacturing energy consumption and the SEDR estimate of total national industrial energy consumption is the consumption of the non-manufacturing sector. As noted in the previous section, this simplifying assumption is less than ideal but does provide a means to estimate otherwise unavailable data. A two-step extrapolation scheme is used to apportion this consumption to the six non-manufacturing groups used in this study. First, the fraction of 1985 non-manufacturing energy consumption for agriculture, mining and construction is calculated for both electricity and other fuels (Table C-1). Next, the change in employment for each group from 1985 to 1991 is calculated from BEA data.[12] The employment changes are then used to weight the consumption distribution in order to apportion the non-manufacturing consumption of the 1991 industrial consumption estimate (Table C-2).

12. *Regional Employment Database*, see note 8.

Table C-2
Estimates of 1991 National Industrial Energy Consumption

Industry Group	SIC	1991 Employ. (1,000s)	1991 Consumption		Energy Employment Ratio	
			Electricity (Mill. kWh)	Fuel (TBtu)	Electric. (kWh/empl.)	Fuel (MBtus/empl.)
Agriculture	1,2,7-9	4,551	68,696	497	15,096	109
Mining		983	143,491	4,103	145,943	4,174
Coal Mining	12	139	24,388	193	175,703	1,390
Metal Mining	10	59	38,166	206	646,874	3,491
Oil and Gas	13	670	57,044	3,113	85,204	4,650
Non-Metal Mining	14	116	23,894	592	206,158	5,105
Construction	15-17	6,681	40,111	2,092	6,004	313
Food	20	1,683	49,536	784	29,440	466
Paper	26	691	58,896	2,271	85,245	3,287
Chemicals	28	1,093	129,093	2,636	118,109	2,411
Petro. Refining	29	158	30,782	2,865	195,070	18,156
Rubber & Plastics	30	865	33,908	121	39,205	140
Stone, Glass, Clay	32	615	30,814	789	50,104	1,283
Primary Metals	33	725	146,276	1,793	201,677	2,472
Metals Fab. Ind.		7,892	136,340	702	17,276	89
Fab. Metal Prod.	34	1,370	29,772	203	21,739	149
Ind. Machinery	35	2,046	29,484	134	14,413	66
Elect. Equipment	36	1,607	29,996	94	18,667	58
Transport Equip.	37	1,896	34,721	215	18,312	113
Instruments	38	974	12,367	56	12,701	57
Other Mfg.		5,336	79,057	712	14,817	133
Tobacco	21	50	1,002	21	20,202	415
Textiles	22	678	29,532	172	43,564	254
Apparel	23	1,049	5,645	25	5,382	24
Wood Prod.	24	802	17,878	362	22,292	451
Furniture	25	500	4,915	50	9,830	100
Printing	27	1,678	15,629	55	9,312	33
Leather	31	130	795	9	6,130	72
Miscellaneous	39	449	3,661	19	8,146	41
National Total		31,272	947,000	19,365	30,283	619

Sources: see text

The ratio of estimated 1991 energy consumption for electricity and other fuels to employment estimates is then calculated for each industry considered. These ratios are used as the basis for apportioning 1995 SEDR[13] estimates of state energy consumption to the different industrial groups (Table C-2).[14] It would be preferable to base the apportioning on an indication other than employment, such as value of shipments or value added, but such data are not uniformly available at the state level for all industry groups. Using value of shipments for the manufacturing sector from ASM data[15] combined with employment-based apportioning for other sectors does not yield significantly different distributions of consumption among the industry groups than did using employment for all sectors. This data deficit represents a void begging to be filled.

Energy and Employment Growth

In order to estimate energy savings in the future it is necessary to project the growth in energy consumption for a "base case" (i.e., in the absence of efficiency improvements). EIA estimates industrial energy consumption growth at the national level by both fuel type and industry group.[16] These projections take into account changes in fuel mix, efficiency improvements due to modernization and changes in products, and changes in the size of the industry group. Electricity consumption is projected to grow 1.4 percent per year from 1995 to 2015. During the same period the principal fossil fuels, natural gas, coal and petroleum, are projected to grow 0.9, 0.0 and 1.2 percent per year respectively. Growth in total energy consumption varies significantly between industry groups, see Table C-3. For example, energy intensive industries like primary metals, paper and petroleum refining are projected to grow at 1.3, 0.2, and 0.9 percent per year respectively, and metal durables grows at 2.1 percent per year.

To make projections of energy growth rates at the state level, it is necessary to weight the national energy growth rates to account for the projected change in the size of the industries at the state level. This weighting is accomplished by multiplying the national energy growth rate by the ratio of rate of employment growth at the state level to the national level. The BEA projections for national employment growth are reported in Table C-3.[17]

13. *State Energy Data Report 1995*, see note 13 in the main report.

14. *Regional Employment Database*, see note 8.

15. *1991 Annual Survey of Manufacturers: Geographic Area Statistics*, see note 9.

16. *Annual Energy Outlook 1998*, see note 15 in the main report.

17. *Regional Employment Database*, see note 8.

Estimation of State Energy Consumption Baseline

The 1995 base-year state industrial energy consumption is estimated by apportioning the SEDR state industrial totals to the industry groups by multiplying the national energy to employment rations by employment at the state level. The annual consumption baseline are made at the two-digit level (except for agriculture and construction that are aggregated). Based on the 1995 consumption estimates, annual electricity and other fuel consumption is estimated for each year from 1995 through 2015.

Table C-3
Estimates of National Energy and Employment Growth Rates

Industry Group	SIC	Annual Growth Rate: Energy	Annual Growth Rate: Employ.
Agriculture	1,2,7-9	1.9%	0.5%
Mining		1.9%	-0.9%
Coal Mining	12	1.9%	-2.6%
Metal Mining	10	1.9%	0.4%
Oil and Gas	13	1.9%	-0.0%
Non-Metal Mining	14	1.9%	0.4%
Construction	15-17	1.9%	0.8%
Food	20	0.9%	0.2%
Paper	26	0.2%	0.2%
Chemicals	28	1.1%	0.4%
Petroleum Refining	29	1.4%	0.4%
Rubber & Plastics	30	1.9%	0.8%
Stone, Glass, Clay	32	-0.33%	-0.5%
Primary Metals	33	1.3%	-1.0%
Metals Fab. Ind.		2.1%	-0.5%
Fab. Metal Prod.	34	2.1%	-0.9%
Ind. Machinery	35	2.1%	-0.6%
Elec. Equipment	36	2.1%	-1.2%
Transport Equip.	37	2.1%	0.0%
Instruments	38	2.1%	0.5%
Other Mfg.		1.9%	0.1%
Tobacco	21	1.9%	-1.5%
Textiles	22	1.9%	-0.8%
Apparel	23	1.9%	-0.5%
Wood Prod.	24	1.9%	-0.0%
Furniture	25	1.9%	0.5%
Printing	27	1.9%	-0.9%
Leather	31	1.9%	-1.8%
Miscellaneous	39	1.9%	-0.5%

Source: Energy EIA, 1998a and Employment BEA, 1994

Estimation of the Savings Potential from Efficiency Improvements

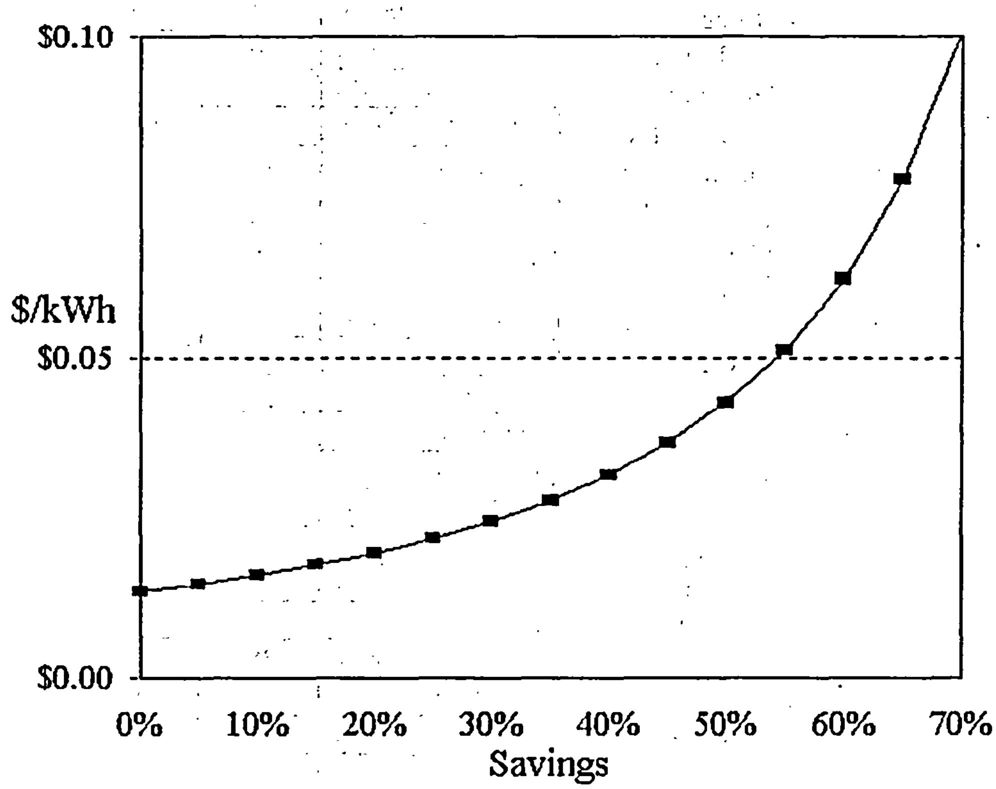
The cumulative energy savings is calculated using conservation supply curves developed from the Long Term Energy Forecasting (LIEF) Model[18] and estimates of the average price for electricity and other fuels for each industry grouping.

The LIEF curves were developed from a historical analysis of 1958-1985 sectoral energy intensities and prices. Most conservation supply curves have been developed by combining various characteristic measures for a particular market. Such an approach is impractical for the industrial sector because of the complexity and site-specific nature of many measures. The LIEF model segregates industries into 18 categories that have similar energy use characteristics

18. Ross et al., see note 22 in the main report.

based on their historical energy use data, and treats electricity and all other fuels use separately.[19] (An example of an electricity conservation supply curve appears in Figure C-1.)

FIGURE C-1. Electricity Conservation Supply Curve for General Manufacturing Derived from LIEF Model



19. Ross et al., see note 22 in the main report.

The LIEF model uses electricity and fuel prices to estimate the economically acceptable energy efficiency potential. The fuel prices for each industry are the average state industrial fuel prices.[20] The average industrial electricity price in the state is used for all industries.[21] This assumption is made to simplify analysis and does not account for the variation in electricity prices among different size customers or the impact of measures on demand charges.

The maximum economic savings potential is assumed to be the point on the conservation supply curve at which the marginal cost of energy saved equals the current fuel or electricity price. In the case of electricity, the calculated average price of industrial electricity in each state is used. For other fuels, the estimated average price (as discussed above) for a particular industry group is used. The efficiency curves reflect the different savings potential based upon price and industry.

As an example, if a food processing plant pays $0.07 per kilowatt-hour (kWh) for electricity, the efficiency potential is 63 percent of current consumption. For a primary metals manufacturing plant, the savings potential is only 22 percent at $4.00 per million Btu. The difference is a function of the way each industry typically uses energy, the steps already undertaken by that industry to save energy, and energy prices paid by each industry.

Efficiency investments in the high efficiency scenario are estimated by multiplying the estimated energy savings in each year by the average capital cost. The investment is calculated for each industry grouping since the average fuel price varies by industry due to differences in fuel mix. Because the average measure life is assumed to be 10 years, the capital expenditures made in the first years must be repeated beginning in 2009 in order to maintain the savings realized in those prior years.

Regarding implementation rate, it is assumed that 80 percent of the maximum savings potential is achievable by the year 2015. But it is assumed that energy efficiency measures are implemented gradually. In particular, the annual savings, beginning in 1999, was estimated to be 4.7 percent of the maximum potential. In other words, it is assumed that the efficiency measures are implemented linearly over the 17-year period. The annual savings potential for each industry is applied to base-case consumption for each year to yield an annual energy savings estimate that is added to the previous year's savings to yield a cumulative energy savings estimate for each year.

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20. *State Energy Price and Expenditure Report 1995*, Energy Information Administration, U.S. Department of Energy, Washington, DC, 1998.

21. *State Energy Price and Expenditure Report 1995*, see note 20.

Costs of Conservation

The investment needed to achieved a particular level of energy savings is based on the assumptions of an average ten-year technology life and a five percent real discount rate. In reality, the life of the measures will vary depending upon the measure and the point in the economic cycle of the specific plant at which the measure is applied. Ten years is the median life for many of the industrial measures and is used as a simplifying assumption. Efficiency investments in the high efficiency scenario are estimated by multiplying the estimated energy savings in each year by the average capital cost for measures. It is assumed that the average cost of measures will remain constant. The investment is calculated for each industry grouping since the average fuel price varies by industry due to differences in fuel mix.

Estimating the Potential from Combined Heat and Power

Estimating the potential for increased installation of CHP is difficult because of a broad range of system types and large numbers of potential sites. This is complicated in that detailed state level data is not readily available. If the barriers are removed, it is anticipated that much of the early capacity additions will occur at larger industrial and district energy sites that already have existing, large boiler systems. As time progresses, smaller industrial, institutional, and commercial facilities will begin to constitute a greater portion of the new capacity. New district energy systems, which consolidate the thermal demands of several facilities or buildings, will take longer to develop because of their complexity.

We have developed an estimate of the potential for CHP in the manufacturing sector. The Census of Manufacturing (Census 1996) was used to determine the value added by in each 2-digit SIC manufacturing group in Illinois, and based on the energy intensity from the Manufacturing Consumption Survey (MECS) (EIA 1997a), an estimate of the energy used was made. Then using the steam end-use energy report in MECS, an estimate was made of the total steam production in all manufacturing. Based on national CHP potential estimates, a fraction of this steam load was assumed to have a potential for CHP, and the implementation rate projected by ACEEE in a recent analysis was used to make estimates of the CHP capacity additions (Geller, et al. 1998).

By 2010, we estimate that a total of 1,310 MW_e of new CHP capacity could be implemented in Illinois if the barriers are removed to a large degree. We estimate that this additional capacity will produce over 7 TWh with a net energy savings of 40 TBtu over what would be required if conventional generation were required. The net energy savings account for some additional energy use on-site. The additional CHP capacity climbs to 2,363 MW_e by 2015, and provides almost 13 TWh of additional electricity that would otherwise have to be generated from new, conventional facilities, and will result in net energy savings of about 66 TBtu.

Overall CHP *overall fuel efficiency* (ratio of total useful energy outputs to fuel inputs as described in Krause and Koomey, 1994) varies with configuration, from 50 percent for some smaller reciprocating engine-based systems to over 80 percent for some larger turbine-based systems. The overall fuel efficiency also varies with the ratio of electricity and/or mechanical energy to heat energy (e.g., steam or chilled water), referred to as the *power to heat ratio* or *electricity production rate*, with the most efficient systems having power-to-heat ratios of less than 0.5. Average overall fuel efficiency in our analysis is assumed to be 70 percent, with an average power-to-heat ratio of 0.5. This implies an *electricity-efficiency* of 23 percent and a *thermal-efficiency* of 47 percent, with a *net electric heat rate*[22] of 4,015 Btu per kWh.

To calculate the avoided utility generation, it is assumed that the CHP electricity generation capacity is operated 7,100 hours per year at 90% of its rate capacity. In practical terms this means that the generation component of the CHP system is size for the base thermal load of the facility, and thermal swings are met by supplemental firing of the additional fuel in the boiler. Based on data reported in the *Electricity Annual* (EIA 1996), it is assumed that the avoided utility generation capacity would have been operated 6,000 hrs per year at 67% of its rate capacity. The incremental cost of CHP capacity, over and above a conventional boiler, was estimated to be $650 per installed kW, while electricity generation was assumed to be $425 per installed kW (Carroll 1998 and Bluestein 1998). The additional fuel required to cogenerate electricity was calculated using the assumed net electric heat rate as discussed above and was assumed to be natural gas. Net energy savings were calculated using the following relationship:

$$Savings_{chp}=(FHR_{utility}-THR_{cogen}-HR_b)Electricity_{avoided}$$

using *AEO98* projected fossil heat rate ($FHR_{utility}$)for utility generation (EIA 1997b), and the *net electricity heat rate (N)*. Cost savings were calculated using the industrial natural gas and electricity prices projected elsewhere in this report.

22. *Net electricity rate* (*N*) the amount of additional fuel need to cogenerate a unit of electricity above the conventional boiler heat rate (HR_b) as defined by:

$$N=\frac{THR_{cogen}-HR_b}{PHR}$$

where, THR_{cogen} is the total heat rate for cogeneration system as defined by the *overall fuel efficiency*.

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11

Illinois Wind Resource Maps

News

- Holy Cross Energy: Wind Cooperative of the Year 2003
- State Wind Working Group Handbook (PDF 11 MB) Download Acrobat Reader
- Some Common Misconceptions about Wind Power (PDF 525 KB) Download Acrobat Reader From the "State Wind Working Group Handbook," pp. 82-87.
- Wind Energy Finance Calculator
- Clean Power Estimator
- Economic Development Benefits of Wind Power (PDF 281 KB) Download Acrobat Reader
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Calendar

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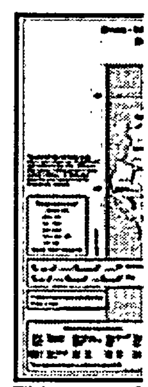
New wind resource maps of Illinois have been produced by the Department of Energy's Wind Program and National Renewable Energy Laboratory (NREL). The new information shows that Illinois has at least 3000 MW more in potential wind capacity from "good" wind resource areas than earlier estimated.[1] In addition, the maps show scattered areas of good wind resource (class 4, or 15.7 - 16.8 mph) in central and northern Illinois. The new Illinois wind maps can serve as prospector's maps for wind developers. At least 5 prime wind zones are identified (SE of Quincy, Bloomington area, north of Peoria, Mattoon area, and between Sterling and Aurora), as well as other potential sites, especially in northern Illinois.

This map of the wind res levels. (click to enl

This new information is presented in two formats. Both formats show the wind resource, using NREL's standard wind power classification system, in relation to transmission lines and major cities. Version 1 shows the wind resource at all levels throughout the state, and Version 2 highlights the best areas suitable for utility-scale wind energy development.

The wind potential from these windy lands is about 3000 MW of installed wind generation capacity. In a class 4 wind regime, the annual average output of a wind power plant is typically about 25% of the installed capacity. The class 4 areas represent about 0.4% of Illinois' land and are largely rural agricultural areas.



This map of highlights th suitable for wind energy developmen (click to enl

Because of likely advances in technology and the significant incentives available in Illinois, a number of additional areas with only slightly lower wind resource (class 3+, or 14.3 - 15.7 mph) may also be suitable for wind development.. These class 3+ areas highlighted on the map of best areas represent an additional 6000 MW of wind potential.

The total amount of class 4 and 3+ lands combined is about 1800 square kilometers (1.2% of Illinois' land area), and the wind potential from these areas is about 9000 MW. Each square kilometer may support about 5 MW of installed wind capacity. All urban and environmentally-sensitive lands (state parks, wildlife refuges, etc) have been excluded in estimating the wind potential.

[1] According to the previous information for Illinois (the 1987 *Wind Energy Resource Atlas of the United States* and the 1991 report *An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States*), Illinois had essentially zero potential in class 4 and above wind areas. The new information shows that Illinois has at least 3000 MW more in potential wind capacity from "good" wind resource areas than earlier estimated.

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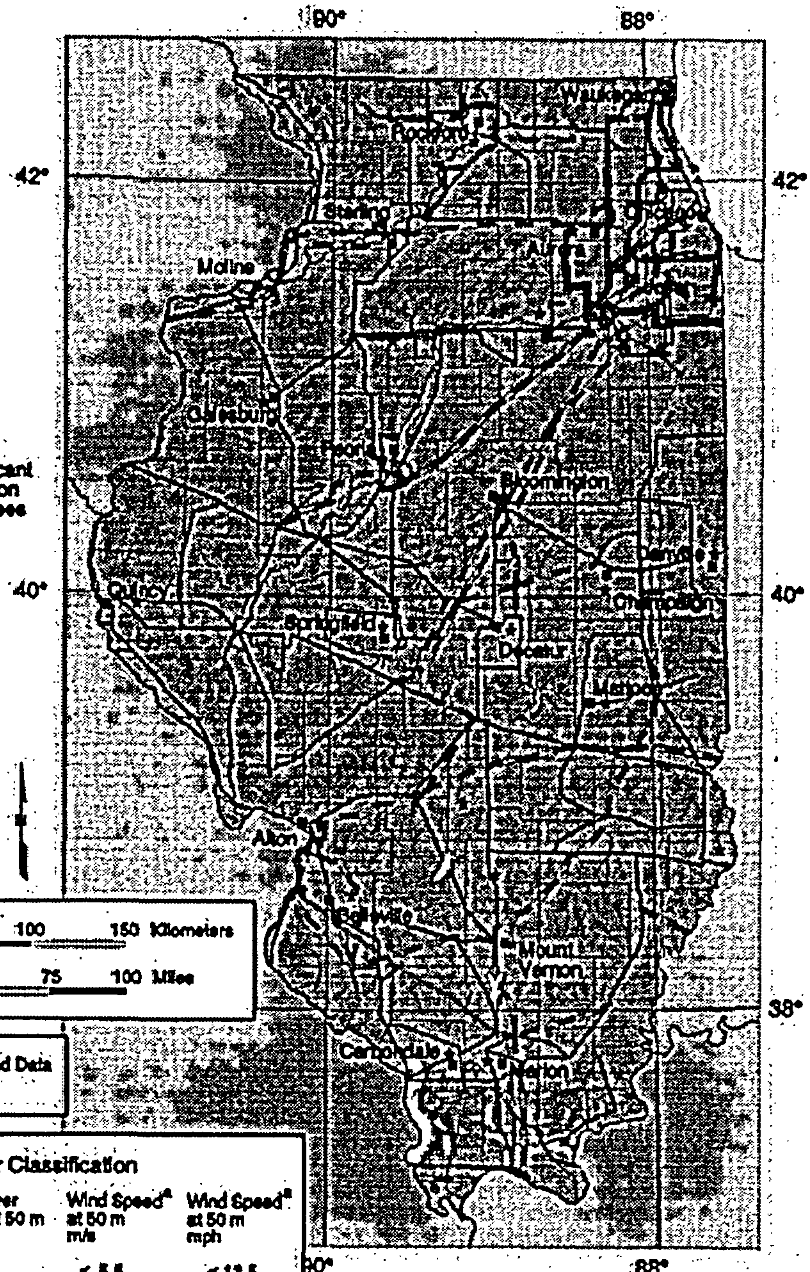
Illinois - Wind Resource Map



The productivity estimates apply only to open areas free of significant obstructions to the wind. Common obstructions include groves of trees and tall buildings. In obstructed areas the wind resource can be considerably reduced.

Transmission Line*
Voltage (kV)
- 735
- 345
- 230
- 115 - 161
- 69

*Source: RDI/FT Energy, Inc.

50 0 50 100 150 Kilometers
25 0 25 50 75 100 Miles

- ★ Meteorological Station with Wind Data
- ■ City or Town

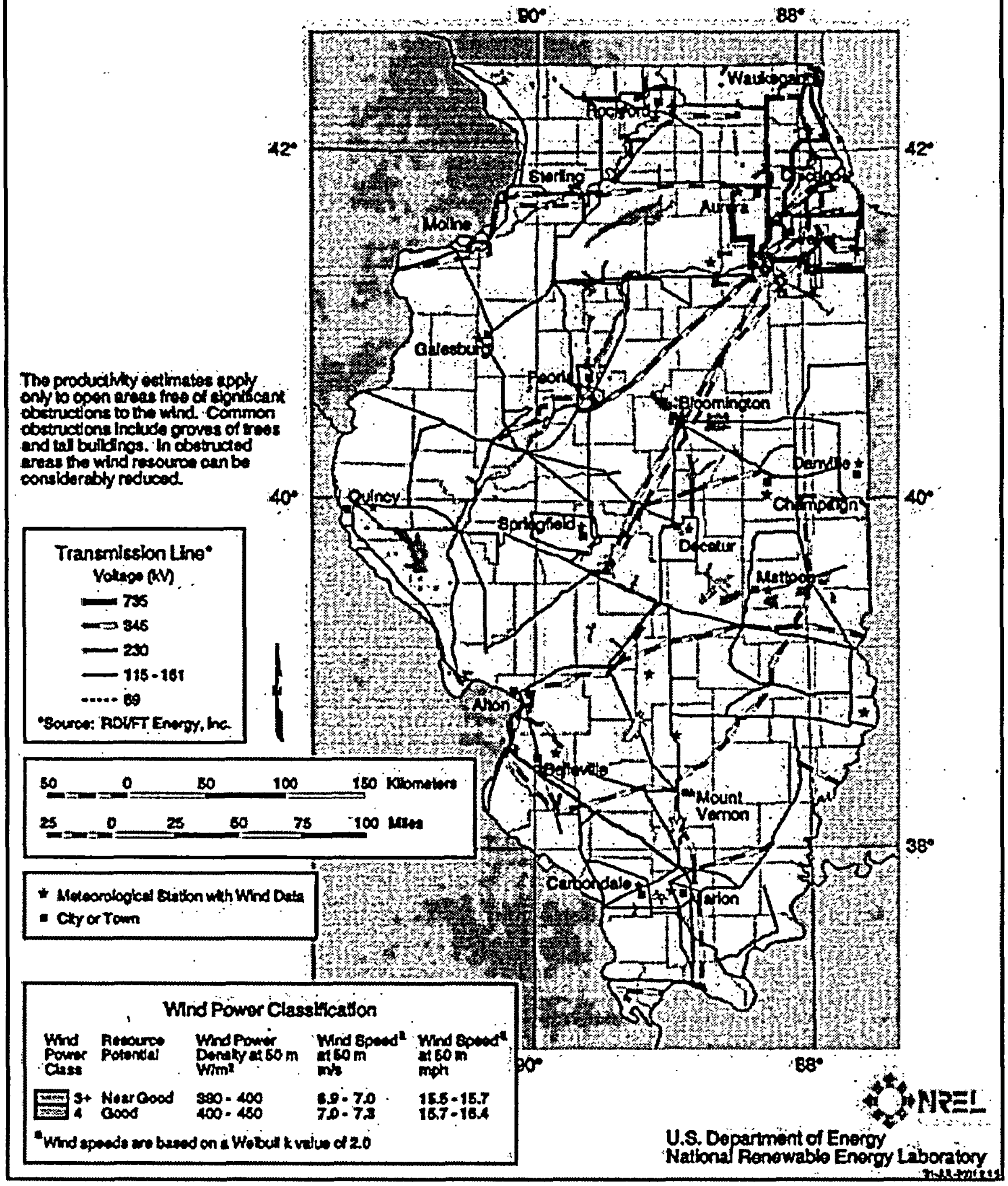
Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	< 200	< 5.6	< 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8

[a]Wind speeds are based on a Weibull k value of 2.0

NREL
U.S. Department of Energy
National Renewable Energy Laboratory

Illinois - Wind Resource Map
Best Areas



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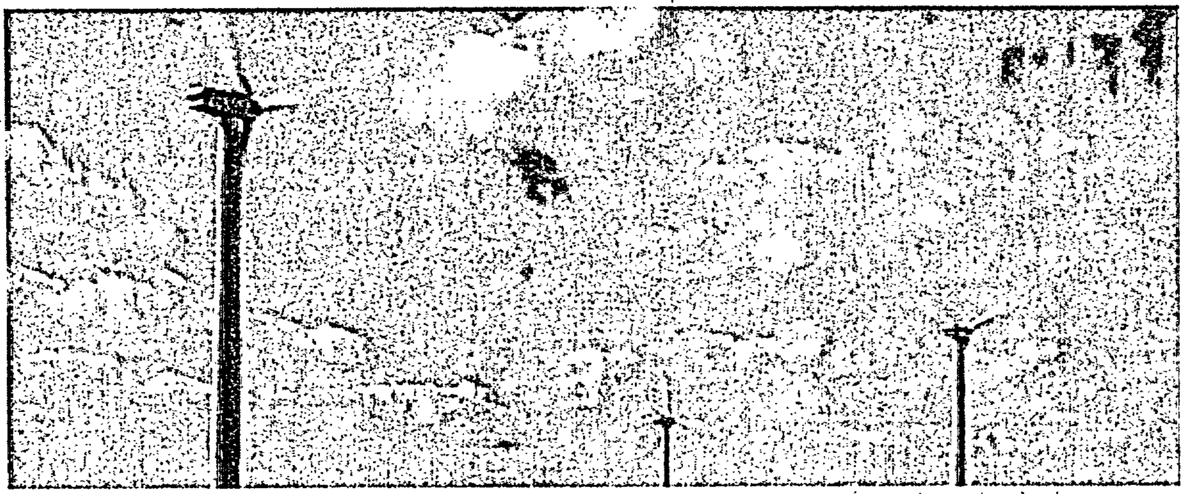


WIND POWER
OUTLOOK 2004

Stiff Challenges, Big Opportunities

The U.S. wind energy industry demonstrated once again in 2003 that it can quickly ramp up production to meet the nation's growing power demand. The industry chalked up a near-record year in new wind farm installations, and utility and policy decision-makers are clearly taking notice of this zero-emissions, domestic power source.

The wind industry's momentum was cut short, however, as the federal wind energy production tax credit (PTC) again expired at the end of the year, due to the inability of Congress to agree on comprehensive energy policy legislation. (The PTC provides a tax credit as an incentive to companies that own wind farms.) Unless the PTC is extended early on, the boom of 2003 is likely to be followed by a bust in 2004. This would be the third such boom-and-bust cycle inflicted on the U.S. wind energy industry in the past five years. The industry is calling on Congress to pass a long-term extension of the PTC to provide a stable market environment and unleash the technology's pent-up potential.

Large Potential Ready to Meet the Power Needs of the 21st Century

America's wind resources are vast, and may be even greater than previously estimated, according to a 2003 Stanford University study. Previously uncharted offshore potential along the southeastern and southern coasts makes wind power generation feasible in these areas, where little or none had been deemed possible before. Taller sizes and sophisticated electronic controls also allow modern turbines to wring ever more power from the wind.

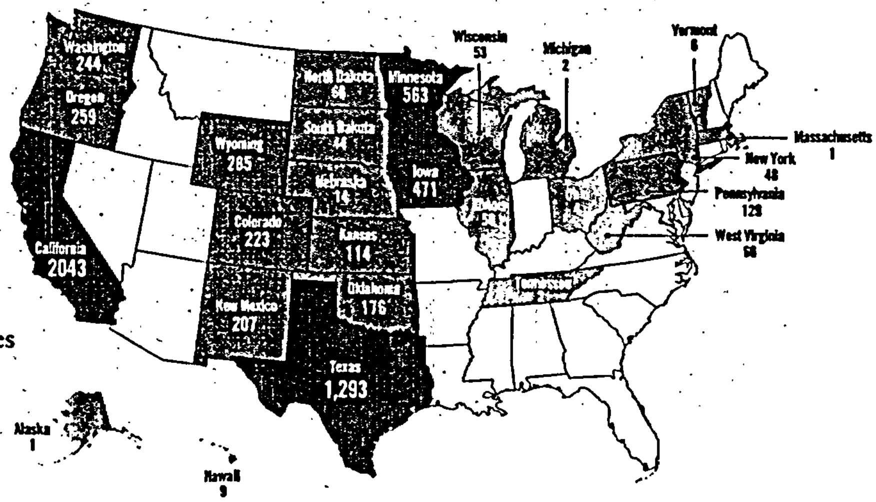
Tapping only a fraction of America's vast wind resources would easily yield much of the new power that the country will need in the years ahead: in order to generate 15 % of America's electricity (twice what hydropower generates today) only 0.6% of the land of the lower 48 states would have to be developed with wind power plants, according to a study by the Pacific Northwest Laboratory for the U.S. Department of Energy. Within that area, as little as 5% of the land would be taken up by equipment and access roads, and most existing land use, such as farming and ranching, would continue as it is now.

With its abundant, inexhaustible potential, its increasingly competitive cost, and environmental advantage, wind energy is one of the best technologies available today with which to meet the world's growing demand for power.

U.S. Wind Energy Industry Sets Near-Record in 2003

United States Wind Power Capacity (MW)

6,374 MW as of 12/31/03
(States with less than 1MW not included in map.)



2003 came very close to the best year ever in the U.S., with 1,687 megawatts (MW) of new wind power constructed -- only a few megawatts shy of the record 1,696 MW installed in 2001. Current installed capacity in the U.S. is 6,374 MW, with utility-scale wind turbines installed in 30 states. One megawatt of wind capacity generates enough to power the equivalent of 300 average American households.

The large buildup in capacity is a 36% increase over the installed wind power base in the U.S. at the beginning of the year. Over the last five years (1999-2003), U.S. wind generating capacity has expanded at an annual average rate of 28%.

The wind industry would only have to maintain an annual growth rate of about 18% to achieve the American Wind Energy Association's (AWEA) estimate that wind can provide 6% of the nation's electricity by the year 2020. The past year has shown that rate to be a readily achievable goal with consistent policy support from federal and state governments. More wind power in the nation's power portfolio means less reliance on fossil fuels and vulnerability to spikes in the cost of fuel, more economic development in rural areas, and more pollution-free power.

The wind farms completed in 2003 will generate approximately $5 million in payments to landowners annually and create skilled, long-term jobs in areas where such employment is scarce.

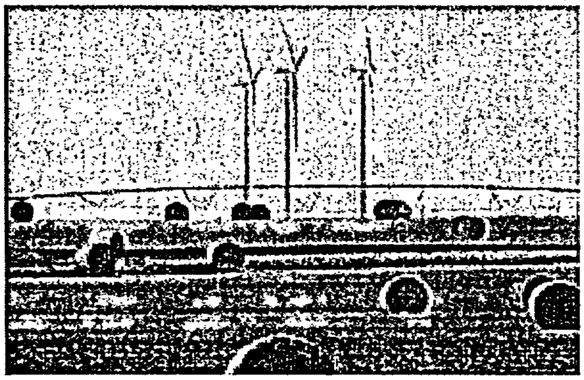
The wind farms completed in 2003 will generate approximately $5 million in payments to landowners annually and create skilled, long-term jobs in areas where such employment is scarce, as well as short-term construction jobs and associated economic activity.

Voluntary green power programs are helping bring new wind farms online throughout the country. Altogether, green power programs have facilitated over 1,200 MW of renewable energy — much of it wind power — since the concept was launched some ten years ago. Universities have been particularly strong first adopters of green power.

Oklahoma, Illinois, and Ohio saw their first installations of large-scale wind turbines.
Minnesota added the most new wind power (226 MW) of any state in 2003, moving back into third place in total capacity behind only California and Texas. Three other states topped the 200-MW mark in new installations in 2003: California, with 212 MW; New Mexico, with 205 MW; and Texas, with 204 MW.

Spanish turbine manufacturer Gamesa and Indian manufacturer Suzlon installed their first machines in the U.S. in 2003, both in Minnesota. More than half of the new capacity installed in the U.S. in 2003 consisted of GE Wind turbines.

In other wind turbine manufacturing news, Vestas and NEG Micon, two global market leaders, announced that they would merge, creating the world's largest single wind turbine manufacturing company. The wind energy industry is also producing ever larger, more powerful, and more sophisticated machines. Several companies introduced turbines in the 2-MW range for land-based commercial applications, and even larger turbines are being tested as prototypes. In 2003 GE Wind installed its first offshore 3.6-MW units, off the coast of Ireland -- the largest commercial wind turbines at the time.



Uncertain Policy Environment

In spite of strong bipartisan support, the wind energy production tax credit (PTC) expired December 31, 2003. An extension of the PTC through December 31, 2006, is contained in wide-ranging energy policy legislation on which Congress has been unable to reach final agreement. The PTC, enacted in 1992, provides a 1.8 cent per kilowatt-hour credit (adjusted periodically for inflation) for electricity produced from a wind farm during the first 10 years of operation, and is important for financing wind projects. The delay in the PTC's renewal is inflicting a high cost on the industry—initial estimates by AWEA were that, with a timely extension, a record-busting 2,000 MW of new wind capacity would have been installed in the U.S. in 2004.

The comprehensive energy policy bill also contained a new investment tax credit for small wind turbines (rated at 75 kW and below) used to power an individual home or farm. The credit would help reduce the cost of a small wind system, making it more affordable for consumers.

Absent from the comprehensive energy bill was a "renewables portfolio standard" (RPS) requiring that a growing share of the nation's power supply come from renewable sources by 2020. The Senate had included an RPS in its energy bill in 2002, and in 2003, a majority of Senators urged Congressional leaders to include the RPS in the final energy bill. That effort did not succeed. By rejecting the RPS, Congress failed to provide the type of stable market signal that will stimulate U.S.-based manufacturing and large-scale deployment of renewable energy.

At the state level, implementation of a state-level RPS announced by New York Governor George Pataki in early 2003 is proceeding slowly. The California RPS, passed by the legislature in 2002, is also moving slowly at the Public Utilities Commission. In a more positive development, in early 2004, an RPS was under consideration in both Colorado and Illinois. In Colorado, advocates were preparing to take the RPS directly to voters in a referendum in case the effort failed in the legislature.

Small Wind Systems At Work In U.S. and Overseas

Small wind turbines allow homeowners, farmers, businesses, and public facilities to generate their own clean power and reduce their electricity bills. In 2003, for example, Hershey Park, an amusement park in Pennsylvania, installed a small wind energy system (right) to promote the benefits of clean energy to the park's 2.4 million annual visitors. The 10-kW Bergey Windpower wind turbine and 80-ft. tower were installed with support from the Pennsylvania Sustainable Energy Fund. The system also includes a small solar array. The amount of clean power generated from the wind turbine and the solar panels is displayed in real time. The environmental benefit is equal to not driving almost 30,000 miles each year or to planting over 2,000 trees.

Small wind energy systems also allow off-grid homes and remote communities to generate their own power. In 2003, for example, two 1-kW wind turbines and small solar arrays were installed for a CARE water treatment project in Afghanistan. By eliminating fuel requirements and generator maintenance, such systems greatly reduce the logistics burden for military or relief agencies. The small systems are easy to ship and install. A 1.2-kW hybrid (wind + solar) system can typically supply enough energy to power a school, a clinic, water pumps, or disinfection systems.

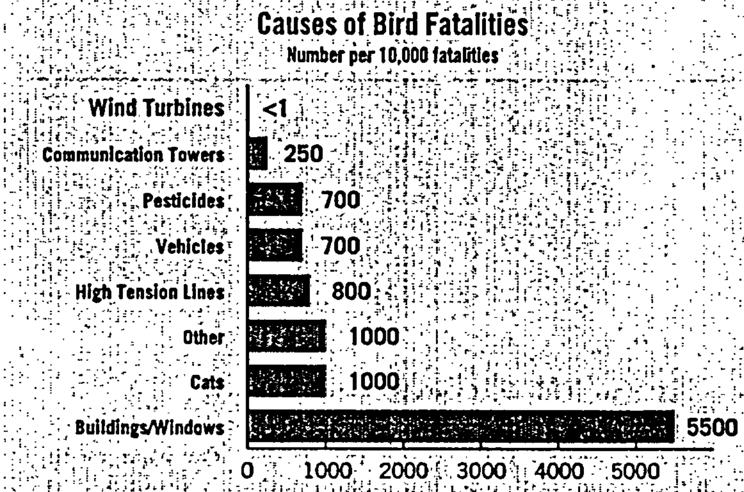
Transmission Reform and Planning: Gordian Knot

As wind energy expands, it faces the challenge of gaining fair access to the utility transmission system and non-discriminatory treatment on its wires. The stakes are high: for the country to tap its wind power potential in a big way and provide 6% or more of the nation's power supply, wind power generators need to get their product to market--for example, from wind-rich areas in the Great Plains and Interior West to urban centers with growing electricity demand.

Securing fair rules, and a planning process that includes wind alongside other power technologies in the design of transmission upgrades and new lines, are key to getting wind power to market across the country.

Over 200 different "tariffs" throughout the country govern the costs and conditions for access to, and use of, the grid. Many of these charge heavy, discriminatory penalties against new technologies like wind. Securing fair rules, and a planning process that includes wind alongside other power technologies in the design of transmission upgrades and new lines, are key to getting wind power to market across the country.

This challenge has been complicated by the sidelining of efforts by the Federal Energy Regulatory Commission (FERC) to overhaul and standardize transmission access rules. National rules proposed by FERC would have eliminated unfair penalties associated with variable output, streamlined interconnection procedures, and leveled the playing field for wind energy. Instead, such non-discriminatory rules will need to be secured on a piecemeal basis. A few jurisdictions, like the Electricity Reliability Council of Texas (ERCOT) and the PJM Interconnection in the mid-Atlantic states, have adopted non-discriminatory transmission pricing, and demonstrate how such reforms enhance competition and benefit consumers. Partial reforms are also in place in California and at the Bonneville Power Administration in the Pacific Northwest. The rules proposed by FERC and already at work in Texas and PJM provide a model for regional transmission organizations throughout the country.



Source: Erickson et al., 2002, Summary of Anthropogenic Causes of Bird Mortality.

Help Save Wildlife With More Wind Power

One of the recurring arguments used by skeptics or opponents of wind energy is that it kills birds. In fact, wind energy is one of the cleanest, most environmentally friendly energy sources available. Estimates run by wind power opponents themselves show that bird deaths due to wind development will never be more than a very small fraction of those caused by other human activities. See **www.yes2wind.com**, the joint Web site of WWF, Friends of the Earth and Greenpeace created to support wind power.

FACT: Even if wind were to generate 100% of U.S. electricity needs today, wind would account for only one of every 250 human-related bird deaths. Leading direct threats to birds include buildings, vehicles, cats, pesticides.

FACT: Power plants are the largest industrial source of air pollutants (including sulfur dioxide, nitrogen oxide, particulate matter, and mercury) in the U.S. A report by the National Wildlife Federation finds that the common loon and other aquatic wildlife in the Great Lakes are at risk from high concentrations of mercury. "Protected" areas such as state and national parks offer no protection to wildlife from this and other forms of airborne pollution.

FACT: Power plants also account for about 34% of the carbon dioxide (CO_2) emitted by the U.S., itself the largest emitter of CO_2 worldwide. Carbon dioxide is the leading greenhouse gas associated with climate change.

FACT: Climate change is predicted to result in countless bird deaths through large-scale alteration of habitat, according to a Defenders of Wildlife report. WWF reports that the gradual warming of the Arctic is already endangering the lives of birds in the polar region. A study published in *Nature* (January, 2004) found that one million species--more than one-third of native species of plants and animals worldwide--could disappear or approach extinction by 2050 if global warming continues.

FACT: The new wind capacity installed in the U.S. in 2003 will displace emissions of three million tons of carbon dioxide (the leading greenhouse gas) annually.

Lots More Wind Power = Cheaper Natural Gas

The cost of wind power, once a wind farm has been built, is steady over time, and not subject to fuel price volatility. This, along with its economic benefits for rural areas and its environmental advantage, makes wind an attractive technology with which to diversify the nation's power portfolio and help reduce the looming natural gas shortage predicted by many energy experts.

As part of a national energy program aimed at moving quickly to deal with the shortage and increase overall reliability of the national electricity transmission system, AWEA has launched a three-step "wind pipeline" proposal to collect wind-generated electricity from the windy, lightly-populated heartland and deliver it to urban centers in the Midwest and West.

Phase I: Transmission reform to more fully utilize existing power line capacity and ensure non-discriminatory access. Cost: $0. New wind capacity facilitated: ~4,000 MW (equivalent to ~0.4 billion cubic feet (Bcf)/day of natural gas, or electricity needs of 1 million homes).

Phase II: Addition of several new local transmission lines to remove existing system bottlenecks and bolster secondary-level reliability. Cost: ~$1 billion. New wind capacity facilitated: ~26,000 MW (equivalent to ~2.4 Bcf/day of natural gas, or electricity needs of 6.5 million homes).

Phase III: Construction of two major high-voltage lines from the northern Plains to the East (Trans-Prairie Wind Pipeline) and West (Interior West Wind Pipeline). Cost: $10 billion to $20 billion. New capacity facilitated: 30,000 MW to 60,000 MW (equivalent to ~2.8-5.5 Bcf/day, or electricity needs of 7.5 million to 15 million homes). Three Bcf/day is about as much natural gas as the states of Colorado and Alaska produce today. Neither Phase III nor any construction of new major transmission lines should occur unless non-discriminatory access and reliability standards are in place.

The AWEA proposal would improve reliability of the electric system, and provide a sturdy link between the Midwest and West. The large-scale investments in wind energy would not only relieve pressure on natural gas prices, but also revitalize rural communities in many parts of the Great Plains.

Wind/Natural Gas Compatibility

WIND		NATURAL GAS
Low Operating Cost	⟷	High Operating Costs
High Capital Cost	⟷	Low Capital Cost
Non-dispatchable	⟷	Dispatchable
No Fuel Supply/Cost Risk	⟷	Fuel Supply/Cost Risk
No Emissions	⟷	Smog, Greenhouse Gas Emissions

Wind and natural gas power plants are a winning combination on the grid and in a utility's power portfolio because of their complementary characteristics.

Wind Energy: A Popular Energy Source

As wind power expands, so has publicity about occasional, not-in-my-backyard (NIMBY) opposition to proposed wind farms. Could wind energy face a backlash of public opinion?

Public opinion surveys conducted over the years and in 2003 in fact reveal strong backing for wind power, and for renewable energy in general.

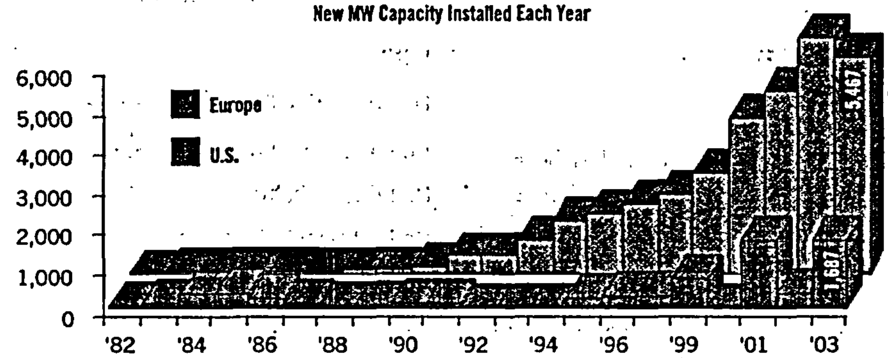
The Nebraska Public Power District in August, 2003, asked its customers whether it should go forward with a $200 million wind project if that meant that utility rates would increase by up to 2.5%. The response was stunning: 96% said yes, and 37% thought the wind project should be larger. A more traditional opinion poll of Colorado residents in March likewise found 82% supporting "wind and solar" even if rates would increase as a result.

Polling in Europe shows that support for wind energy tends to strengthen after a wind plant has been installed and operating for some time.

Polling in Europe shows that support for wind energy tends to strengthen after a wind plant has been installed and operating for some time.

In Scotland, according to a 2003 survey, people living close to the 10 largest wind farms in the region strongly support wind, 82% of the respondents want an increase in electricity generated from wind, and 54% support an increase in the number of turbines at their local wind farm. In Spain, studies surveying the Catalonian province of Tarragona showed that four out of five Catalonians favor wind energy, with the strongest support coming from people residing near a wind farm.

Comparing European and American Growth



Smart Wind Turbines Can Enhance Grid Reliability

The massive blackout that affected much of the American Northeast in August, 2003, exposed long-standing weaknesses in the nation's transmission infrastructure and management. However, agreement on what needs to be done remains elusive.

Inefficient, "balkanized" markets and tariffs should be avoided, and development of "smart" transmission system controls should be aggressively pursued, according to AWEA. Sophisticated new communications and monitoring hardware and software should be installed to enable grid controllers to monitor and manage power flows more easily. The cost of such investments to expand capacity and efficiency of transmission is relatively small compared to the costs of a large blackout or to the savings that would be gained from increased efficiency in the much-larger electricity generation sector.

The wind energy industry is developing performance standards and interconnection requirements for its own technology that could enhance grid reliability. New designs make it possible for wind turbines to continue operating through a problem on the utility system such as a short circuit or a lightning strike instead of being required and designed to shut down. In fact, turbines have become so advanced that they can stay connected in such events and actually help maintain the stability of the system's power quality. The offshore Horns Rev wind farm in Denmark, a country that gets more than 20% of its power from wind, provides an example of such advances in the technology.

The challenge facing the U.S. wind energy industry is to ensure that officials at the North American Electric Reliability Council (NERC) and regional and state counterparts, backed by effective enforcement by the Federal Energy Regulatory Commission (FERC), not only recognize wind's technological capabilities, but also work with the wind energy industry to establish fair, non-exclusionary reliability standards.

World Market Expands Steadily

Global wind power generating capacity increased by over 8,000 MW in 2003, a 26% increase, with most of the market growth occurring in Europe. The near-record year in the U.S. offset a slight decline in new installations in the massive German market. Spain added the most wind power (1,377 MW) after Germany (2,645 MW) and the U.S. (1,687 MW). The world's total wind power generating capacity was over 39,000 MW at the end of 2003—up from just over 31,000 MW a year before. In 2002, some 6,868 MW of new capacity were installed worldwide.

European installations grew by 5,467 MW in 2003, according to the European Wind Energy Association (EWEA), bringing total capacity in the European region to 28,706 MW. Europe– and within Europe, Germany, Spain, and Denmark– remains the world's largest wind power market.

American Wind Energy Association

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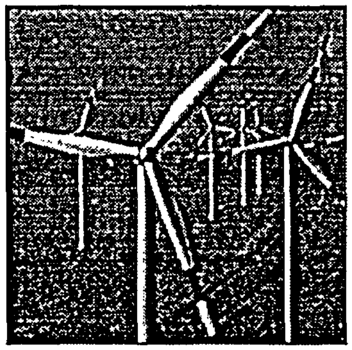

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Wind Energy for Electric Power

A REPP Issue Brief

By Ari Reeves
With Fredric Beck, Executive Editor

July, 2003
(updated November 2003)

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FORWARD

This paper presents a general background on utility-scale wind power, providing the interested reader with a basis for understanding wind power in general, as well as providing a solid foundation for further understanding of the technical, economic, and policy dimensions of wind power development world wide. The concepts in this paper are illustrated with economic data and current policy from the U.S. wind sector. The paper provides extensive references and links to well-established bodies of knowledge on wind power in written form and on the Web, enabling the reader to become aware of and conversant in the latest developments in wind power for clean energy generation.

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INTRODUCTION

Overview

Over 15,000 billion kWh of electricity are generated annually worldwide. Of this, about 65% is produced by burning fossil fuels and the remainder is obtained from other sources, including nuclear, hydropower, geothermal, biomass, solar and wind energy.[1] Only about 0.3% of this power is produced by converting the kinetic energy in the wind into electrical energy.[2] However, the use of wind for electricity generation has been expanding rapidly in recent years, due largely to technological improvements, industry maturation and an increasing concern with the emissions associated with burning fossil fuels. There is still more room to grow, as only a small portion of the useable wind resource is being tapped. Government and electrical industry regulations, as well as government incentives, play a large role in determining how quickly wind power is adopted. Effective policies will help level the playing field and ensure that wind can compete fairly with other fuel sources in the electricity market.

This paper focuses on utility-scale electricity generation from wind and provides an overview of the history, technologies, economics, environmental impacts, regulations and policies related to this use of wind power. References to other sources of information are provided throughout and in a separate section at the end.

Benefits of Wind Power

Wind power has many benefits that make it an attractive source of power for both utility-scale and small, distributed power generation applications. The beneficial characteristics of wind power include:

- *Clean and inexhaustible fuel*—Wind power produces no emissions and is not depleted over time. A single one megawatt (1 MW) wind turbine running for one year can displace over 1,500 tons of carbon dioxide, 6.5 tons of sulfur dioxide, 3.2 tons of nitrogen oxides, and 60 pounds of mercury (based on the U.S. average utility generation fuel mix).[3]
- *Local economic development*—Wind plants can provide a steady flow of income to landowners who lease their land for wind development, while increasing property tax revenues for local communities.
- *Modular and scalable technology*—Wind applications can take many forms, including large wind farms, distributed generation, and single end-use systems. Utilities can use wind resources strategically to help reduce load forecasting risks and stranded costs.
- *Energy price stability*—By further diversifying the energy mix, wind energy reduces dependence on conventional fuels that are subject to price and supply volatility.
- *Reduced reliance on imported fuels*—Wind energy expenditures are not used to obtain fuels from abroad, keeping funds closer to home, and lessening dependence on foreign governments that supply these fuels.

RESOURCES & TECHNOLOGY

This section explains where wind comes from and how it is harnessed to produce electricity. Because wind power technology has been treated extensively elsewhere, this paper does not go into great technical detail. For detailed technical information see, for example, the web sites of the Danish Wind Industry Association (www.windpower.org) and the U.S. Department of Energy's National Wind Technology Center (www.nrel.gov/wind), as well as the Wind Energy Technical Information page of the American Wind Energy Association's web site (www.awea.org/faq).

Source of Wind Energy

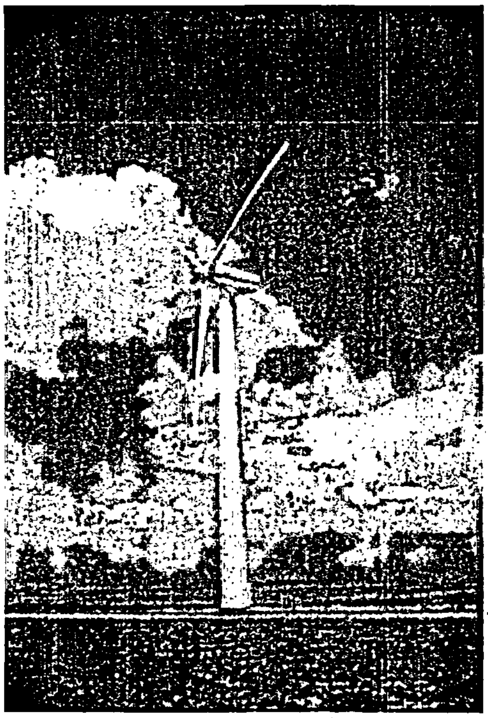
Wind energy, like most terrestrial energy sources, comes from solar energy. Solar radiation emitted by the sun travels through space and strikes the Earth, causing regions of unequal heating over land masses and oceans. This unequal heating produces regions of high and low pressure, creating pressure gradients between these regions. The second law of thermodynamics requires that these gradients be minimized–nature seeks the lowest energy state in order to maximize entropy. This is accomplished by the movement of air from regions of high pressure to regions of low pressure, what we know as wind. Large-scale winds are caused by the fact that the earth's surface is heated to a greater degree at the equator than at the poles.

Prevailing winds combine with local factors, such as the presence of hills, mountains, trees, buildings and bodies of water, to determine the particular characteristics of the wind in a specific location. Because air has mass, moving air in the form of wind carries with it kinetic energy. A wind turbine converts this kinetic energy into electricity. The energy content of a particular volume of wind is proportional to the square of its velocity. Thus, a doubling of the speed with which this volume of air passes through a wind turbine will result in roughly a fourfold increase in power that can be extracted from this air. In addition, this doubling of wind speed will allow twice the volume of air to pass through the turbine in a given amount of time, resulting in an eightfold increase in power generated. This means that only a slight increase in wind velocity can yield significant gains in power production.

$E_k = \frac{1}{2} \cdot m \cdot v^2$	$P \sim v^3$
The amount of kinetic energy in an air mass (E_k) is equal to half the product of its mass (m) and the square of its velocity (v).	The amount of power (P) exerted by the wind is proportional to the cube of its velocity (v).

Wind Turbines and Wind Parks

A wind turbine is a mechanical assembly that converts the energy of wind into electricity. The three key elements of any wind turbine are the rotor, the nacelle—which contains the gearbox, the generator and control and monitoring equipment (see Figure 1)—and the tower. Modern utility-scale wind turbines typically are equipped with three-bladed rotors ranging from 42 to 80 meters (138 to 262 feet) in diameter, contain generators with rated capacity of between 600 kW and 2 MW, and are mounted on towers that are between 40



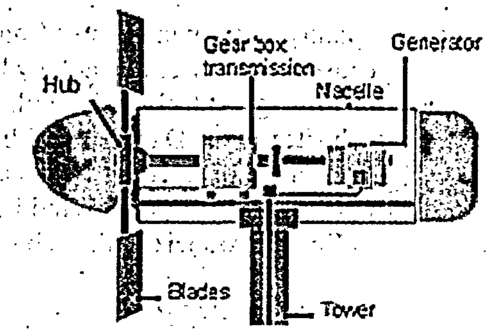


Figure 1. Above: Nacelle Components. Source: Sustainable Energy Development Authority, NSW, Australia (http://www.seda.nsw.gov.au/ren_wind_body.asp)

Figure 2. Left: A 600 kW Vestas American Wind Technology, Inc. turbine at Medicine Bow, Wyoming. Source: DOE/NREL (http://www.nrel.gov/data/pix)

and 100 meters (131 and 328 feet) tall (see Figure 2).[4] A utility-scale wind installation, called a wind farm or wind park, consists of a collection of these turbines.

Siting Considerations

Accurate estimates of wind speed are critical to assessing the wind power potential at any location. Wind resources are characterized by wind power density classes, which range from Class 1 (the lowest) to Class 7 (the highest). The U.S. Department of Energy has developed a map that identifies areas with good wind potential in the U.S. (see http://rredc.nrel.gov/wind/pubs/atlas/). These areas (class 3 and above) are found along the East Coast, the Appalachian Mountain chain, the Great Plains, the Pacific Northwest and in some other locations. In total, they cover more than 1 million square kilometers, or about 14% of the land area of the 48 contiguous states. However, estimates suggest that wind power generation on only 43,000 square kilometers of land—with less than 5% of this actually occupied by turbines, electrical equipment and access roads—could supply about 560 billion kWh of electricity annually, equivalent to about 15% of total U.S. demand.[5]

The roughness of the surface across which the wind blows before arriving at a turbine determines the amount of turbulence that a turbine will experience. Turbulent winds put greater stresses on the rotor and tower, reducing the turbine's lifespan as a result. Thus, the vast majority of wind farms are in rural locations, away from wind-disrupting buildings, trees and other obstacles.

While the technical characteristics of the wind in a specific location are very important, many other factors also contribute to siting decisions. A location far removed from the power transmission grid might be uneconomic, as new transmission lines will be required to connect the wind farm to the grid. Existing transmission infrastructure may need to be upgraded to handle the additional supply. Soil conditions and the terrain must be suitable for the construction of the towers' foundations. Finally, the choice of a location may be limited by land use regulations and the ability to obtain the required permits from local, regional and national authorities.

Tower Height

Tower height affects the amount of power that can be extracted by a given wind turbine, as well as the stresses on the rotor and nacelle. One kilometer above the ground, wind speeds are not influenced by the terrain below. The wind moves more slowly at lower heights, with the greatest reduction in wind speed found very close to the ground. This phenomenon, known as wind shear, is the key factor when deciding on tower height, as higher rotors are exposed to faster winds. In addition, the difference in wind speeds between the top and bottom of the rotor decreases with height, causing less wear on the turbine.

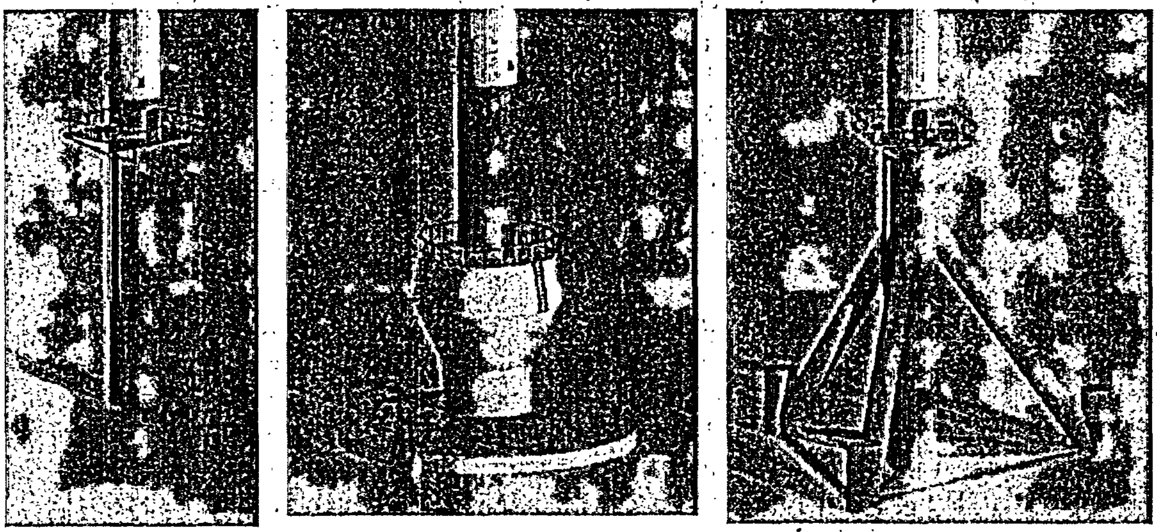
Offshore Wind Resources

Average wind speeds over water are typically 20% higher than nearby locations on land. Thus, due to the cubic relationship between velocity and power, an offshore turbine can expect to capture 50% more wind energy than a similar onshore turbine. In addition, because of the lower wind shear at a given height above water compared to that same height above land, offshore turbines can be built with shorter towers and can last longer (see discussion of wind shear above).[6]

Several foundation types are currently in use (see Figure 3). The mono pile foundation—used in more than half of existing offshore wind farms[7]—consists of a single steel pile driven or drilled into the seabed. The gravitation foundation consists of a steel box sitting on the seabed that supports a cylindrical tube. The tripod foundation consists of three smaller piles connected by a frame to a central pile.[8] Regardless of foundation type, the wind turbine's platform and tower sit atop the foundation, above the water.

Due to technical and economic limitations, offshore wind farms are currently limited to relatively shallow waters. In the future, wind turbines could be mounted on floating platforms, tethered to the sea floor. These turbines could be situated in deeper waters where they would be invisible from land and could take advantage of even stronger open-ocean winds. Instead of feeding electricity into the grid, they could be used to produce hydrogen that would then be shipped or piped to shore. Preliminary feasibility studies suggest that facilities of this type could be built; however, further research is needed before such a wind farm can become a reality.[9]

Figure 3: Foundation Types for Offshore Wind: Monopile, Gravitation and Tripod



Source: Offshore Wind Energy (http://www.offshorewindenergy.org)

HISTORY

First Steps

Harnessing the wind for large-scale electric power generation is a relatively recent development. Wind had been used for hundreds of years to power sailing vessels and to drive windmills, but it wasn't until the late 19th century that the first wind turbine for electricity generation came into use. This windmill was built by Charles Brush (inventor of several technologies key to the then nascent electrical industry), stood 17 meters (50 feet) tall and had 144 rotor blades, all made of cedar wood. Soon thereafter Poul la Cour, a Dane, discovered that fast rotating wind turbines with fewer rotor blades generated electricity more efficiently than slow moving wind turbines with many rotor blades.[10]

20th Century Advances

This opened the door to a number of wind turbine advances during the 20th century. These included the introduction of AC generators, the standardization of the upwind model (in which the rotor is upwind of the nacelle), electromechanical yawing to ensure that the rotor always faces directly into the wind, and stall controls to keep the rotor from turning too fast in very strong winds.[11] Modern wind turbines make use of very few but very large blades to capture winds energy. Because these are large machines, they rotate relatively slowly, but generate large amounts of power while doing so.

The oil crisis of 1973 boosted interest in large wind turbines and sparked several government-sponsored research programs in Germany, Sweden, Canada, the U.K. and the U.S. Because of these efforts, the cost of wind power on a per-kWh basis was cut in half in less than a decade. Today's wind turbines generate power more cost-effectively than ever before, with the busbar cost dropping from 38 cents per kWh in the early 1980's to between two and six cents today, depending on location.[12] Wind power approaches competitiveness with conventional generation at this price point.

Wind Power Today

Wind power is the world's fastest growing source of electricity. Generating capacity grew at an average annual rate of 25% between 1990 and 2000, exceeding less than 2% annual growth in each of nuclear, oil and natural gas, and an average annual decline of 1% in coal consumption over this period.[13] As of the end of 2002 total global wind generating capacity exceeds 31,000 MW, and provides about 65 billion kWh of electricity annually.[14] This is enough to meet the needs of over 6 million average American homes.[15] Generating capacity is mainly concentrated in just five countries; Germany (36%), the U.S. (18%), Spain (14%), Denmark (10%) and India (6%) together account for 84% of the total (see Figure 4).[16]

As of the end of 2002, generating capacity in the U.S. was highly concentrated in just two states, California and Texas, which together accounted for about two thirds of the national total of 4,660 MW (see Figure 5).[17]

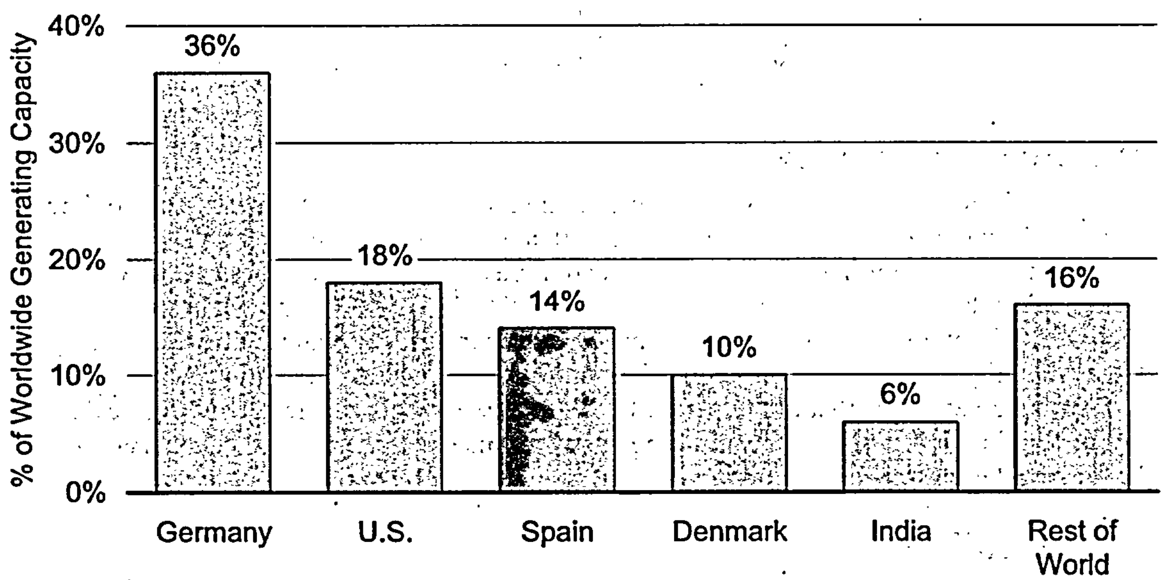
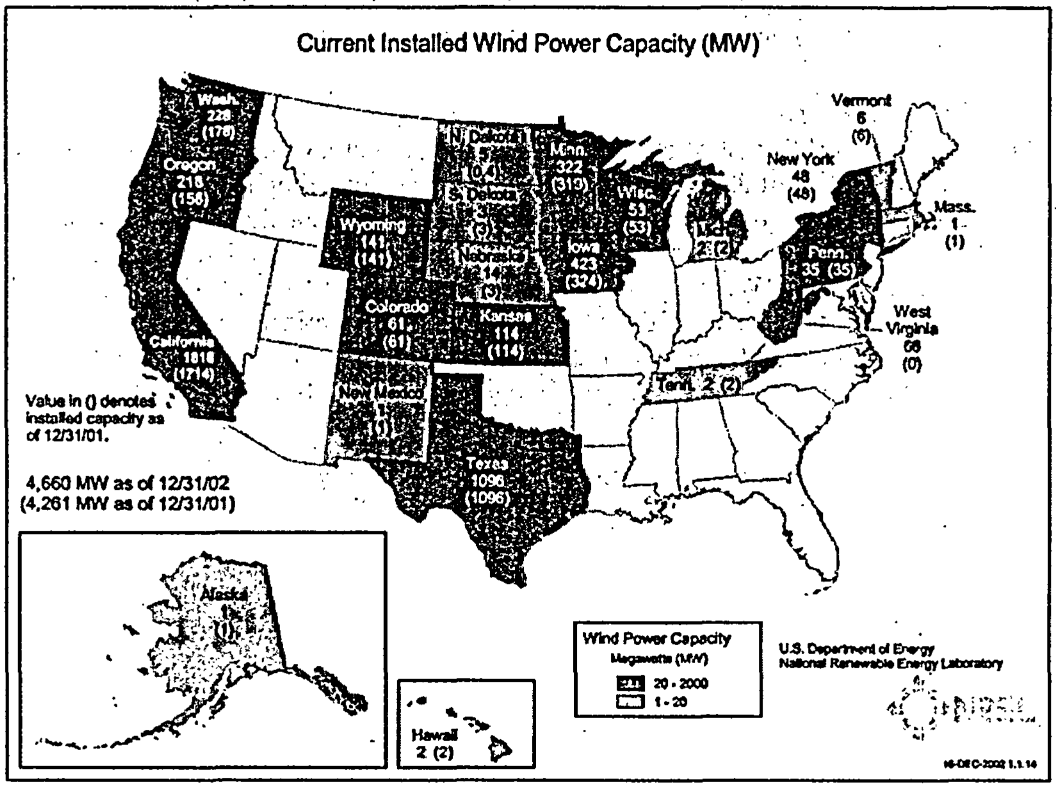


Figure 4. Distribution of Wind Power Generating Capacity Worldwide, 2001
Source: AWEA Global Wind Energy Market Report, March 2002

Figure 5. Wind Generating Capacity in the United States, 2001 and 2002



Source: U.S. Dept. of Energy, National Renewable Energy Laboratory (NREL)

History of Offshore Wind

The first offshore wind park, a five MW installation near Vindeby, Denmark, came online in 1991.[18] By the end of 2002, there were ten offshore wind farms in operation worldwide—all in Northern Europe—with a combined generating capacity of 250 MW. This represents a compound annual growth rate of 43%.[19] This development has been fueled largely by the presence of good wind resources in the North and Baltic Seas and by the availability of ever larger, more efficient turbines with which to tap this resource. "Mega" turbines, those that can generate 1 MW of power or greater, reached large-scale production in 1998, and today "multi-megawatt" turbines with capacities of 2.5 MW are being installed in some locations.[20]

ECONOMICS

Overview

While wind is a free resource, the systems used to capture the energy in the wind and convert it into electricity are not. Wind power production requires large capital outlays up-front, but does not incur fuel costs over the life of the plant. Wind producers also incur significant costs due to transmission infrastructure and regulatory frameworks that have been developed to suit the special characteristics of the fuels from which electricity has traditionally been produced—such as coal, nuclear and hydropower—but not wind. The many benefits of wind power accrue to producers, utilities and society. Benefits to utilities are discussed later in this section; benefits to society are discussed in the Environmental Impacts section below. Governments can help to spur wind development by revising regulations and providing financial incentives to wind power producers.

Cost Measures

The installed capital cost of a wind farm includes planning, equipment purchase and construction of the facilities. This cost, typically measured in $/kW, has decreased from more than $2,500/kW in the early 1980's to less than $1,000/kW for wind farms in the U.S. This decrease is due primarily to improvements in wind turbine technology, but also to the general increase in wind farm sizes. Larger wind farms benefit from economies of scale in all phases of a wind project from planning to decommissioning, as fixed costs can be spread over a larger total generating capacity.

Capital costs, which include the purchase of the turbine itself, construction of access roads and foundations, connecting to the grid and installation, account for about 70% of the total cost of energy. This is in contrast to fossil fuel-powered generation, which typically has lower up-front capital costs, but incurs fuel costs over the life of the system. Capital costs are now typically less than $1000 per kW of generating capacity for large wind farms.

Maintenance costs account for about 20% of the total cost of energy. Much of this is for unscheduled, but statistically predictable, maintenance. These costs increase steadily with increased wear and tear on the turbines. Since the amount of wear and tear is roughly proportional to the amount of power produced, maintenance costs are roughly proportional to energy production. A reasonable rule of thumb for large wind farms is $0.005/kWh.[21]

Property taxes, land use, insurance, transmission/wheeling, substation maintenance, and general & administrative costs together account for the remaining 10% of the total cost of energy.[22]

Levelized Cost

The levelized cost of energy, commonly expressed in cents/kWh, is the annual cost of recovering the total capital costs plus the recurring costs such as operations and maintenance and royalty payments divided by annual expected output. Table 1 (below) shows levelized costs for a 500 kW turbine, representative of a small-sized turbine for utility-scale applications.

Utility-scale wind farms in the U.S. produce wind power at a levelized cost of approximately two to six cents per kWh.[23] Cost varies due to differences in scale, quality of wind resource, and cost of financing. Cost of energy is the best of the three cost measures described here by which to compare the cost of wind power with the cost of electricity from other sources. However, while the cost of energy of a particular wind project is relatively straightforward, the comparison of the cost of wind generation to other types of generation is often controversial.

Table 1. Typical Levelized Cost of Energy for a Single 500 kW Turbine ($1997)

Cost of Energy Component	*Value (cents/kWh)*	*Percent of Total Cost of Energy*
Capital cost	3.08	70%
Unscheduled maintenance	0.68	16%
Preventive maintenance	0.18	4.1%
Major overhaul	0.04	0.92%
Other operating costs	0.39	8.9%
Total cost of Energy	4.37	**100%**

Source: National Wind Coordinating Committee[24]

Wind and natural gas generation were compared head-to-head in a 1999 decision by the State of Colorado Public Utility Commission (PUC) on choice of generation contracts to meet new load in the area served by Xcel Energy. Xcel had initially rejected wind contracts for 162 MW in favor of natural gas, based on assumptions of low natural gas costs, low capacity value for wind, and high wind ancillary service costs. However, after careful economic analysis the Colorado PUC found that wind "is justified on purely economic grounds, without weighing other benefits of wind generation that could be considered under the Integrated Resource Planning (IRP) rules."[25]

Specifically, the Colorado PUC found three important results to support the decision that the wind power bid was cost effective:

- New wind generation on Xcel's system is predicted to cost less than new gas-fired generation, assuming that gas costs are more than $3.50 per million cubic feet (mcf)
- For the 162 MW project, wind power receives a fair capacity value of 49 MW.
- Ancillary services to back up new wind power are not a major cost.

Variability and Grid Integration

Just as wind resources vary over time, demand for electricity fluctuates seasonally and over the course of the day. Utilities can, to a certain degree, predict peaks and troughs in demand and, since electricity is difficult to store, must arrange to secure just the right amount of power from generators at all times. Generally, this is done by having some plants run continuously at relatively constant output levels to meet what is called base load demand. These include primarily coal-fired, natural gas combined-cycle, hydropower and nuclear plants. Peaks in demand are satisfied by plants that can be more quickly turned on and off, such as natural-gas-fired simple-cycle plants.

Wind power is used when available to offset use of conventional fuels, which provides diversity in a utilities energy generation portfolio and a hedge against the impacts of natural gas price volatility. When and where wind resource peaks coincide with demand peaks, utilities benefit if they can use wind power to offset more expensive natural gas peak generation.

There has been criticism that the cost of integrating wind power into utility grids may be excessive due to the variable nature of the wind resource. However, according to the American Wind Energy Association (AWEA), costs are low at low levels of wind penetration in the grid. AWEA states that the technical limits of integration are reached when wind is providing about 40% or more of the total electricity on an annual basis. The economic costs of adding wind at low penetration levels are less than 0.2 cents/kWh, and at medium levels less than 0.2-0.5 cents/kWh. What is low and medium varies by application.[26]

Capacity Credit

The unresolved issue in cost comparisons between generating types is this: How should the cost of wind generated electricity be compared to coal and natural gas if wind is intermittent and the other resources are firm.

Electricity usage is measured in two ways: maximum usage at a point in time and total usage over time. Since electricity cannot be easily stored, utilities can only provide reliable service if they can serve both the maximum demand and the total usage likely to be placed on a system. They must, in addition, provide reserves to cover the unexpected outage of the largest units in the system plus unexpected outages affecting all units in a 10 even 20 year probability. For most systems reserves are 15% to 20% of expected peak demand.

The costs related to providing reliable service break down in the same two dimensions: capacity cost is the cost of meeting peak demand and energy cost is the cost of providing a KWh usage. Wind is an intermittent resource. Given good historical weather records we can say with some certainty what the expected annual output will be from a wind project. We cannot say with the same certainty what wind production will be at the time of peak demand. As the Colorado decision showed, it is clear that wind generation should receive some credit for providing capacity.

It is beyond the scope of this paper to do any more than note this debate and caution that comparisons between different generating sources are for total bus bar costs. The determination of the capacity credit for wind generation will be determined in regulatory proceedings.

Benefits to Utilities

The addition of wind power generation to the mix can provide economic benefit to power utilities.[27] Wind power can:

1. Help hedge against the volatile prices and uncertain availability of fossil fuels, as well as the uncertainty inherent in hydropower generation (due to variations in rainfall).
2. Be added incrementally, thus reducing the risk of incurring stranded costs due to excess capacity.
3. Provide generation capacity in geographic areas that are underserved by existing generation capacity. This can help to maintain proper voltage and current levels throughout the grid and reduce the need for upgrades to the transmission grid.

4. Help utilities to meet government-mandated Renewable Portfolio Standards (RPS).[28]
5. Serve as a hedge against future environmental regulations. In the past utilities could easily pass on to their customers any increased costs that they incurred due to the imposition of more stringent environmental regulations. This is not necessarily the case in today's competitive markets, where reducing exposure to regulatory risk may increase competitive advantage.
6. Provide an attractive product to customers who are seeking "green" power.

Economics of Offshore Wind

Two key factors differentiate offshore wind economics from those of onshore wind. The presence of stronger, less turbulent winds increases the revenue potential, while the location at sea increases construction and maintenance costs. These two factors tend to balance one another, resulting in a total cost of energy from offshore sites similar to that found at onshore sites.[29]

Capital costs at offshore sites are between 30 and 70% greater than at onshore sites, according to a British Wind Energy Association report published in 2000.[30] This is driven primarily by the high cost of building marine foundations, procuring installation equipment, and running submarine cables to carry the electricity to shore. However, these costs have decreased substantially in recent years, particularly because of improvements in foundation technology.[31] Operation and maintenance costs are also considerably higher because ships are needed to bring personnel and equipment to the turbines and a turbine may be inaccessible when the seas are rough.

As mentioned, these additional costs are balanced by the increased energy production possible at sea. In addition, because of the reduced wind shear encountered over water, offshore wind farms are being designed to last for 50 years, rather than the more common 20-25 year lifespan found on land. With a major refurbishment after 25 years, the greater investment required for an offshore wind park can be amortized over roughly twice as many years as a similar onshore park.

High energy prices, proximity to major population centers, and the presence of excellent wind resources in the North and Baltic Seas have fueled the development of offshore wind farms in Northern Europe. In contrast, the first offshore wind farms in the U.S. are still in the planning stages. Lower energy prices and the availability of good wind resources inland have delayed the development of offshore wind there. However, more than half of U.S. residents live in coastal counties[32], so offshore wind farms in these areas could avoid the higher transmission costs faced by wind farms in remote locations. In addition, several states in the densely populated Northeast, including New Jersey, Connecticut and Massachusetts, have established Renewable Portfolio Standards (RPS)[33], and wind may be one of the least-cost options available to meet these requirements.

ENVIRONMENTAL IMPACTS

Environmental Benefits

The environmental benefits of wind power are felt locally, regionally and globally. Wind power can displace power from fossil fuel-powered plants, and thereby help to improve local air quality, mitigate regional effects such as acid rain, and reduce greenhouse gas emissions. On average, each MWh of electricity generated in the U.S. results in the emission of 1,341 pounds of carbon dioxide (CO_2), 7.5 pounds of sulfur dioxide (SO_2) and 3.55 pounds of nitrogen oxides (NO_x).[34] Thus the 10 million MWh of electricity generated annually by U.S. wind farms represents about 6.7 million tons in avoided CO_2 emissions, 37,500 tons of SO_2 and 17,750 tons of NO_x.[35] This avoided CO_2 equals over 1.8 million tons of carbon, enough to fill 180 trains, each 100 cars long, with each car holding 100 tons of carbon every year.[36] Note that these figures are national averages and do not account for regional differences in fuel mix. Wind has the potential to displace relatively more emissions in areas where more heavily polluting fuels predominate.

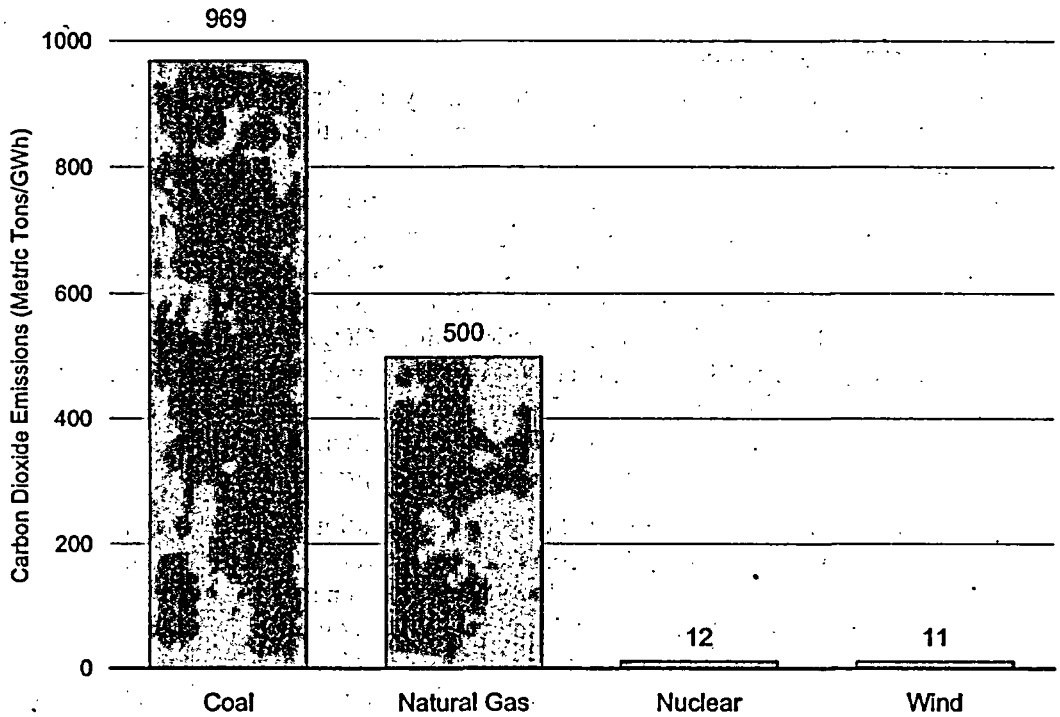
Power plants emit pollutants as a by-product of power generation, but also may account for further emissions in connection with plant construction, operation, and decommissioning. For example, the mining and transport of fuel are themselves energy-intensive activities, with associated emissions and environmental impacts. Wind compares favorably to traditional power generation on this metric as well: lifecycle CO_2 emissions per unit of power produced by a wind farm are about 1% of that for coal plants and about 2% of that for natural gas facilities (see Figure 7).[37]

Wind power is also comparatively energy efficient. The Energy Payback Ratio, a comprehensive measure of energy efficiency, is calculated by dividing the total amount of energy produced by a plant by the total energy consumed by the plant. One recent study calculated an Energy Payback Ratio of 23 for wind, 16 for nuclear, 11 for coal and 5 for natural gas.[38] This means that for each unit of energy put into building, maintaining and decommissioning a wind plant, for example, 23 units of electrical energy are obtained, on average.

Traditional power generation makes use of large amounts of water for the cooling of condensers and reactors and in mining processes. Overall, the power sector returns about 98% of the water it uses back to the source. However, much of this water is returned to lakes or streams containing heavy metals (from mining) or at significantly higher temperatures, causing damage to local ecosystems. In contrast, wind power makes use of small amounts of water, primarily for cleaning rotor blades.[39]

When a wind development is located on farm or range lands, the landowner typically receives royalties from the wind farm developer. One large wind turbine, occupying just a quarter acre of land, can provide approximately \$2000 to \$4500 in royalties annually. This income effectively increases the land's economic value and can provide the farmer with a hedge against crop price fluctuations. And the land can be used concurrently for both "wind farming" and conventional farming and ranching, since the wind turbines themselves occupy only about 5 to 15% of the land area encompassed by the wind farm.[40]

Figure 7. Life Cycle Carbon Dioxide Emissions, by Fuel



Sources: "Life Cycle Energy Cost of Wind and Gas-Turbine Power" by White, Radcliffe and Kulcinski, University of Wisconsin, 1999 (http://fti.neep.wisc.edu/FTI/POSTERS/sww_energy_ctr.pdf) and CA-OWEE, Final Report, Dec 2001, p7-1 (http://owe.starforze.net/ca-owee/indexpages/downloads/CA-OWEE_Complete.pdf)

As a result, wind developments can help expand rural tax bases and in some cases stave off urban development.[41]

These and other factors contribute to the positive environmental profile of wind power. A more detailed comparison of the environmental impacts of various power generation technologies is available in "The Environmental Imperative for Renewable Energy: An Update" by Adam Serchuk for Renewable Energy Policy Project, April 2000 (http://www.repp.org/repp_pubs/articles/envImp/envImp.pdf).

Environmental Concerns

The primary environmental concerns with wind power are related to potential visual, auditory, locational and wildlife impacts of windfarm installations. However, these concerns can be addressed through proper siting, public education, and the use of improved technologies.

Some are concerned by the visual impact of wind farms. On land, wind turbines are located where the wind resource is best—typically in highly visible, exposed locations. Offshore wind parks, likewise, are usually situated within sight of the shore. In both cases, the vertical towers and the motion of the rotors cause the wind turbines to become focal points in the landscape for observers close to the wind towers.[42] Fortunately, newer, larger rotors rotate more slowly than their predecessors, and thus are less eye-catching. To further mitigate the visual impact of wind turbines they can be painted to match their surroundings—NATO standard gray for offshore sites, for example.

Some of the wind energy captured by wind turbines is unavoidably transformed into sound energy. Air moving by the rotors generates sound, though improvements in rotor technology have greatly diminished the amount of sound produced in this way. Some sound may also emanate from the gearbox and generator, though sound absorbing materials are used to mitigate this. The apparent noise level of a typical wind farm at 350 meters distance varies between 35 and 45 dB(A). This is similar to the noise level in the reading room of a library. Keep in mind that a wind turbine produces no sound when it is not producing electricity, that is, below the "cut-in" speed. Above this speed, the amount of sound increases as the wind speed increases. Thus, wind farm noise will be partly masked by ambient noise, such as that from the wind rustling leaves or grasses. The sound also tends to be spread out across many frequencies, like white noise, further contributing to its unobtrusiveness. With proper considerations for sound propagation, wind turbines can be sited to have negligible noise impacts.[43]

Surveys indicate widespread public support for wind energy in countries where wind development has already taken place. However, proposed wind farms do sometimes encounter local opposition, especially in more densely populated areas. The above-mentioned issues—visual impact and sound—are the most commonly voiced concerns. This pattern of local opposition, known as NIMBY (Not In My Backyard), arises in response to many other forms of new development as well, including buildings, highways, airports, tunnels and other types of power plants. Research suggests that where the local population is educated on the benefits of wind power and is involved in the planning process, involved opposition is less.[44]

Concern arose when studies in the early 1990's documented the death of raptors from collisions with wind turbines in Altamont Pass, California. It was discovered that these turbines had been sited in the middle of prime raptor habitat. Extensive studies performed subsequently at sites around the U.S. measured only one or two bird deaths per turbine per year.[45] This is a small number, when contrasted with the estimated four to ten million birds that die each year in the U.S. from nighttime collisions with lighted telecommunications towers and the several hundred million more that die each year because of other human activities.[46] In addition, birds can see (and avoid) the newer, larger, more slowly rotating rotors more easily. Nevertheless, wind farms, and even individual turbines, should be carefully sited to avoid undue harm to birds.

Environmental Impacts at Sea

Developers of offshore wind farms must consider the potential impacts of the construction and operation of the wind turbines on sea life, including mammals, fish, plants and birds. The exact nature of these impacts will vary widely from site to site, due to the varied conditions found at sites around the world. Experience to date gives no strong indications of severe environmental impacts, though research on this subject is still sparse. For an excellent review of current knowledge regarding the environmental impacts of offshore wind farms, see chapter 7 of the final report of Concerted Action on Offshore Wind Energy in Europe, Dec. 2001.[47]

REGULATORY ISSUES

From permitting to transmission, government and industry regulations determine the rules for the electricity marketplace. These rules create the framework within which electricity is traded between generators, utilities and end-customers. They influence whether, where and what type of new plants are built. In some cases, these rules have been slow to change, giving unfair advantage to the traditional power generators that were in place when the rules were established, and unfairly penalizing newer forms of generation such as wind. These regulations, as well as government incentives (discussed in the next section), play a large role in determining how quickly wind power is adopted. Effective policies will help level the playing field and ensure that wind can compete fairly with other fuel sources in the electricity market.

Permitting Issues

An important part of any wind development project is securing the permits necessary to build and operate the proposed wind farm. Developers may be required to obtain permits from multiple jurisdictions, including local municipalities and counties, state agencies and the federal government. They must consider many factors, including soil erosion, air and water quality, birds and other wildlife, the view shed, public health and safety and the presence of archaeological resources. This permitting process may take from several months to several years to complete.[48] The vast majority of large wind projects subject to the National Environmental Protection Act (NEPA) have required only a *Finding of No Significant Impact*, and not a full-blown Environmental Impact Statement (EIS).

Offshore wind facilities in the U.S. face a similar permitting process, but it is less well defined and more uncertain, since no such facility has yet been approved. Individual states have authority over waters within three miles of their shores, and the federal government controls waters up to 200 miles out. Thus, projects situated in federal waters must obtain the approval of the Army Corps of Engineers, the lead regulatory agency for offshore wind projects in federal waters. They must also obtain approval from the appropriate state agencies for the cabling that will link the wind farm with the grid.[49] The U.S. Coast Guard must confirm that the wind turbines will not interfere with established shipping lanes and the U.S. Department of Interior (U.S. Fish and Wildlife Service) is involved with determining possible effects on fisheries.

The U.S. Department of Interior currently oversees all oil and natural gas exploration and commercial drilling operations in the Outer Continental Shelf. As of 2002, proposed legislation would put offshore wind farms under their authority as well, and would provide a transparent and uniform permitting process for offshore energy projects.[50]

Transmission Issues

Wind producers face significant challenges due to transmission infrastructure and related regulatory frameworks that have been developed to suit the special characteristics of traditional electricity production—coal, nuclear and hydropower—and not wind. Three characteristics of wind put it at a particular disadvantage vis-à-vis traditional generation sources: (1) it is supplied intermittently, (2) the best wind resources are often located far from where the electricity is needed, and (3) wind is a relatively new entrant to the electricity generation market.

As mentioned earlier, electric utilities must match supply with demand throughout the day. In order to ensure a reliable and predictable supply of power, they contract with power generators to provide pre-determined amounts of power according to fixed schedules. Regulatory penalties for deviation from these schedules are significant—anywhere from two to ten cents per kWh.[51] This system is predicated on the assumption that power plant operators can guarantee a certain output at some future time. However, this assumption is not valid for wind power plants, except in the case of short-term—hour-ahead or 10-minute-ahead—forecasts, which are reasonably accurate. The ability to perform these near-term forecasts makes it possible for wind to participate in real-time balancing markets, which can help address reliability concerns.

Most electricity demand is in urban areas. To reduce transmission costs, fossil and nuclear fuel-powered plants are typically situated close to urban areas and their fuels are transported to them. In contrast, good wind resources are often found far from urban areas, and cannot be transported. Electricity produced by wind plants located in these remote areas must be transmitted great distances to its users. In some cases, wind developers are required to pay for the additional transmission infrastructure required, thereby reducing the economic feasibility of proposed wind projects. Some utilities charge generators on a per-mile basis, resulting in wind generators having to shoulder a disproportionate share of transmission costs. In other cases, a wind plant may have to pay a separate fee for each of several transmission systems through which the power it generates passes on its way to the distant consumers. This is known as "rate pancaking" in the utility literature. Another common practice is to levy a transmission charge on generators based upon their *peak output* during a given period. Revenues, however, are more closely related to *average output*. This practice is reasonable when there is little difference between peak and average output levels, but unfairly penalizes wind plants, which often experience a large difference between peak and average output levels.

Wind's status as a relatively new entrant to the electricity market also puts it at a disadvantage when competing for scarce transmission capacity. When the demand for a transmission path exceeds its reliable capacity, utilities react by limiting generation. Historically, they have allocated transmission capacity to those generators that have been in the market longest. When newer market entrants have been allowed to bid for constrained capacity, wind producers have been frustrated by their inability to accurately predict how much capacity they will need at a given hour on a given day in the future.

Impact of Emissions Regulations

Stricter emission regulations can improve wind power's competitiveness by forcing fossil fuel-fired generating plants to internalize costs associated with their plants' emissions. In the U.S., the Clean Air Act of 1970/1977 is the Federal law that regulates air emissions from power plants. It was amended in 1990 to improve on existing, and introduce new, programs to address acid rain, smog and other environmental problems.[52] These programs, by introducing pollution caps or providing disincentives to pollute, affect the mix of fuel sources used to generate electricity in the U.S.

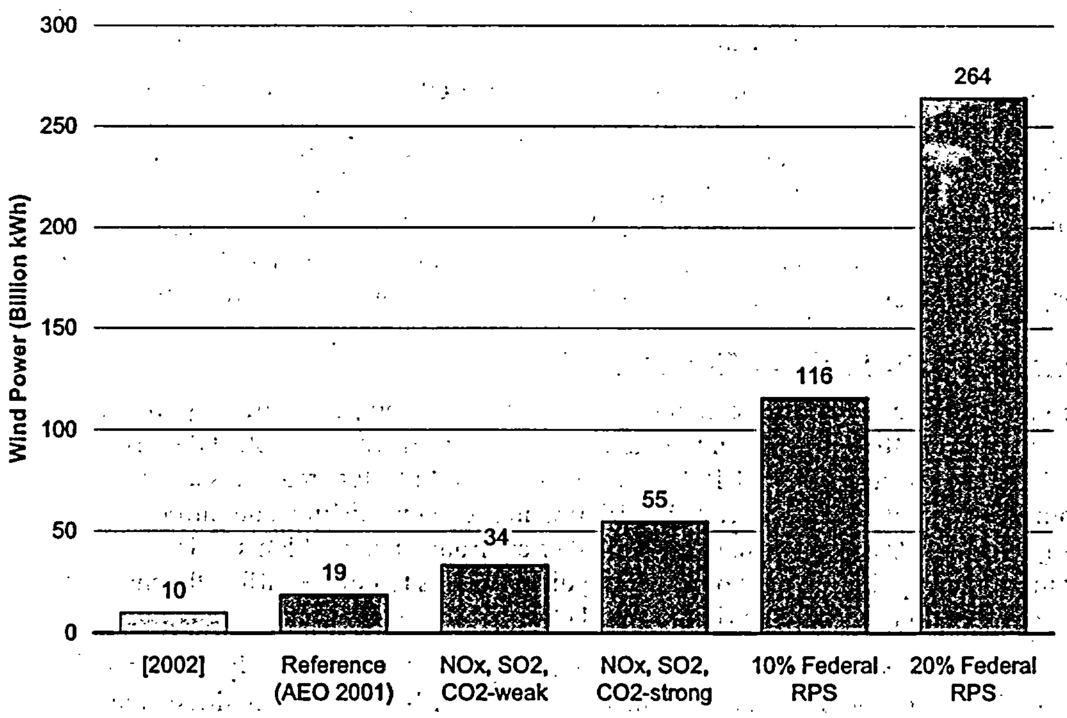
For example, U.S. EPA has set NO_x emissions caps for the most heavily polluting states. These states must devise State Implementation Plans (SIP) for meeting these goals, and these plans may include the use of energy efficiency and renewable energy offsets. Thus, in some states wind power can play an important role in limiting NO_x emissions and meeting EPA's requirements.[53] Incentives for limiting emissions can also be pursued indirectly, for example, by offering Production Tax Credits to those who produce emissions-free electricity.

Proposed changes to policy can be evaluated for their expected effects on the amount of wind power generated in the future. The U.S. Energy Information Administration (EIA) performed just such an analysis in 2001, at the request of the U.S. House of Representatives. In their reference case scenario, which takes into account the laws and regulations that were in place as of the end of August 2000, annual wind power generation increases almost twofold from 10 billion kWh today to 19 billion kWh in 2020. If NO_x and SO_2 regulations are strengthened, they forecast 34 billion kWh in 2020; and if, instead, a 20% Federal Renewable Portfolio Standard (RPS) is implemented, annual wind power generation is projected to climb to over 260 billion kWh in 2020 (see Figure 8).[54]

PROMOTING RENEWABLES

While wind power is approaching direct competitiveness with conventional electricity generation, governmental policies and incentives play an important role in helping to level the playing field and give wind a chance to compete fairly. Well-written and enforced policy addressing the issues outlined below will help wind power reach its full potential.

Figure 8. Electricity Generation from Wind in the U.S. Under Various EIA Emissions Policy Scenarios, 2020



Source: EIA and AWEA[55]

Subsidies

Government subsidies in the electricity industry have helped newer fuel sources to compete with traditional fossil fuel-powered plants, which often can produce electricity at lower cost to the producer. They can do so principally because the human health and environmental costs are largely externalized and born by society, creating a subsidy of sorts to fossil fuel burners. Subsidies, both direct and indirect, can reduce the effective cost of electricity from renewable energy sources, and thus increase sales. Direct subsidies consist of actual agency expenditures, including funds for research, technology development and regulation. Indirect or "off-budget" subsidies typically take the form of tax credits, interest rate discounts and insurance. Subsidies for renewable energy have often been proportionally less than those for conventional generation. For example, from 1947 to 1999, the U.S. government provided approximately $150 billion in total subsidies to nuclear, solar and wind electricity production and technologies. Less than 1% of this went to wind, while nuclear and solar received roughly 96% and 3% of the total, respectively.[56]

Tax Incentives

The federal Production Tax Credit (PTC) is the most significant U.S. policy driving wind power production. Those producing electricity from wind, closed-loop biomass and poultry waste receive 1.5 cents (adjusted for inflation) for each kWh produced during the first ten years of a plant's operation.[57] The federal PTC has been instrumental in spurring the development of wind power since its adoption in 1992. It was renewed in 1999, but was allowed to expire on December 31, 2001, creating uncertainty regarding the prospects for wind power in the U.S. On March 8, 2002, Congress passed legislation to extend the PTC to December 31, 2003, but its long-term future is still uncertain.[58]

This uncertainty is causing wind developers to incur added costs as they rush to get new plants online before PTC expiration. Many power analysts believe that uncertainty about the future economic viability of wind power is also causing under-investment in wind energy. In fact, the U.S. Energy Information Administration projects that were the PTC extended to cover plants coming on-line by the end of 2006, wind power generating capacity nationwide could be expected to increase to 13,000 MW by 2020, compared to 9,000 MW without the extension.[59]

Some U.S. states also provide tax incentives to wind developers. These incentives include investment tax credits, production tax credits, and property and sales tax incentives. The state investment tax credits have been found to lessen the value of the federal PTC, due to "double-dipping" provisions in the latter. The effect of other state incentives on the effective value of the federal PTC to producers is unclear.[60]

Renewable Portfolio Standards

A Renewable Portfolio Standard (RPS) requires that a certain minimum percent of all electricity generation be from renewables. As of 2002, twelve U.S. States have an enforceable RPS in place and another three have established voluntary renewable energy goals or have enacted RPS-type legislation without enforcement provisions.[61] A notable example of wind development spurred by an RPS is found in Texas, where a well-designed RPS combined with the Federal PTC resulted in the construction of more than ten wind projects in the first year, with a combined generating capacity of 930 MW.[62] Provisions for a federal RPS were contained in bills before both houses of the U.S. Congress in 2002, but no action has been taken to date.[63] The 108th Congress is expected to consider energy legislation when it convenes in early 2003, though it is uncertain whether an RPS would be included in any such legislation.

Public Benefit Funds

Several U.S. states have established Public Benefit Funds (PBF) to fund renewable energy, energy efficiency and other energy programs.[64] Typically, a small per-kWh charge—called a System Benefit Charge (SBC)—is added to residents' electricity bills to raise the needed funds. Many PBFs make funds available to promote wind development. In Illinois, for example, wind projects greater than 10 MW in size are eligible to have up to 10% of project costs ($2.75 million maximum) paid for out of the PBF. Smaller projects can have an even larger share of their project costs paid.[65] The Connecticut PBF has provided funding for a statewide wind energy study; and the state of California, through its PBF, can assist with the development and maintenance of existing wind power plants.[66]

FUTURE TRENDS

Decreasing Costs, Increasing Supply

The market for wind power generation is rapidly expanding, due largely to decreasing technological costs and the institution of government incentives, especially in Europe and the U.S. Approximately 6500 MW of new generating capacity was installed around the world in 2001, about 2600 MW of which was in Germany and nearly 1700 MW of which was in the U.S. These additions increased total global generating capacity by 37% from the 17,500 MW that existed at the end of 2000.[67] The Danish consultancy BTM Consult expects growth to continue at an average annual rate of 16% through 2006, reaching a total capacity of about 75,000 MW at that time, though political, technical and economic developments may combine to either over- or under-shoot this estimate.[68]

Several individual countries have committed to producing some significant portion of their electricity from wind in the coming years. Germany's goal is to produce 25% of its power from wind by 2030.[69] Canada aims to have 10,000 MW of generating capacity online by 2010,[70] and analysts expect India to have a generating capacity of at least 6,000 MW by then. The World Energy Council estimates that wind power generating capacity worldwide may total as much as 474,000 MW by the year 2020, though again time will tell whether this goal is met.

In the U.S., the Department of Energy's *Wind Powering America* initiative calls for wind to meet 5% of the country's electricity demand by 2020. However, the U.S. DOE Energy Information Administration's Reference Case Forecast projects that wind will meet only one tenth of that, or 0.5% of demand, by 2020.[71] Clearly, significant changes to "business as usual", including regulatory reforms and well-designed incentives, will be needed to meet the goals set by the *Wind Powering America* initiative.

While 1 to 2.5 MW turbines are increasingly common, 3 to 5 MW turbines are being developed, and may become common in the future.[72] Technological developments may also improve the economics of placing turbines in lower-class wind regimes (areas with lower wind speeds), significantly increasing wind power production potential worldwide.

While capital and operating costs are likely to continue to decrease as the wind industry continues to gain experience, utility-scale wind power expansion will continue to be strongly influenced by the scope and effectiveness of regulatory policy, as well as implicit and explicit power-generation subsidy and incentive structures. Concern about global warming and governments' commitments to reduce greenhouse gas emissions will likely increase the demand for "green" power. Wind power is a proven technology and is poised to help meet this increased demand in many countries.

Future of Offshore Wind

Offshore wind power generating capacity is expected to expand significantly in the coming years, especially in Northern Europe. The European Wind Energy Association (EWEA) has set a target of 50,000 MW of offshore wind capacity by 2020, one third of the total wind goal for Europe. The U.K., with the largest wind energy potential of any country in Europe, has identified 13 potential sites that could collectively offer a capacity of more than 1,000 MW.[73] Germany plans to obtain most of its wind power from offshore installations, with 20,000 to 25,000 MW of capacity targeted for 2025.[74] An Irish company, Airtricity, plans to begin construction in early 2003 of a 520 MW, 200-turbine wind farm in the Arklow Bank area of the Irish Sea.[75]

While Northern Europe enjoys substantial wind resources at relatively shallow water depths, the U.S. isn't as fortunate. Shallow waters (<100 feet deep) extend out for only a few miles from most of the East Coast, while the sea floor descends even more quickly along much of the West Coast. Tethered, floating platforms that could support multiple turbines at water depths of up to 1,000 feet are used by the oil and gas industries. However, their feasibility and cost-effectiveness in offshore wind farm development has not yet been proven.

As of late 2002, several offshore wind farms proposed for sites along the East Coast are under review. These include a wind farm off Cape Cod, Massachusetts proposed by Cape Wind Associates, LLC (discussed above) and 22 sites proposed by Winergy, LLC of Shirley, New York. The approval of one of these proposed wind farms would constitute a major milestone in the development of wind power in the U.S., as it could open the door to further offshore wind development.

NON-UTILITY-SCALE WIND POWER SYSTEMS

More than 99% of wind power generating capacity is part of large utility-scale plants that produce electricity for the retail market, with the remainder accounted for by smaller-scale installations. These smaller installations are referred to as "distributed" generation. Distributed wind installations, ranging in size from a single turbine with 100 kW generating capacity to a collection of turbines with a combined capacity of 12 MW, are designed to meet the power needs of a business, farmers cooperative, or small community.[76] Small wind systems, with less than 100 kW of generating capacity, are typically used to produce power for a single home.

Distributed Wind

Distributed wind projects are not directly connected to the transmission grid, but usually are connected to the local power distribution network, and as such can help to shore up the distribution grid in places where it is weak. The construction of a new one MW wind farm outside Seattle, Washington, for example, postponed the need for costly upgrades to transmission and distribution lines in the area. It also reduced line losses due to the very strong correlation between the available wind resource and the load on the distribution system.[77] An Oak Ridge National Laboratory review of seven case studies suggests that it is possible to add 50 to 100 MW of new wind generating capacity to supply local load in many areas, without needing to significantly upgrade the transmission system.[78]

Small Wind

About 15 MW of small wind (<100 kW) generating capacity exists in the U.S. today.[79] Many such systems are connected to the grid so that any excess electricity generated can be sold to the utility. In places where net metering is allowed, the utility purchases this electricity at the retail rate, effectively offsetting electricity purchased from the utility when the customer's electricity needs exceed the amount generated by the turbine. Where net metering is not required, excess electricity generated at the customer site is purchased by the utility at the lower wholesale rate or avoided cost of power production. Thus, net metering reduces the customer's total cost of electricity and makes on-site electricity generation more attractive to many electricity customers.

More information about small-scale wind can be found on the American Wind Energy Association (AWEA) web site (http://www.awea.org/smallwind.html) and on the *Wind Powering America* web site (http://www.eren.doe.gov/windpoweringamerica/small_wind.html), an initiative of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EREN).

CLOSING

We hope this paper has provided the reader with a balanced overview of the utility-scale wind power industry. We believe clean, reliable power can be developed from renewable resources, with wind power making an important contribution. Examples from the U.S. wind sector have been used to illustrate the costs, benefits, policies, and trends in wind energy today. What follows is a list or further resources available on the Web to allow the reader to gain a deeper understanding of the potential of wind power and the issues surrounding its development. We urge the reader to seek further understanding of these issues, and the means to their resolution, in order to support the progress of wind energy in providing clean, reliable, and economic power.

SOURCES OF FURTHER INFORMATION

General

- American Wind Energy Association http://www.awea.org
- Danish Wind Industry Association--Guided Tour on Wind Energy http://www.windpower.org/
- Energy Information Administration, U.S. Department of Energy http://www.eia.doe.gov
- National Wind Coordinating Council http://www.nationalwind.org
- National Wind Technology Center, National Renewable Energy Laboratory, U.S. Department of Energy http://www.nrel.gov/wind
- Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy http://www.eere.energy.gov/windpoweringamerica/

Offshore Wind

- The British Wind Energy Association http://www.offshorewindfarms.co.uk
- Offshore Windenergy in Europe http://www.offshorewindenergy.org
- Massachusetts Technology Collaborative http://www.masstech.org/RenewableEnergy/green_power/outreach/offshore_cape.htm

International Wind Trade Associations

- Australian Wind Energy Association http://www.auswea.com.au
- British Wind Energy Association http://www.britishwindenergy.co.uk/main.html
- Canadian Wind Energy Association http://www.canwea.ca
- Danish Wind Energy Association http://www.windpower.dk
- European Wind Energy Association http://www.ewea.org
- Irish Wind Energy Association http://www.iwea.com
- New Zealand Wind Energy Association http://www.windenergy.org.nz
- South African Wind Energy Association http://www.icon.co.za/~sawea/

ENDNOTES

[1] Based on global electricity production data for 2000 from *Key World Energy Statistics from the IEA*
[2] BTM Consult Press Release, April '02 (http://www.btm.dk/Documents/Press%20release%20WMU01.pdf).
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[70] Canadian Wind Energy Association (http://www.canwea.ca/pdfs/CanWEA-WindVision.pdf)
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The Most Frequently Asked Questions About Wind Energy

American Wind Energy Association

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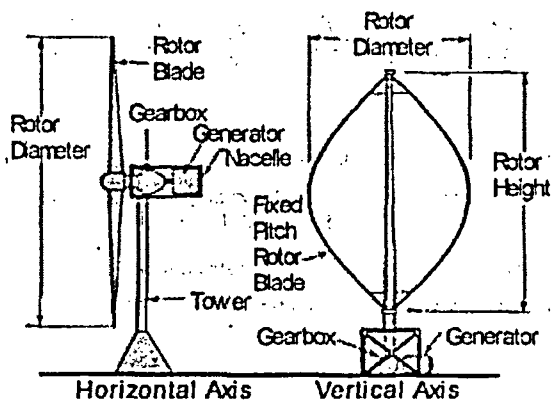
Contents

Wind Energy Basics

What is a wind turbine and how does it work?

A wind energy system transforms the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use. Mechanical energy is most commonly used for pumping water in rural or remote locations. Wind electric turbines generate electricity for homes and businesses and for sale to utilities.

There are two basic designs of wind electric turbines: vertical-axis, or "egg-beater" style, and horizontal-axis machines. Horizontal-axis wind turbines are most common today, constituting nearly all of the "utility-scale" (100 kilowatts, kW, capacity and larger) turbines in the global market.



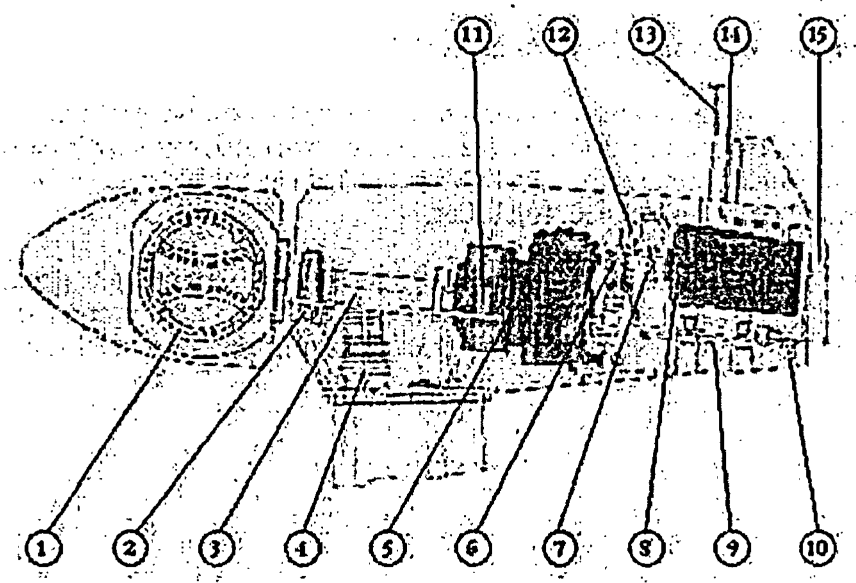
Wind Turbine Configurations

Turbine subsystems include:

- a **rotor,** or **blades,** which convert the wind's energy into rotational shaft energy;
- a **nacelle** (enclosure) containing a **drive train**, usually including a **gearbox*** and a **generator;**
- a **tower,** to support the rotor and drive train; and
- **electronic equipment** such as controls, electrical cables, ground support equipment, and interconnection equipment.

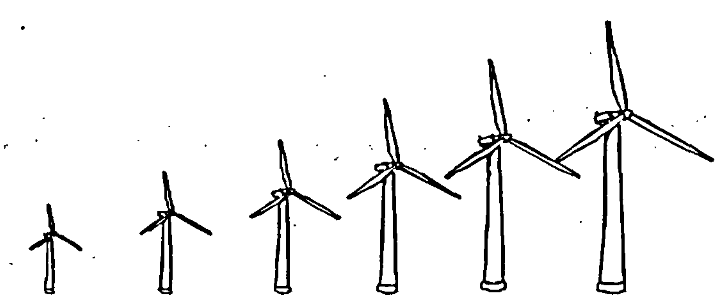
*Some turbines operate without a gearbox.

The following illustration shows the inside of a nacelle:



1. Spherical hub
2. Main bearing
3. Main shaft
4. Yaw gear
5. Gearbox
6. Fail safe hydraulic disc brake unit
7. Flexible coupling
8. Liquid-cooled generator
9. Frame
10. Heat exchanger for cooling of the gearbox oil
11. Gearbox suspension
12. Crane for maintenance work
13. Anemometer and wind vane
14. Radiator
15. Cover

Wind turbines vary in size. The following chart depicts a variety of turbine sizes and the amount of electricity they are each capable of generating (the turbine's capacity, or power rating).



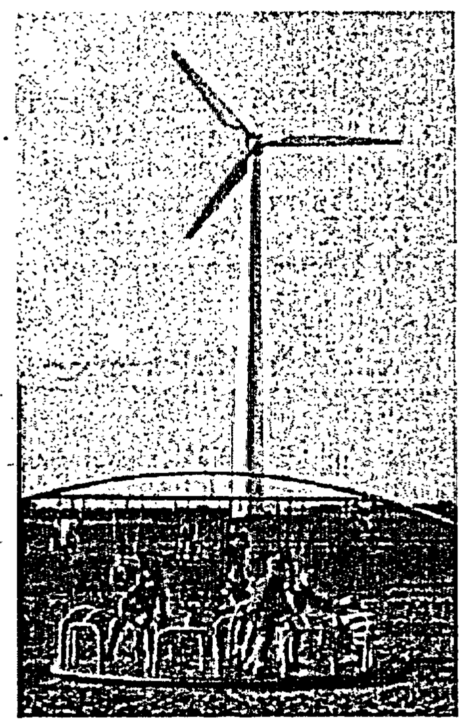
	1981	1985	1990	1996	1999	2000
Rotor (meters)	10	17	27	40	50	71
KW	25	100	225	550	750	1,650
MWh	45	220	550	1,480	2,200	5,600

How much electricity can one wind turbine generate?

The ability to generate electricity is measured in watts. Watts are very small units, so the terms *kilowatt* (kW, 1,000 watts), *megawatt* (MW, 1 million watts), and *gigawatt* (pronounced "jig-a-watt," GW, 1 billion watts) are most commonly used to describe the capacity of generating units like wind turbines or other power plants.

Electricity production and consumption are most commonly measured in *kilowatt-hours (kWh)*. A kilowatt-hour means one kilowatt (1,000 watts) of electricity produced or consumed for one hour. One 50-watt light bulb left on for 20 hours consumes one kilowatt-hour of electricity (50 watts x 20 hours = 1,000 watt-hours = 1 kilowatt-hour).

The output of a wind turbine depends on the turbine's size and the wind's speed through the rotor. Wind turbines being manufactured now have power ratings ranging from 250 watts to 1.8 megawatts (MW).



Example: A 10-kW wind turbine can generate about 16,000 kWh annually, more than enough to power a typical household. A 1.8-MW turbine can produce more than 5.2 million kWh in a year--enough to power more than 500 households. The average U.S. household consumes about 10,000 kWh of electricity each year.

Example: A 250-kW turbine installed at the elementary school in Spirit Lake, Iowa, (pictured at left) provides an average of 350,000 kWh of electricity per year, more than is necessary for the 53,000-square-foot school. Excess electricity fed into the local utility system has earned the school $25,000 over five years. The school uses electricity from the utility at times when the wind does not blow. This project has been so successful that the Spirit Lake school district has since installed a second turbine with a capacity of 750 kW.

Wind speed is a crucial element in projecting turbine performance, and a site's wind speed is measured through wind resource assessment prior to a wind system's construction. Generally, annual average wind speeds greater than four meters per second (m/s) (9 mph) are required for small wind electric turbines (less wind is required for water-pumping operations). Utility-scale wind power plants require minimum average wind speeds of 6 m/s (13 mph).

The power available in the wind is proportional to the cube of its speed, which means that doubling the wind speed increases the available power by a factor of eight. Thus, a turbine operating at a site with an average wind speed of 12 mph could in theory generate about 33% more electricity than one at an 11-mph site, because the cube of 12 (1,768) is 33% larger than the cube of 11 (1,331). (In the real world, the turbine will not produce quite that much more electricity, but it will still generate much more than the 9% difference in wind speed. The important thing to understand is that what seems like a small difference in wind speed can mean a large difference in available energy and in electricity produced, and therefore, a large difference in the cost of the electricity generated.

How many turbines does it take to make one megawatt (MW)?

Most manufacturers of utility-scale turbines offer machines in the 700-kW to 1.8-MW range. Ten 700-kW units would make a 7-MW wind plant, while 10 1.65-MW machines would make a 18-MW facility. In the future, machines of larger size will be available, although they will probably be installed offshore, where larger transportation and construction equipment can be used.

How many homes can one megawatt of wind energy supply?

An average U.S. household uses about 10,000 kilowatt-hours (kWh) of electricity each year. One megawatt of wind energy can generate between 2.4 million and 3 million kWh annually. Therefore, a megawatt of wind generates about as much electricity as 240 to 300 households use. It is important to note that since the wind does not blow all of the time, it cannot be the only power source for that many households without some form of storage system. The "number of homes served" is just a convenient way to translate a quantity of electricity into a familiar term that people can understand.

What is a wind power plant?

The most economical application of wind electric turbines is in groups of large machines (660 kW and up), called "wind power plants" or "wind farms." For example, a 107-MW wind farm near the community of Lake Benton, Minn., consists of turbines sited far apart on farmland along windy Buffalo Ridge (below). The wind farm generates electricity while agricultural use continues undisturbed.

Wind plants can range in size from a few megawatts to hundreds of megawatts in capacity. Wind power plants are "modular," which means they consist of small individual modules (the turbines) and can easily be made larger or smaller as needed. Turbines can be added as electricity demand grows. Today, a 50-MW wind farm can be completed in 18 months to two years (including resource assessment and permitting).

What is "capacity factor"?

Capacity factor is one element in measuring the productivity of a wind turbine or any other power production facility. It compares the plant's actual production over a given period of time with the amount of power the plant would have produced if it had run at full capacity for the same amount of time.

$$\text{Capacity Factor} = \frac{\text{Actual amount of power produced over time}}{\text{Power that would have been produced if turbine operated at maximum output 100\% of the time}}$$

A conventional utility power plant uses fuel, so it will normaly run much of the time unless it is idled by equipment problems or for maintenance. A capacity factor of 40% to 80% is typical for conventional plants.

A wind plant is "fueled" by the wind, which blows steadily at times and not at all at other times. Most modern utility-scale wind turbines operate with a capacity factor of 25% to 40%, although they may achieve higher capacity factors during windy weeks or months. It is possible to achieve much higher capacity factors by combining wind with a storage technology such as pumped hydro or compressed-air energy storage (CAES).

It is important to note that while capacity factor is almost entirely a matter of reliability for a fueled power plant, it is not for a wind plant—for a wind plant, it is a matter of economical turbine design. With a very large rotor and a very small generator, a wind turbine would run at full capacity whenever the wind blew and would have a 60-80% capacity factor—but it would produce very little electricity. The most electricity per dollar of investment is gained by using a larger generator and accepting the fact that the capacity factor will be lower as a result. Wind turbines are fundamentally different from fueled power plants in this respect.

If a wind turbine's capacity factor is 33%, doesn't that mean it is only running one-third of the time?

No. A wind turbine at a typical location in the Midwestern U.S. should run about 65-80% of the time. However, much of the time it will be generating at less than full capacity (see previous answer), making its capacity factor lower.

What is "availability factor"?

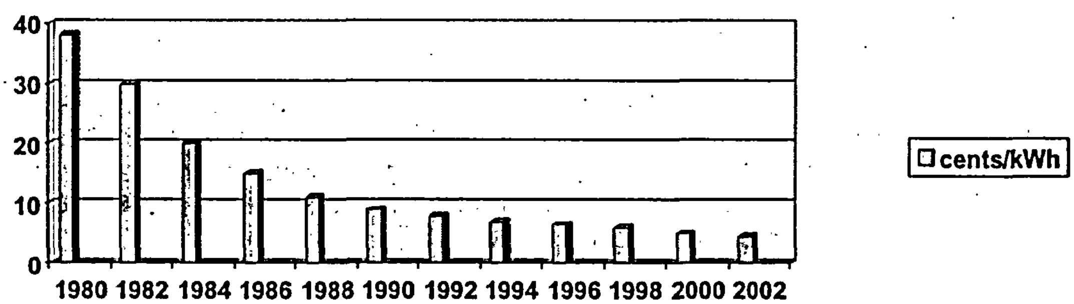
Availability factor (or just "availability") is a measurement of the reliability of a wind turbine or other power plant. It refers to the percentage of time that a plant is ready to generate (that is, not out of service for maintenance or repairs). Modern wind turbines have an availability of more than 98%–higher than most other types of power plant. After two decades of constant engineering refinement, today's wind machines are highly reliable.

Wind Energy Costs

How much does wind energy cost?

Over the last 20 years, the cost of electricity from utility-scale wind systems has dropped by more than 80%. In the early 1980s, when the first utility-scale turbines were installed, wind-generated electricity cost as much as 30 cents per kilowatt-hour. Now, state-of-the-art wind power plants can generate electricity for less than 5 cents/kWh in many parts of the U.S., a price that is in a competitive range with many conventional energy technologies.

Cost of Wind-Generated Energy in Levelized Cents/kWh

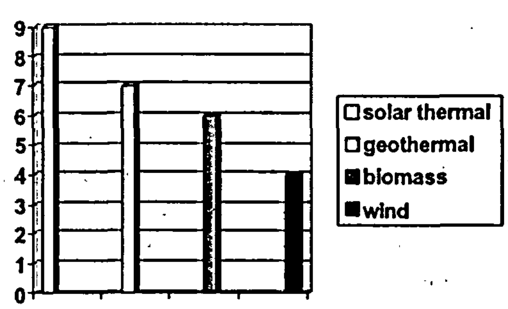


Assumptions: levelized cost at excellent wind sites, large project size, not including PTC

The National Renewable Energy Laboratory (NREL) is working with the wind industry to develop a next generation of wind turbine technology. The products from this program are expected to generate electricity at prices competitive with natural gas turbines, the least expensive conventional power source.

How do utility-scale wind power plants compare in cost to other renewable energy sources?

Wind is the low-cost emerging renewable energy resource.



Wind Costs Compared With Other Renewable Energy Technologies (in cents/kWh)
Assumptions for wind energy cost: levelized cost at excellent wind sites, large project size

What is the "production tax credit" for wind energy?

A 1.5-cent per kilowatt-hour* production tax credit (PTC) for wind energy was included in the Energy Policy Act of 1992. Passage of the PTC reflected a recognition of the important role that wind energy can and should play in our nation's energy mix. It also was intended to partially correct the existing tilt of the federal energy tax code, which has historically favored conventional energy technologies such as oil and coal.

Generally, the credit is a business credit that applies to electricity generated from wind plants for sale at wholesale (i.e., to a utility or other electricity supplier). It applies to electricity produced during the first 10 years of a wind plant's operation.

The wind PTC is currently scheduled to expire on December 31, 2003. An effort is underway to extend it through December 31, 2006, to provide a stable financial environment for the wind energy industry. For information on the status of that effort, contact the American Wind Energy Association (AWEA), phone (202) 383-2500, e-mail <windmail@awea.org>.

*The PTC is adjusted annually for inflation, and currently stands at 1.7 cents/kWh.

If wind energy is competitive, why does it need a tax credit subsidy from the government? Isn't this government interference in the free market?

The energy market has never been free—large energy producers such as coal and oil have always been able to win government subsidies of various kinds. To take just one example, the federal government has paid out $35 billion over the past 30 years to cover the medical expenses of coal miners who suffer from "black lung disease." These subsidies mean that the true cost of coal is not reflected in its market price.

As the previous answer indicates, the wind PTC was passed by Congress to give wind a "level playing field" compared with other subsidized energy sources. More information on energy subsidies is available at **http://www.repp.org/repp_pubs/articles/resRpt11/preleasesubsidies.pdf**.

More generally, coal receives a huge hidden subsidy resulting from the fact that its full environmental and health costs are not accounted for. A recent article in *Science* magazine reported that coal-fired electricity would cost 50-100% more if these costs were taken into account ("Exploiting Wind Versus Coal," Mark Z. Jacobson and Gilbert M. Masters, *Science*, 24 August 2001, Vol. 293, p. 1438).

Wind Energy's Potential

The wind doesn't blow all the time. How much can it really contribute to a utility's

generating capacity?

Utilities must maintain enough power plant capacity to meet expected customer electricity demand at all times, plus an additional reserve margin. All other things being equal, utilities generally prefer plants that can generate as needed (that is, conventional plants) to plants that cannot (such as wind plants).

However, in two separate studies, researchers have found that despite its intermittent nature, wind can provide capacity value for utilities.

The studies, by the Tellus Institute of Boston, Mass., and the Prince Edward Island (Canada) Energy Corp., concluded that when wind turbines are added to a utility system, they increase the overall statistical probability that the system will be able to meet demand requirements. They noted that while wind is an intermittent resource, conventional generating systems also experience periodic outages for maintenance and repair.

The exact amount of capacity value that a given wind project provides depends on a number of factors, including average wind speeds at the site and the match between wind patterns and utility load (demand) requirements.

How much energy can wind realistically supply to the U.S.?

Wind energy could supply about 20% of the nation's electricity, according to Battelle Pacific Northwest Laboratory, a federal research lab. Wind energy resources useful for generating electricity can be found in nearly every state.

U.S. wind resources are even greater, however. North Dakota alone is theoretically capable (if there were enough transmission capacity, storage capability, etc.) of producing enough wind-generated power to meet more than one-third of U.S. electricity demand. The theoretical potentials of the windiest states are shown in the following table.

1	North Dakota	1,210	11	Colorado	481
2	Texas	1,190	12	New Mexico	435
3	Kansas	1,070	13	Idaho	73
4	South Dakota	1,030	14	Michigan	65
5	Montana	1,020	15	New York	62
6	Nebraska	868	16	Illinois	61
7	Wyoming	747	17	California	59
8	Oklahoma	725	18	Wisconsin	58
9	Minnesota	657	19	Maine	56
10	Iowa	551	20	Missouri	52

THE TOP TWENTY STATES for wind energy potential, as measured by annual energy potential in the billions of kWhs, factoring in environmental and land use exclusions for wind class of 3 and higher.

Source: An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, Pacific Northwest Laboratory, 1991.

Experience also shows that wind power can provide at least up to a fifth of a system's electricity, and the figure could probably be higher. Wind power currently provides nearly 25% of electricity demand in the north German state of Schleswig Holstein. In western Denmark, wind supplies more than 50% of the electricity that is used during windy winter nights.

What is needed for wind to reach its full potential in the U.S.?

First, new transmission lines. The entire transmission system of the Missouri River Basin, which covers the central one-third of the U.S., needs to be extensively redesigned and redeveloped. At present, this system consists mostly of small distribution lines—instead, a series of new high-voltage transmission lines is needed to transmit electricity from wind plants to population centers. Such a redevelopment will be expensive, but it will also benefit consumers and national security, through increased system reliability.

Second, nondiscriminatory access to transmission lines. Transmission line operators typically charge generators large penalty fees if they fail to deliver electricity when it is scheduled to be transmitted. The purpose of these penalty fees is to punish generators and deter them from using transmission scheduling as a "gaming" technique gain advantage against competitors, and the fees are therefore not related to whether the system operator actually loses money as a result of the generator's action. But because the wind is variable, wind plant owners cannot guarantee delivery of electricity for transmission at a scheduled time. Wind energy needs a new penalty system that recognizes the different nature of wind plants and allows them to compete on an equitable basis.

Transmission will be a key issue for the wind industry's future development over the next few decades.

How much energy can wind supply worldwide?

Today, there are approximately 50,000 wind turbines generating power worldwide, totalling 24,000 megawatts of generating capacity and producing more than 50 billion kilowatt-hours each year—as much as five million average American households use, or as much as eight large nuclear power plants could generate. Yet this is but a tiny fraction of wind's potential.

According to the U.S. Department of Energy, the world's winds could theoretically supply the equivalent of 5,800 quadrillion BTUs (quads) of energy each year--more than 15 times current world energy demand. (A quad is equal to about 172 million barrels of oil or 45 million tons of coal.)

A study ("Wind Force 10") performed by Denmark's BTM Consult for the European Wind

Energy Association and Greenpeace found that by the year 2017, wind could provide 10% of world electricity supplies, meeting the needs of 500 million average European households.

The potential of wind to improve the quality of life in the world's developing countries, where more than two billion people live with no electricity or prospect of utility service in the foreseeable future, is vast.

I've heard that Denmark is pulling back on wind development. Does that mean wind is a failure?

No. As this is being written (early 2002), Denmark is revisiting its current wind policy. The degree to which that means the U.S. should reexamine its own policy revolves around the degree to which our situation is similar to Denmark's. In fact, a brief analysis of some major differences suggests that there are strong reasons for continuing to support wind development in the U.S. rather than back away from it:

--Denmark is small, the U.S. is not:

(1) Wind supplies 15% of national electricity demand in Denmark. Although the U.S. has nearly twice as much installed wind equipment as Denmark, wind generates only 0.3% of our electricity, far below the 10% threshold identified by most analysts as the point at which wind's variability becomes a significant issue for utility system operators.

(2) Denmark is also so small geographically (half the size of Indiana) that high winds can cause many of its wind plants to shut down almost at once--in the U.S., wind plants are much more geographically dispersed and do not all experience the same wind conditions at the same time.

--Denmark has transformed its national power system, the U.S. has not:
Rapid development of wind and new small-scale power plants within the past five years has brought Denmark to the point where power produced by so-called non-dispatchable resources in the country's West exceeds 100% of demand in the region. At many times, this excess generation leaves the country scrambling to increase electricity export capabilities to handle the surplus. This situation is essentially unimaginable in the U.S.

--Danish wind plants are typically small, U.S. wind plants are not:
Denmark's approach encourages community involvement, but places particular stress on low-capacity distribution networks (at the "end of the line" on transmission systems). In the U.S., our larger wind plants require advance transmission planning, but feed into main transmission lines and do not affect the customer distribution network.

In summary, Denmark's situation should not cause concern in the U.S. Denmark's problem is that wind has been very successful very quickly in a small country, and it must now take steps to manage that success; would that the U.S. had dealt with its energy problems so decisively.

What is the "energy payback time" for a wind turbine?

The "energy payback time" is a term used to measure the net energy value of a wind turbine or other power plant--i.e., how long does the plant have to operate to generate the amount of electricity that was required for its manufacture and construction? Several studies have looked at this question over the years and have concluded that wind energy has one of the shortest energy payback times of any energy technology. A wind turbine typically takes only a few months (3-8, depending on the average wind speed at its site) to "pay back" the energy needed for its fabrication, installation, operation, and retirement.

Since you can't count on the wind blowing, what does a utility gain by adding 100 megawatts (MW) of wind to its portfolio of generating plants? Does it gain anything? Or should it also add 100 MW of fueled generation capacity to allow for the times when the wind is calm?

First, it needs to be understood that the bulk of the "value" of <u>any</u> supply resource is in the energy the resource produces, not the capacity it adds to a utility system. Having said that, utilities use fairly complicated computer models to determine the value in added capacity that each new generating plant adds to the system. According to those models, the capacity value of a new wind plant is approximately equal to its capacity factor. Thus, adding 100-MW wind plant with an average capacity factor of 35% to the system is approximately the same as adding 35 MW of conventional fueled generating capacity. The exact answer depends on, among other factors, the correlation between the time that the wind blows and the time that the utility sees peak demand. Thus wind farms whose output is highest in the spring months or early morning hours will generally have a lower capacity value than wind farms whose output is high on hot summer evenings.

Since wind is a variable energy source, doesn't its growing use present problems for utility system managers?

At current levels of use, this issue is still some distance from being a problem on most utility systems. The rule of thumb (admittedly rough) is:

- Up to the point where wind generates about 10% of the electricity that the system is delivering in a given hour of the day, it's not an issue. There is enough flexibility built into the system for reserve backup, varying loads, etc., that there is effectively little difference between such a system and a system with 0% wind.

- At the point where wind is generating 10% to 20% of the electricity that the system is delivering in a given hour, it is an issue that needs to be addressed, but that can probably be resolved with wind forecasting (which is fairly accurate in the time frame of interest to utility system operators), system software adjustments, and other changes.

- Once wind is generating more than about 20% of the electricity that the system is delivering in a given hour, the system operator begins to incur significant additional expense because of the need to procure additional equipment that is solely related to the system's increased variability.

These figures assume that the utility system has an "average" amount of resources that are complementary to wind's variability (e.g., hydroelectric dams) and an "average" amount of load that can vary quickly (e.g., electric arc furnace steel mills). Actual utility systems can vary quite widely in their ability to handle as-available output resources like wind farms. However, as wholesale electricity markets grow, fewer, larger utility systems are emerging. Therefore, over time, more and more utility systems will look like an "average" system.

Wind Energy and the Economy

What does the U.S. wind industry contribute to the economy?

Wind power supplies affordable, inexhaustible energy to the economy. It also provides jobs and other sources of income. Best of all, wind powers the economy without causing pollution, generating hazardous wastes, or depleting natural resources—it has no "hidden costs."

What are America's current sources of electricity?

Coal, the most polluting fuel and the largest source of the leading greenhouse gas, carbon dioxide (CO_2), is currently used to generate more than half of all of the electricity (52%) used in the United States. Other sources of electricity are: natural gas (16%), oil (3%), nuclear (20%), and hydropower (7%).

How many people work in the U.S. wind industry?

The U.S. wind industry currently directly employs more than 2,000 people. The wind industry contributes directly to the economies of 46 states, with power plants and manufacturing facilities that produce wind turbines, blades, electronic components, gearboxes, generators, and a wide range of other equipment.

The American Wind Energy Association estimates that every megawatt of installed wind capacity creates about 2.5 job-years of direct employment (short-term construction and long-term operations and maintenance jobs) and about 8 job-years of total employment (direct and indirect). This means that a 50-MW wind farm creates 125 job-years of direct employment and 400 job-years of total employment.

Wind and solar energy are likely to furnish one of the largest sources of new manufacturing jobs worldwide during the 21st Century.

What is the value of export markets for wind?

Export markets are growing rapidly. Overseas markets account for about half of the business of U.S. manufacturers of small wind turbines and wind energy developers. Small wind turbine markets are diverse and include many applications, both on-grid (connected to a utility system) and off-grid (stand-alone). A recent market study predicts that small wind turbine sales will increase fivefold by 2005.

The potential economic benefits from wind are enormous. At a time when U.S. manufacturing employment is generally on the decline, the production of wind equipment is one of the few potentially large sources of new manufacturing jobs on the horizon.

AWEA estimates that wind installations worldwide will total more than 75,000 megawatts over the next decade, or more than $75 billion worth of business. If the U.S. industry could capture a 25% share of the global wind market through the year 2012, many thousands of new jobs would be created.

In what other ways does wind energy benefit the economy?

Wind farms can revitalize the economy of rural communities, providing steady income through lease or royalty payments to farmers and other landowners.

Although leasing arrangements can vary widely, a reasonable estimate for income to a landowner from a single utility-scale turbine is about $3,000 a year. For a 250-acre farm, with income from wind at about $55 an acre, the annual income from a wind lease would be $14,000, with no more than 2-3 acres removed from production. Such a sum can significantly increase the net income from farming. Farmers can grow crops or raise cattle next to the towers.

Wind farms may extend over a large geographical area, but their actual "footprint" covers only a very small portion of the land, making wind development an ideal way for farmers to earn additional income (picture at left). In west Texas, for example, farmers are welcoming wind, as lease payments from this new clean energy source replace declining payments from oil wells that have been depleted.

Farmers are not the only ones in rural communities to find that wind power can bring in income. In Spirit Lake, Iowa, the local school is earning savings and income from the electricity generated by a turbine. In the district of Forest City, Iowa, a turbine recently erected as a school project is expected to save $1.6 million in electricity costs over its lifetime.

Additional income is generated from one-time payments to construction contractors and suppliers during installation, and from payments to turbine maintenance personnel on a long-term basis. Wind farms also expand the local tax base, and keep energy dollars in the local community instead of spending them to pay for coal or gas produced elsewhere.

Finally, wind also benefits the economy by reducing "hidden costs" resulting from air pollution and health care. Several studies have estimated that 50,000 Americans die prematurely each year because of air pollution.

Wind Energy and The Environment

What are the environmental benefits of wind power?

Wind energy system operations do not generate air or water emissions and do not produce hazardous waste. Nor do they deplete natural resources such as coal, oil, or gas, or cause environmental damage through resource extraction and transportation. Wind's pollution-free electricity can help reduce the environmental damage caused by power generation in the U.S. and worldwide.

In 1997, U.S. power plants emitted 70% of the sulfur dioxide, 34% of carbon dioxide, 33% of nitrogen oxides, 28% of particulate matter and 23% of toxic heavy metals released into our nation's environment, mostly the air. These figures are currently increasing in spite of efforts to roll back air pollution through the federal Clean Air Act.

Sulfur dioxide and nitrogen oxides cause acid rain. Acid rain harms forests and the wildlife they support. Many lakes in the U.S. Northeast have become biologically dead because of this form of pollution. Acid rain also corrodes buildings and economic infrastructure such as bridges. Nitrogen oxides (which are released by otherwise clean-burning natural gas) are also a primary component of smog.

Carbon dioxide (CO_2) is a greenhouse gas--its buildup in the atmosphere contributes to global warming by trapping the sun's rays on the earth as in a greenhouse. The U.S., with 5% of the world's population, emits 23% of the world's CO_2. The build-up of greenhouse gases is not only causing a gradual rise in average temperatures, but also seems to be increasing fluctuations in weather patterns and causing more severe droughts.

Particulate matter is of growing concern because of its impacts on health. Its presence in the air along with other pollutants has contributed to make asthma one of the fastest growing childhood ailments in industrial and developing countries alike, and it has also recently been linked to lung cancer. Similarly, urban smog has been linked to low birth weight, premature births, stillbirths and infant deaths. In the United States, the research has documented ill effects on infants even in cities with modern pollution controls. Toxic heavy metals accumulate in the environment and up the biological food chain.

Development of just 10% of the wind potential in the 10 windiest U.S. states would provide more than enough energy to displace emissions from the nation's coal-fired power plants and eliminate the nation's major source of acid rain; reduce total U.S. emissions of CO_2 by almost a third and world emissions of CO_2 by 4%; and help contain the spread of asthma and other respiratory diseases aggravated or caused by air pollution in this country.

If wind energy were to provide 20% of the nation's electricity--a very realistic and achievable goal with the current technology--it could displace more than a third of the emissions from coal-fired power plants, or all of the radioactive waste and water pollution from nuclear power plants.

The 10 billion kilowatt-hours currently generated by wind plants in the U.S. each year displace some 13.5 billion pounds (6.7 million tons) of carbon dioxide, 35,000 tons of sulfur dioxide (98 tons per day), and 21,000 tons of nitrogen oxides (58 tons per day).

How does wind stack up on greenhouse gas emissions when the "total fuel cycle" (including manufacture of equipment, plant construction, etc.) is considered?

The claim is sometimes made that manufacturing wind turbines and building wind plants creates large emissions of carbon dioxide. This is false. Several studies have found that even when these operations are included, wind energy's CO2 emissions are quite small—on the order of 1% of coal or 2% of natural gas per unit of electricity generated.

What are wind power's other environmental impacts?

Wind power plants, like all other energy technologies, have some environmental impacts. However, unlike most conventional technologies (which have regional and even global impacts due to their emissions), the impacts of wind energy systems are local. This makes them easier for local communities to monitor and, if necessary, mitigate.

The local environmental impacts that can result from wind power development include:

* **Erosion**, which can be prevented through proper installation and landscaping techniques. Erosion can be a concern in certain habitats such as the desert, where a hard-packed soil surface must be disturbed to install wind turbines.

* **Bird and bat kills and other effects.** Birds and bats occasionally collide with wind turbines, as they do with other tall structures such as buildings. Avian deaths have become a concern at Altamont Pass in California, which is an area of extensive wind development and also high year-round raptor use. Detailed studies, and monitoring following construction, at other wind development areas indicate that this is a site-specific issue that will not be a problem at most potential wind sites. Also, wind's overall impact on birds is low compared with other human-related sources of avian mortality—see [Avian Perspectives Paper Web address] for more information. No matter how extensively wind is developed in the future, bird deaths from wind energy are unlikely to ever reach as high as 1% of those from other human-related sources such as hunters, house cats, buildings, and autos. Wind is, quite literally, a drop in the bucket. Still, areas that are commonly used by threatened or endangered species should be regarded as unsuitable for wind development. The wind industry is working with environmental groups, federal regulators, and other interested parties to develop methods of measuring and mitigating wind energy's effect on birds.

Bat collisions at wind plants tend to be low in number and to involve common species that are quite numerous. Human disturbance of hibernating bats in caves is a far greater threat to species of concern.

* **Visual impacts**, which can be minimized through careful design of a wind power plant.

Using turbines of the same size and type and spacing them uniformly generally results in a wind plant that satisfies most aesthetic concerns. Computer simulation is helpful in evaluating visual impacts before construction begins. Public opinion polls show that the vast majority of people favor wind energy, and support for wind plants often increases after they are actually installed and operating. For more information on public attitudes toward wind, see http://www.awea.org/faq/survpub.html .

* **Noise** was an issue with some early wind turbine designs, but it has been largely eliminated as a problem through improved engineering and through appropriate use of setbacks from nearby residences. Aerodynamic noise has been reduced by adjusting the thickness of the blades' trailing edges and by orienting blades upwind of the turbine tower. A small amount of noise is generated by the mechanical components of the turbine. To put this into perspective, a wind turbine 250 meters from a residence is no noisier than a kitchen refrigerator.

How much land is needed for a utility-scale wind plant?

In open, flat terrain, a utility-scale wind plant will require about 50 acres per megawatt of installed capacity. However, only 5% (2.5 acres) or less of this area is actually occupied by turbines, access roads, and other equipment--95% remains free for other compatible uses such as farming or ranching. In California, Minnesota, Texas, and elsewhere, wind energy provides rural landowners and farmers with a supplementary source of income through leasing and royalty arrangements with wind power developers.

A wind plant located on a ridgeline in hilly terrain will require much less space, as little as two acres per megawatt.

How much water do wind turbines use compared with conventional power plants?

Water use can be a significant issue in energy production, particularly in areas where water is scarce, as conventional power plants use large amounts of water for the condensing portion of the thermodynamic cycle. For coal plants, water is also used to clean and process fuel.

According to the California Energy Commission (cited in Paul Gipe's WIND ENERGY COMES OF AGE, John Wiley & Sons, 1995), conventional power plants consume the following amounts of water (through evaporative loss, not including water that is recaptured and treated for further use):

WATER CONSUMPTION--CONVENTIONAL POWER PLANTS

Technology	gallons/kWh	liters/kWh
Nuclear	0.62	2.30
Coal	0.49	1.90
Oil	0.43	1.60
Combined Cycle Gas	0.25	0.95

Small amounts of water are used to clean wind turbine rotor blades in arid climates (where rainfall does not keep the blades clean). The purpose of blade cleaning is to eliminate dust and insect buildup, which otherwise deforms the shape of the airfoil and degrades performance.

Similarly, small amounts of water are used to clean photovoltaics (solar) panels. Water use numbers for these two technologies are as follows:

WATER CONSUMPTION–WIND AND SOLAR

Technology	gallons/kWh	liters/kWh
Wind [1]	0.001	0.004
Solar [2]	0.030	0.110

Wind therefore uses less than 1/600 as much water per unit of electricity produced as does nuclear, approximately 1/500 as much as coal, and approximately 1/25 as much as natural gas, the most popular choice for new power plants

NOTES

[1] American Wind Energy Association estimate, based on data obtained in personal communication with Brian Roach, Fluidyne Corp., December 13, 1996. Assumes 250-kW turbine operating at .25 capacity factor, with blades washed four times annually.

[2] Meridian Corp., "Energy System Emissions and Materials Requirements," U.S. Department of Energy, Washington, DC. 1989, p. 23.

I've heard that wind energy doesn't really reduce pollution, because other, fossil-fired generating units have to be kept running on a standby basis in case the wind dies down. Is this true?

No. It is true that other generating plants have to be available to the power system's operator to supply electricity when the wind is not blowing. However, the wind does not just start and stop. Typically, wind speeds increase gradually and taper off gradually, and the system operator has time to move other plants on and off line (start and stop them from generating) as needed--the fluctuations in wind plant output change more slowly than do the changes in customer demand that a utility must adjust to throughout the day. Studies indicate that for a 100-megawatt wind plant, only about 2 megawatts of conventional capacity is needed to compensate for changes in wind plant output.

What about turbines throwing blades, or ice? Is wind energy dangerous to the public?

It has been estimated by a number of reliable sources that 50,000 Americans a year die from air pollution, of which about one-third is produced by power plants. By contrast, in 20 years of operation, the wind industry (which emits no pollutants) has recorded only one death of a member of the public--a skydiver in Germany who parachuted off-course into an operating wind plant. Blade throws were common in the industry's early years, but are unheard of today because of better turbine design and engineering. Ice throw, while it can occur, is of little danger because of setbacks typically required to minimize noise (see above).

Wind Industry Statistics

How much wind generating capacity currently exists in the U.S.? How much will be added over the next several years?

At the end of 2001, U.S. capacity reached 4,261 MW, after a year of record-shattering growth during which 1,695 MW were added. Utility wind power projects now under construction or under negotiation will add at least 3,000 megawatts of wind capacity in the U.S. over the next five years.

The U.S. Department of Energy has announced a goal of obtaining 5% of U.S. electricity from wind by 2020--a goal that is consistent with the current rate of growth of wind energy nationwide. As public demand for clean energy grows, and as the cost of producing energy from the wind continues to decline, it is likely that wind energy will provide a growing portion of the nation's energy supply.

In what states is there significant wind power development?

California is the state in which most wind power development has occurred up to now. As of the end of 2001, the Golden State had a total of 1,671MW of wind generating capacity. However, Texas powered into a strong second place during 2001, installing more new capacity—916 MW—than had ever before been installed in the entire U.S. during a single year. Texas' total wind capacity now amounts to 1,096 MW. Other states with sizable wind plants include Colorado, Iowa, Kansas, Minnesota, New York, Oregon, Pennsylvania, Texas, Washington, Wisconsin, and Wyoming.

Wind plants are now operating in many regions of the country. For information on wind projects in individual states, visit the AWEA Web site at <http://www.awea.org> and click on Wind Projects.

How much wind generating capacity currently exists worldwide? How fast is it growing and where?

In 2001, world wind capacity soared past the 24,000 MW mark, having doubled in the past two years. Of that amount, about 6,500 MW was installed during 2001 alone. Since 1990, , wind has been the fastest-growing power source worldwide on a percentage basis, with an annual average growth rate of just over 25%. During the past two years, it has tripled in Germany and quadrupled in Spain.

Wind power plants are heavily concentrated in Europe and the United States, with the exception of India and China. The "top 10" nations listed below accounted for over 95% of the total wind energy produced in 2001.

World Leaders in Wind Capacity, December 2001

Country	Capacity (MW)		
Germany	8,750	Italy	697
United States	4,261	Netherlands	483
Spain	3,337	United Kingdom	474
Denmark	2,417	China	399
India	1,407	Sweden	290

Elsewhere, wind is catching on slowly but steadily, with new plants having been built recently in Portugal, Morocco, and many other countries.

How much is currently invested in the U.S. wind industry?

Wind plants typically cost approximately $1,000 per kilowatt of installed capacity. Thus, today's installed base of 4,261 megawatts in the U.S. amounts to over $4 billion in investment.

The U.S. wind energy industry is composed of many small- to medium-sized companies with a growing range of capabilities, plus a few large firms that are divisions of Fortune 500 companies. U.S. wind companies can provide vertically-integrated services ranging from wind turbine manufacturing to financing, project development, and operation and maintenance.

How much electricity does wind generate in the U.S. today?

About 4,261 megawatts of wind power capacity are currently installed in the U.S., generating about 10 billion kilowatt-hours annually. That is as much electricity as about 1 million average American households use each year.

In what states is there significant wind power development activity?

Wind power plant development is occurring in many regions of the country. States in which utility wind power projects are operating or being developed include Alaska, California, Colorado, Hawaii, Illinois, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Montana, Nebraska, Nevada, New Mexico, New York, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Vermont, Washington, Wisconsin, and Wyoming.

Small Wind Energy Systems

How many turbines are needed to power a household or farm?

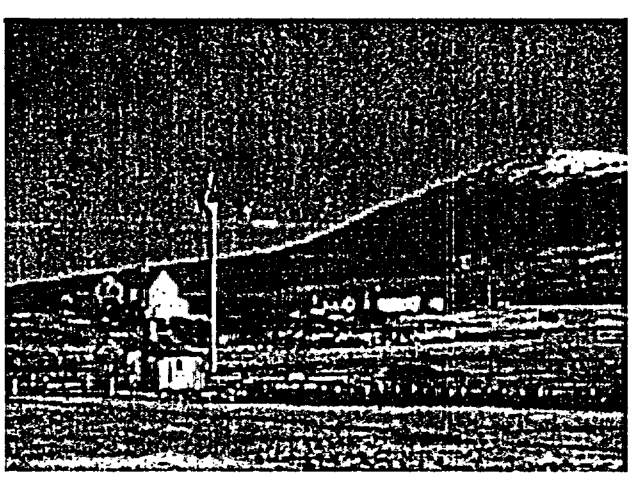
For a home or farm, one turbine is normally installed. The turbine's size is chosen to meet the energy requirements given the available wind resource. Turbines with power ratings from 1 kW to 25 kW are typically used.

For village electrification applications, both single and multiple turbine installations are common, and turbines up to 100 kW in capacity may be used.

How much land is needed for a small wind system?

The actual space required for a small wind turbine tower is quite small. It can be as small as one square yard, but as a general rule, at least one-half acre is recommended for a single small turbine installation.

What size tower is used for a small-scale wind turbine?



Usually a tower between 80 and 120 feet in height is supplied with the wind turbine. Towers of this height raise the turbine above turbulence generated by obstacles (such as buildings and trees) on the ground. Also, wind velocity increases with greater altitude, so wind turbine performance improves with height.

How do small turbine costs compare to the costs of other alternatives?

Small wind turbines (ranging in size from 250 watts to 50 kW) are often the least expensive source of power for remote sites that are not connected to the utility system.

A study by the Congressional Office of Technology Assessment found wind to be cheaper for meeting remote loads than diesel generators, photovoltaics, or utility transmission line extensions. (Micro-hydro also was found to be less expensive in many locations.)

Hybrid systems--wind/photovoltaic, wind/diesel, and other combinations--can often provide the most efficient and cost-effective option for rural electrification. Photovoltaics (PV)--the direct conversion of sunlight into electricity--is often used to supplement wind power since PV tends to operate best in low wind months. Diesel generators or batteries can be used for backup power and to maintain power production during low wind seasons.

One study of an Arctic community with annual average wind speeds of 15 mph compared the cost of a 500-kW diesel system to that of a 200-kW diesel generator and four mid-sized wind turbines. If found that the wind/diesel combination cost considerably more to install ($378,000 versus $125,000), but would deliver fuel savings of $90,000 per year, paying for itself in less than three years.*

*For more information, see Proceedings of the Seventh Wind-Diesel Workshop, 1993.

Why are small wind turbines better than diesel generators or extension of utility lines in developing countries?

Small wind turbines are better because they are more sustainable and offer a number of other socioeconomic benefits. Wind systems come in smaller sizes than diesel generators and have a shorter construction lead time than extending the utility lines ("grid"). For grid extension distances as short as one kilometer, a wind system can be a lower cost alternative for small loads. While wind turbines cost more initially than diesels, they are often much better from the user's point of view because of typical foreign aid practices. Donor agencies, for example, typically supply diesels at no cost, but leave operational costs (fuel, maintenance and replacement) to be supplied by the local people. These expenses (in particular, fuel and parts) require scare hard currency. This usually leads to limited utilization and a shortened diesel lifetime due to inadequate maintenance. Many countries must also import their fossil fuels, further magnifying the burden imposed by diesels.

How do small wind turbines compare with other renewable energy technologies suitable for decentralized rural electrification?

Wind power is very competitive with photovoltaics (solar), biomass, and diesel generators, but is usually more expensive than micro-hydro. Wind is also very attractive for the ease with which the technology can be transferred to developing countries. Generally speaking, wind power complements these other power sources by providing a least cost approach under certain conditions. This expands the range of potential projects, pointing to the day when decentralized electrification projects will be implemented on the same scale as current utility line extension projects. In many situations, the lowest-cost centralized system will be a hybrid system that combines wind, photovoltaics and diesel.

Aren't wind turbines too "high-tech" for rural people?

The high technology of a wind turbine is in just a few manufactured components such as the blades. A wind turbine can actually be much simpler than a diesel engine, and also require substantially less attention and maintenance. Some types of small turbines can operate for extended periods, five years or more, without any attention. With training and spare parts, local users can support the wind turbine equipment they use.

What companies make small wind electric systems?

The following AWEA members manufacture small wind electric systems:

- Atlantic Orient Corp.
- Bergey Windpower Co.
- Northern Power Systems
- Southwest Wind Power Co.
- Synergy Power Corp. (Hong Kong)
- Wind Turbine Industries Corp.

What companies make water pumping wind turbines?

The following AWEA members manufacture water pumping wind turbines:

- Bergey Windpower Co.
- Southwest Wind Power Co.
- Synergy Power Corp. (Hong Kong)
- WindTech International

Wind Energy Policy Issues

I've heard that the U.S. utility industry is being "restructured." How will that affect wind energy?

Where wind energy is concerned, utility restructuring will have both positive and negative impacts.

On the positive side, as with long-distance telephone service, restructuring will offer consumers a chance to choose to buy their electricity from among a number of different service providers. Since electricity generation, unlike phone service, has major environmental impacts, it seems likely that some of these service providers will choose to offer "green" (environmentally-friendly) products from clean power sources like wind. Indeed, many electric utilities are already offering wind-generated electricity as an option today.

On the negative side, the primary purpose of restructuring is to allow large industrial companies to shop among power suppliers for the cheapest price. It will do this regardless of the environmental impacts of the sources that are used. Already, this appears to be leading to increasing generation from older, dirtier coal-fired plants that were "grandfathered" (exempted from having to install new pollution controls) under the Clean Air Act. To the degree that restructuring encourages cheap generation regardless of environmental costs, it will be harmful to wind energy.

One solution that has been suggested to some of the problems posed by restructuring is the Renewables Portfolio Standard (RPS) (see next question).

What is the Renewables Portfolio Standard and how does it work?

The Renewables Portfolio Standard (RPS) would require each company that generates electricity in the U.S., or in a given state, to obtain part of the electricity it supplies from renewable energy sources such as wind. To meet this requirement, the company could either generate electricity from renewables itself or buy credits or electricity from a renewable generator such as a wind farm. This "credit trading" system has been used effectively by the federal Clean Air Act to require utilities to reduce pollutant emissions.

Aside from the "minimum renewable content" requirement, the RPS imposes very few other requirements on companies--they are free to buy, trade, or generate electricity from renewables in whatever fashion is most efficient and economical for them. The RPS is therefore often described by its supporters as being "market-friendly," because it allows market forces to decide which renewable energy sources will be developed where, and also allows price competition.

Several federal restructuring bills have included an RPS, and at least 12 states have also adopted RPS laws. Typically, the RPS gradually increases over time, by 1% per year or some such number, in order to encourage the sustained, orderly development of renewable energy industries.

What exactly is "green power"? Can you tell me more about it? How can I buy it?

Green power is a term applied to electricity that is generated from wind and other renewable energy sources, such as solar, geothermal, biomass, and small hydropower. Typically, the environmental impacts of these sources are quite modest compared to those of coal and other conventional sources.

Green power programs vary, but one common approach, called "green pricing," is for a utility to offer its customers the option of buying electricity generated from wind at a premium price. For example, a customer might be able to sign up to receive a certain number of 100-kilowatt-hour "blocks" of electricity from wind each month for an extra $2 each (that is, for 2 cents per kilowatt-hour). A customer signing up for 2 blocks at $2 would pay $4 more for electricity each month and "receive" 200 kilowatt-hours of wind-generated electricity. The utility would then add enough wind capacity to its generating mix to provide the additional electricity required. (The utility cannot deliver specific electrons from any of its plants to a specific customer. Instead, its generating mix should be thought of as a pool. Power plants add electricity to the pool and customers take it out. With green power, the utility adds more wind energy to the pool based on the amount customers have said they desire to purchase.)

A second form of green power is used in states that have opened their electricity markets to competition (in much the same way as long-distance telephone service is now open to competition). In these states, electricity suppliers offer electricity "products" from renewable and other sources, and customers are free to sign up for the product and company they prefer. One company, for example, might offer a product that is called "Earth Saver" that is 50% wind-generated electricity and 50% electricity from landfill gas, and charge 1.5 cents/kWh more than "system power" (regular commodity electricity from the regional generating mix).

A third form of green power is called "green tags" and can be used by consumers anywhere to "green" their electricity supply. With this approach, when a certain amount of electricity (e.g., 1,000 kWh) is generated from a renewable source, a certificate called a "green tag" is created. The generator sells the electricity into the commodity wholesale market, but keeps the certificate (which represents the beneficial environmental attributes of the electricity) and sells it to an interested buyer for an agreed-upon price (e.g., $20, or 2 cents/kWh). By buying green tags that represent the amount of renewable generation equal to your electricity use, you can, in effect, "green" your power supply in much the same way that you would through "green pricing" or "green power"—you are paying extra, and extra renewable energy is being delivered to the utility system based upon your payment.

No one knows yet how successful green programs and products will be in the electricity marketplace. If consumers learn more about the air pollution, strip mining, and other harmful environmental impacts of electricity generation and decide to "vote with their dollars" for clean energy, green power could become a large and growing business over the next decade and beyond.

Customers in many states have the option today to participate in green pricing or green power programs, while of course, customers anywhere can buy green tags. To find out more about your options, check the U.S. Department of Energy's Green Power Network Web site at http://www.eren.doe.gov/greenpower/consumers.shtml.

What about government purchases? Do federal and state governments use their purchasing power to encourage clean energy?

Governments–federal, state, and local–are jointly the largest consumer of energy and electricity in the United States.

In 1998, the federal government alone consumed 1,077 trillion British thermal units (Btu) of energy, or 1.14% of total energy use. Within that total, it consumed approximately 54 billion kilowatt-hours of electricity, or about 1.6% of total national electricity use. The federal government's total energy bill was $8 billion, or 2% of the federal consumption of goods and services. Its electricity bill was approximately $3.5 billion. Perhaps more important, in 1998 the federal government used more than twice as much electricity as was generated by all the solar, wind, and geothermal facilities owned by utilities and the industrial sector nationwide. Federal energy dollars could have a great impact on renewable energy markets.

By and large, the potential of government purchases to encourage clean energy industries has not been realized. In early 1999, President Clinton issued an Executive Order that urges government agencies to consider the federal government's policy of supporting renewable energy in making energy purchases. More recently, the federal Environmental Protection Agency (EPA) has announced that one of its facilities in California will be entirely supplied by green power, and the U.S. Army has announced plans to develop wind energy at Fort Bliss, New Mexico. More commonly, though, government agencies, like industrial companies and many individual consumers, look for the cheapest electricity source, regardless of environmental consequences.

Is wind energy heavily subsidized? More than other forms of energy?

Wind energy currently receives a direct subsidy, the Production Tax Credit (PTC). The PTC provides a tax credit of 1.5 cents per kilowatt-hour (adjusted for inflation, currently 1.7 cents) to the producer of electricity from wind energy. The PTC was an acknowledgement that wind energy can play an important role in the nation's energy mix. It was also a recognition that the federal energy tax code favors established, conventional energy technologies. The wind industry is currently seeking to have the PTC extended for another three years, to December 31, 2006.

All energy technologies are subsidized by the U.S. taxpayer. Subsidies come in various forms, including payment for production, tax deductions, guarantees, and leasing of public lands at below-market prices. Subsidies can also be provided indirectly, for example through federal research and devebpment programs, and provisions in federal legislation and regulations. For example, loopholes in the Clean Air Act currently exempt older power plants from compliance with federal pollution standards and become, in effect, a subsidy that lowers the price of electricity from coal-fired power plants.

Here are some conclusions from a detailed 1993 study of energy subsidies by the Alliance to Save Energy (*Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*):

"Energy subsidies in 1989 favored mature, conventional energy supply resources by \$32.3 billion to \$3.8 billion over non-conventional energy resources." \$21 billion went to fossil fuels, \$11 billion to nuclear, and \$900 million to all renewable energy sources including wind. "There is currently no free market in energy. Given the size of federal energy subsidies, now and in the past, it is erroneous to speak of a 'free market' in energy. . . It may be appropriate to subsidize emerging energy resources, but mature resources should stand the test of the market. When this test is applied to subsidies in 1989, the pattern appears to be almost completely backward. In other words, the mature, conventional technologies received almost 90% of the subsidies."

The pattern of subsidies that the Alliance found is also flatly opposed to the views of the American public. In numerous public opinion surveys over the past several years, those surveyed have favored providing government assistance to clean energy sources and not to nuclear or fossil fuels. For example, in one national poll conducted in mid-1999, 80% of respondents said they favor the use of tax incentives to increase the use of renewable energy for the production of electricity.

What is "net metering" ("net billing") and how does it work?

Net metering or net billing is a term applied to laws and programs under which a utility allows the meter of a customer with a residential power system (such as a small wind turbine) to turn backward, thereby in effect allowing the customer to deliver any excess electricity he produces to the utility and be credited on a one-for-one basis against any electricity the utility supplies to him.

> Example: During a one-month period, John Doe's wind turbine generates 300 kilowatt-hours (kWh) of electricity. Most of the electricity is generated at a time when equipment in John's household (refrigerator, lights, etc.) is drawing electricity and is used on site. However, some is generated at night when most equipment is turned off. At the end of the month, the turbine has generated 100 kWh in excess of John's instantaneous needs and that electricity has been transmitted to the utility system. During the month, the utility also supplied John with a total of 500 kWh for his use at times when the wind turbine was not generating or was insufficient for his needs. Since the meter ran backward while 100 kWh was being transmitted to the utility, the utility will only bill John for 400 kWh, rather than 500 kWh.

Net metering can improve the economics of a residential wind turbine by allowing the turbine's owner to use her excess electricity to offset utility-supplied power at the full retail rate, rather than having to sell the power to the utility at the price the utility pays for the wholesale electricity it buys or generates itself. Many utilities have argued against net metering laws, saying that they are being required, in effect, to buy power from wind turbine owners at full retail rates, and are therefore being deprived of a profit on part of their electricity sales. However, wind energy advocates have successfully argued that what is going on is a power swap, and that it is standard practice in the utility industry for utilities to trade power among themselves without accounting for differences in the cost of generating the various kilowatt-hours involved.

Today, net metering's popularity is growing. Thirty-four states have enacted it in some form, and others are considering it.

Wind Energy Resource Guide

Where can I go for more information?

Trade Associations

American Wind Energy Association
122 C Street, N.W.
Washington, D.C. 20001
(202) 383-2500, fax (202) 383-2505
windmail@awea.org
http://www.awea.org

Kern Wind Energy Association
P.O. Box 277
Tehachapi, CA 93581-0277
(661) 822-7956, fax (661) 331-3868
kweawhite@aol.com

Technical Assistance

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
Technical Inquiries (303) 275-4099
National Wind Technology Center (303) 384-6900
http://www.nrel.gov

General Information

The following publications can be purchased from AWEA. To order, please visit AWEA's **Online Bookstore** at www.awea.org or call the AWEA publications department at (202) 383-2500.)

**Introduction to Small Wind Systems*
published by AWEA
Booklet answering many of the basic questions people have about small wind systems. Topics include: determining your energy needs, siting the turbine, energy backup options, purchasing a system, and operation and maintenance. While this publication is not intended to be a "how-to" manual, it is a useful introduction to small wind systems and their application.

**Understanding Your Wind Resource*
published by AWEA
Booklet designed to give an overview of the nature of wind and the methods of assessing the wind energy potential of a given site. The publication will help the reader understand the methods used in site evaluation and the process of determining a wind resource's viability.

**Wind Power for Home & Business*
by Paul Gipe

A comprehensive guide for those who want to learn how wind energy systems work and how they can tap wind resources.

* *Wind Energy Handbook*
by Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi
Book providing comprehensive treatment of wind energy for electricity generation. Covers issues ranging from practical concerns about component design to the economic importance of sustainable power sources.

**AWEA Membership Directory*
Provides a listing of wind turbine manufacturers, project developers and others, including contact information. (The directory is available only on the World Wide Web, at http://www.awea.org.)

Online Information

AWEA Web site
http://www.awea.org
Contains the AWEA Membership Directory (http://www.awea.org/directory/), free AWEA publications (http://www.awea.org/pubs/complimentary.html), and AWEA Online Bookstore, plus a wide variety of other information about wind energy systems and the wind industry.

References

The Wind Energy Production Tax Credit: A User's Guide
published by AWEA

International Wind Power Markets
by Arthur D. Little

Renewable Energy for New York State–Policy Options for a Clean Energy Future
published by AWEA

Workshop Report: Seventh International Wind-Diesel Workshop, August 22-25, 1993
published by AWEA and the Canadian Wind Energy Association

Electricity Transmission Pricing Report
by Dr. Richard Rosen and Dr. Stephen Bernow
The Tellus Institute, Boston, Mass.

The Most Frequently Asked Questions About Wind Energy was produced by the American Wind Energy Association in cooperation with the U.S. Department of Energy and the National Renewable Energy Laboratory.

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WIND ENERGY FACT SHEET

American Wind Energy Association

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(202) 383-2500

Comparative Cost Of Wind And Other Energy Sources

The cost of wind energy is declining steadily. Long-term forecasts of the early 1990s by Pacific Gas & Electric and the Electric Power Research Institute (EPRI) that wind would ultimately become the least expensive electricity generation source are no longer pipe dreams. It is clear that wind's costs are now in a competitive range with those of mainstream power technologies.

Based on its knowledge of current market conditions, the American Wind Energy Association (AWEA) estimates the levelized cost [1] of wind energy at many of the larger sites as less than 5 cents per kilowatt-hour (kWh), not including the federal production tax credit (PTC). The credit (1.5 cents/kWh, adjusted for inflation) applies to the first 10 years that a new wind plant operates, and can reduce the levelized cost of wind by about 0.7 cents/kWh over the plant's 30-year lifetime.

The following table compares the costs of major energy sources with wind energy. The figures are from the California Energy Commission's 1996 *Energy Technology Status Report [2],* which examined the costs and market readiness of various energy options. The CEC calculations do not include subsidies or environmental costs.

Fuel	Levelized costs (cents/kWh) (1996)
Coal	4.8-5.5
Gas	3.9-4.4
Hydro	5.1-11.3
Biomass	5.8-11.6
Nuclear	11.1-14.5
Wind (without PTC)	4.0-6.0
Wind (with PTC)	3.3-5.3

The cost of natural gas has increased since 1996, so that the levelized cost of gas-fired power plants would now be considerably higher. In January 2001, the cost of natural gas generated power was running as high as 15 cents to 20 cents per kWh in certain markets [3]. The cost of wind power, meanwhile, has declined slightly.

Four additional points about the economics of wind energy should be considered when estimating its relative cost.

First, the cost of wind energy is strongly affected by average wind speed and the size of a wind farm. Since the energy that the wind contains is a function of the cube of its speed, small differences in average winds from site to site mean large differences in production and, therefore, in cost. The same wind plant will, all other factors being equal, generate electricity at a cost of 4.8 cents/kWh in 7.16 m/s (16 mph) winds, 3.6 cents/kWh at 8.08 m/s (18 mph) winds, and 2.6 cents/kWh in 9.32 m/s (20.8 mph) winds. Larger wind farms provide economies of scale. A 3-MW wind plant generating electricity at 5.9 cents per kWh would, all other factors being equal, generate electricity at 3.6 cents/kWh if it were 51 MW in size.

Second, wind energy is a highly capital-intensive technology; its cost reflects the capital required for equipment manufacturing and plant construction. This in turn means that wind's economics are highly sensitive to the interest rate charged on that capital. One study found that if wind plants were financed on the same terms as natural gas plants, their cost would drop by nearly 40%. [4]

Third, the cost of wind energy is dropping faster than the cost of conventional generation. While the cost of a new gas plant has fallen by about one-third over the past decade, the cost of wind has dropped by 15% with each doubling of installed capacity worldwide, and capacity has doubled three times during the 1990s. Wind power today costs only about one-fifth as much as in the mid-1980s, and its cost is expected to decline by another 35-40% by 2006. [5]

Fourth, if environmental costs were included in the calculation of the costs of electricity generation, wind energy's competitiveness would increase further because of its low environmental impacts. Wind energy produces no emissions, so there is no damage to the environment or public health from emissions and wastes such as are associated with the production of electricity from conventional power plants. Wind energy is also free of the environmental costs resulting from mining or drilling, processing, and shipping a fuel. [6]

NOTES

1. Levelized costing calculates in current dollars all capital, fuel, and operating and maintenance costs associated with the plant over its lifetime and divides that total cost by the estimated output in kWh over the lifetime of the plant.
2. California Energy Commission (CEC) *Energy Technology Status Report 1996*. Sacramento. All CEC estimates are in constant dollars as of 1993, with costs "levelized over a typical lifetime (usually 30 years) beginning in 2000" (p. 57). All cost estimates are for investor-owned utility (IOU) ownership.
3. *Wall Street Journal*, January 26, 2001, p B1.
4. Wiser, Ryan, and Edward Kahn. 1996. "Alternative Windpower Ownership Structures." LBNL-38921. Berkeley, Calif.: Lawrence Berkeley Laboratory. May.
5. Chapman, Jamie, Steven Wiese, Edgar DeMeo, and Adam Serchuk. 1998. "Expanding Wind Power: Can Americans Afford It?" Research Report No. 6. Washington, D.C.: Renewable Energy Policy Project.
6. State attempts to set up a process by which some of the environmental costs of electricity production, or externalities, could be taken into account in economic calculations have focused on air emissions alone and set externalities estimates in the range of 3-6 cents per kWh for coal and 0.5 to 2 cents for natural gas. For a comprehensive study of environmental costs, see Richard Ottinger et al.

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WIND ENERGY FACT SHEET

American Wind Energy Association

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WIND ENERGY: AN UNTAPPED RESOURCE

The United States has tremendous wind energy resources. Although California gave birth to the modern U.S. wind industry, 16 states have greater wind potential.

Installed wind energy generating capacity totaled 2,550 MW in 2000 and generated about 5.5 billion kWh of electricity—less than 1% of U.S. electricity generation. By contrast, the total amount of electricity that could potentially be generated from wind in the United States has been estimated at 10,777 billion kWh annually—three times the electricity generated in the U.S. today.

The American wind energy industry is poised for rapid growth in 2001. At least 40 projects in 20 states are proposed to come online, boosting U.S. wind energy capacity by 2,000 MW to 4,500 MW. These new wind farms demonstrate how wind energy can help meet the growing need for affordable, reliable power in the West and other regions of the United States.

THE TOP TWENTY STATES for wind energy potential, as measured by annual energy potential in the billions of kWhs, factoring in environmental and land use exclusions for wind class of 3 and higher.

1	North Dakota	1,210	11	Colorado	481
2	Texas	1,190	12	New Mexico	435
3.	Kansas	1,070	13	Idaho	73
4	South Dakota	1,030	14	Michigan	65
5	Montana	1,020	15	New York	62
6	Nebraska	868	16	Illinois	61
7	Wyoming	747	17	California	59
8	Oklahoma	725	18	Wisconsin	58
9	Minnesota	657	19	Maine	56
10	Iowa	551	20	Missouri	52

Source: *An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, Pacific Northwest Laboratory, 1991.*

For more information, see AWEA's web page at http://www.awea.org.

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Final

Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Volume II

Appendixes A through O

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250

February 2002

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Appendix A

Inventory and Characteristics of Spent Nuclear Fuel, High-Level Radioactive Waste, and Other Materials

APPENDIX A. INVENTORY AND CHARACTERISTICS OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND OTHER MATERIALS

A.1 Introduction

This appendix describes the inventory and characteristics of the spent nuclear fuel and high-level radioactive waste that the U.S. Department of Energy (DOE) anticipates it would place in a monitored geologic repository at Yucca Mountain. It includes information about other highly radioactive material that DOE could dispose of in the proposed repository. It also provides information on the background and sources of the material, present storage conditions, the final disposal forms, and the amounts and characteristics of the material. The data provided in this appendix are the best available estimates of projected inventories.

The Proposed Action inventory evaluated in this environmental impact statement (EIS) consists of 70,000 metric tons of heavy metal (MTHM), comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE materials. The DOE materials consist of 2,333 MTHM of spent nuclear fuel and 4,667 MTHM (8,315 canisters) of solidified high-level radioactive waste. The inventory includes surplus weapons-usable plutonium, which would be in the forms of spent mixed-oxide fuel and immobilized plutonium.

The Nuclear Waste Policy Act, as amended (also called the NWPA), prohibits the U.S. Nuclear Regulatory Commission from approving the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Section 114(d)]. However, in addition to the Proposed Action, this EIS evaluates the cumulative impacts for two additional inventories (referred to as Inventory Modules 1 and 2):

- The Module 1 inventory consists of the Proposed Action inventory plus the remainder of the total projected inventory of commercial spent nuclear fuel (for maximum projections, see Section A.2.1.5.1), high-level radioactive waste, and DOE spent nuclear fuel. Emplacement of Inventory Module 1 wastes in the repository would raise the total amount emplaced above 70,000 MTHM. As mentioned above, emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste would require legislative action by Congress unless a second licensed repository was in operation.

- Inventory Module 2 includes the Module 1 inventory plus the inventories of the candidate materials, commercial Greater-Than-Class-C low-level radioactive waste and DOE Special-Performance-Assessment-Required waste. There are several reasons to evaluate the potential for disposing of these candidate materials in a monitored geologic repository in the near future. Because both materials exceed Class C low-level radioactive limits for specific radionuclide concentrations as defined in 10 CFR Part 61, they are generally unsuitable for near-surface disposal. Also, the Nuclear Regulatory Commission specifies in 10 CFR 61.55(a)(2)(iv) the disposal of Greater-Than-Class-C waste in a repository unless the Commission approved disposal elsewhere. Further, during the scoping process for this EIS, several commenters requested that DOE evaluate the disposal of other radioactive waste types that might require isolation in a repository. Disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require a determination by the Nuclear Regulatory Commission that these wastes require permanent isolation. The present 70,000-MTHM limit on waste at the Yucca Mountain Repository could have to be addressed either by legislation or by opening a second licensed repository.

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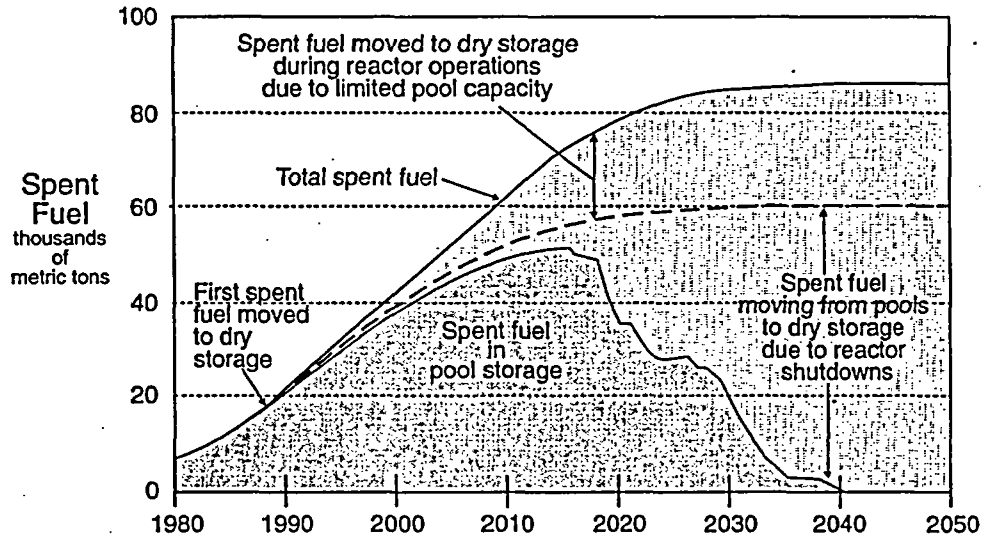
Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance

A Report to Congress
and
the Secretary of Energy

Nuclear Waste Technical Review Board
March 1996

Figure 2:
Movement of spent fuel from pools to dry storage under a no-repository scenario



Note: The figure showing spent fuel in pool storage assumes the movement of all spent fuel from pools to dry storage approximately five years after plant shutdown. Assumptions include: 40-year operating licenses with no renewals and no new plant orders; all spent fuel remains at reactors.

Source: Adapted from DOE, Spent Fuel Storage Requirements: 1992–2036, *Dec. 1993 and DOE,* Spent Fuel Storage Requirements: 1993–2040, *Sept. 1994.*

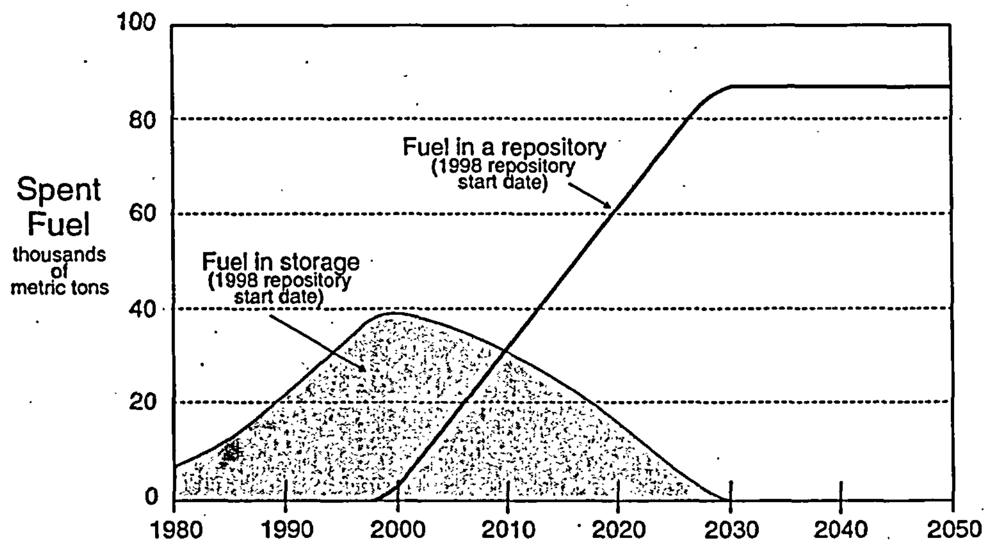
By the year 2000 alone, 25 plants are estimated to require additional spent fuel storage capacity (DOE 1993). Beginning in 2015, much of the fuel moving into dry storage probably will be at shutdown reactors. (See Figure 2.)

Planning for storage

As Figure 3 shows, in the early 1980s when repository operation was expected to begin in 1998, a maximum of about 40,000 metric tons of spent fuel were projected to require storage. Moreover, assuming the DOE's planning number of 3,000 metric tons shipped per year, all of the backlog could have been disposed of by the mid-2020s. On the other hand, if repository operations do not begin until sometime between 2015 and 2020,[4] nearly 80,000 metric tons of spent fuel will require storage. The spent fuel would not be disposed of completely until approximately 2050. As Figure 4 illustrates, each decade of delay

4 The Secretary of Energy projected in testimony submitted to the U.S. Senate that repository operations probably would not begin before 2015 (DOE 1995c).

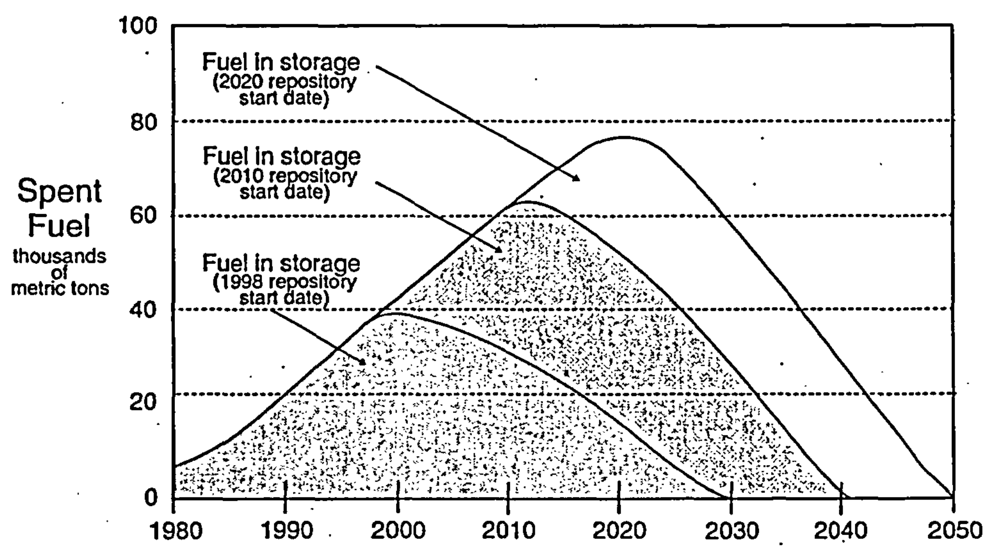
Figure 3:
Storage expectations in early 1980s when the repository start date was 1998



Note: Disposal curve based on 3,000 metric tons/year acceptance rate in a repository after a five-year ramp up. Curves assume 40-year operating licenses with no renewals and no new plant orders.

Source: Storage curves adapted from DOE, Spent Fuel Storage Requirements: 1993–2040, *Sept. 1994.*

Figure 4:
Repository delays increase storage needs by about 20,000 metric tons each decade



Note: Assumes 3,000 metric tons/year acceptance rate in a repository after a five-year ramp up. Curves assume 40-year operating licenses with no renewals and no new plant orders. Recent DOE estimates put repository start date at around 2015.

Source: Storage curves adapted from DOE, Spent Fuel Storage Requirements: 1993–2040, *Sept. 1994.*

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Appendix A

Inventory and Characteristics of Spent Nuclear Fuel, High-Level Radioactive Waste, and Other Materials

Table A-8. Inventory Modules 1 and 2 spent nuclear fuel inventory (MTHM).[a]

Site	Fuel type[b]	1995 actual	1996-2046[c]	Total[d]	Equivalent assemblies	Site	Fuel type[b]	1995 actual	1996-2046[c]	Total[d]	Equivalent assemblies
Arkansas Nuclear One	PWR	643	1,007	1,650	3,757	Monticello	BWR	147	390	537	2,924
Beaver Valley	PWR	437	1,395	1,832	3,970	North Anna	PWR	570	1,384	1,955	4,246
Big Rock Point	BWR	44	14	58	439	Oconee	PWR	1,098	1,576	2,674	5,774
Braidwood	PWR	318	1,969	2,287	5,385	Oyster Creek	BWR	374	470	844	4,619
Browns Ferry	BWR	840	2,508	3,348	18,024	Palisades	PWR	338	395	733	1,845
Brunswick	Both	448	992	1,440	7,355	Palo Verde	PWR	556	3,017	3,573	8,712
Byron	PWR	404	1,777	2,181	5,139	Peach Bottom	BWR	908	1,404	2,312	12,523
Callaway	PWR	280	1,008	1,288	2,953	Perry	BWR	178	732	910	4,974
Calvert Cliffs	PWR	641	1,069	1,710	4,466	Point Beach	PWR	529	614	1,143	2,961
Catawba	PWR	465	1,752	2,217	5,168	Prairie Island	PWR	518	692	1,210	3,234
Clinton	BWR	174	910	1,084	5,876	Quad Cities	BWR	813	1,020	1,834	9,982
Comanche Peak	PWR	176	2,459	2,635	5,816	Pilgrim	BWR	326	444	770	4,170
Cook	PWR	777	1,379	2,155	4,892	Rancho Seco	PWR	228	–[e]	228	493
Cooper	BWR	175	587	762	4,106	River Bend	BWR	176	956	1,132	6,153
Crystal River	PWR	280	525	805	1,734	Salem/Hope Creek	Both	793	2,452	3,245	11,584
Davis-Besse	PWR	243	582	825	1,757	San Onofre	PWR	722	1,321	2,043	5,144
Diablo Canyon	PWR	463	1,725	2,187	4,878	Seabrook	PWR	133	831	964	2,083
Dresden	BWR	1,557	984	2,541	13,740	Sequoyah	PWR	452	1,393	1,845	4,001
Duane Arnold	BWR	258	434	692	3,776	Shearon Harris	Both	498	707	1,205	3,535
Fermi	BWR	155	1,005	1,160	6,429	South Texas Project	PWR	290	2,029	2,319	4,286
Fort Calhoun	PWR	222	312	534	1,485	St. Lucie	PWR	601	1,010	1,611	4,265
Ginna	PWR	282	283	565	1,507	Summer	PWR	225	732	958	2,141
Grand Gulf	BWR	349	1,261	1,610	8,976	Surry	PWR	660	1,029	1,689	3,682
H. B. Robinson	PWR	145	364	509	1,197	Susquehanna	BWR	628	1,745	2,373	13,338
Haddam Neck	PWR	355	65	420	1,017	Three Mile Island	PWR	311	513	825	1,777
Hatch	BWR	755	1,517	2,272	12,347	Trojan	PWR	359	–	359	780
Humboldt Bay	BWR	29	–	29	390	Turkey Point	PWR	616	905	1,520	3,334
Indian Point	PWR	678	1,005	1,683	3,787	Vermont Yankee	BWR	387	434	822	4,451
James A. FitzPatrick/ Nine Mile Point	BWR	882	2,018	2,900	15,732	Vogtle	PWR	335	2,122	2,458	5,378
Joseph M. Farley	PWR	644	1,225	1,869	4,070	Columbia Generating Station	BWR	243	924	1,167	6,476
Kewaunee	PWR	282	330	612	1,591						
La Crosse	BWR	38	–	38	333	Waterford	PWR	253	685	938	2,282
La Salle	BWR	465	1,398	1,863	10,152	Watts Bar	PWR	–	893	893	1,937
Limerick	BWR	432	1,958	2,390	12,967	Wolf Creek	PWR	226	1,052	1,278	2,759
Maine Yankee	PWR	454	82	536	1,421	Yankee-Rowe	PWR	127	–	127	533
McGuire	PWR	714	1,813	2,527	5,720	Zion	PWR	841	211	1,052	2,302
Millstone	Both	959	1,695	2,655	8,930	***Totals***		***31,926***	***73,488***	***105,414***	***359,963***

a. Source: DIRS 155725-CRWMS M&O (1998, all).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. Projected.
d. To convert metric tons to tons, multiply by 1.1023.
e. – = no spent nuclear fuel production.

DOE used the fuel characteristics derived in Section A.2.1.5 and listed in Table A-6 to establish the fission product and radionuclide inventories of the pressurized-water and boiling-water reactor representative fuel assemblies used for accident analyses. For these analyses, DOE included a radionuclide contribution from activated corrosion products deposited on the surfaces of spent nuclear fuel assemblies during reactor operation. This material is called *crud.*

DOE used the fuel assembly surface concentration values in *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et. al. 2000, all) to develop the radioactive inventory from crud. The crud contains eight radionuclides. However, because all of these radionuclides except cobalt-60 decay rapidly, after storage (aging) for 5 years or longer, cobalt-60 is the only significant radionuclide remaining. The surface concentration values at discharge from the reactor range from 2 to 140 microcuries per square centimeter for pressurized-water reactor fuel assemblies and from 11 to 595 microcuries per square centimeter for boiling-water reactor assemblies, based on measurements of fuel rods (DIRS 152476-Sprung et al. 2000, p. 7-48; DIRS 103696-Sandoval 1991, all). Due to the wide range in concentration values and the limited number of measurements, DOE elected to use the maximum (cobalt-60) crud concentration numbers (DIRS 152476-Sprung et al. 2000, p. 7-48).

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United States General Accounting Office

GAO

Report to Congressional Requesters

December 2001

NUCLEAR WASTE

Technical, Schedule, and Cost Uncertainties of the Yucca Mountain Repository Project

GAO

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GAO-02-191

complete through submission of a license application and the estimated schedule and cost to complete this work.[11]

When Bechtel was contracted to manage the nuclear waste program, one of its first assignments was to document the remaining technical work that had to be completed to support the submission of a license application and to estimate the time and cost to complete this work. The contractor's revised, unofficial baseline for the program shows that it will take until January 2006 to complete essential technical work and submit an acceptable license application. DOE also estimated that completing the remaining technical work would add about $1.4 billion to the cumulative cost of the program, bringing the total cost of the Yucca Mountain project's portion of the nuclear waste program to $5.5 billion.[12] As noted above, DOE has not accepted Bechtel's proposed new baseline extending out until January 2006. Instead, DOE is considering accepting, at present, only that portion of the baseline that Bechtel proposed to complete in fiscal year 2002.

Extension of License Application Date Will Likely Postpone 2010 Repository Goal

An extension of the license application date to 2006 would almost certainly preclude DOE from achieving its long-standing goal of opening a repository in 2010. According to DOE's May 2001 report on the program's estimated cost, after submitting a license application in 2003, DOE estimates that it could receive an authorization to construct the repository in 2006 and complete the construction of enough surface and underground facilities to open the repository in 2010, or 7 years after submitting the license application. This 7-year estimate from submittal of the license application to the initial construction and operation of the repository assumes that NRC would grant an authorization to construct the facility in 3 years, followed by 4 years of construction. Assuming these same estimates of time, submitting a license application in January 2006 would extend the opening date for the repository until about 2013.

[11] In 1998 and 2000, independent cost and schedule reviews of the program were performed by DOE contractors. On the latter review, the contractor concluded that DOE's schedule for licensing, constructing, and opening the repository by 2010 was optimistic by about 2 years and that DOE's estimate of the total cost of the program over its 100-plus-year lifetime—$58 billion (2000 dollars)—was understated by about $3 billion.

[12] DOE estimated that the program cost $4.1 billion, on the basis of year-of-expenditure dollars from the program's inception in 1983 through March 2002. The $5.5 billion estimate for the license application is based on year-of-expenditure dollars from 1983 through January 2006.

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

November 25, 2003

Dr. Margaret S. Y. Chu
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Chu:

We are pleased to transmit a technical report prepared by the Nuclear Waste Technical Review Board (Board) that includes additional analyses supporting the Board's conclusions related to corrosion in its October 21, 2003, letter to you. Although the enclosed report touches on a variety of corrosion issues, its main focus is the potential for deliquescence-induced localized (or crevice) corrosion of the Alloy 22 waste packages in the Department of Energy's proposed high-temperature repository design. The conditions used by the Board for its analyses were presented by the DOE at the Board's January and May 2003 meetings. The report also evaluates the vaporization barrier and capillary barrier concepts that were discussed at the May meeting. Appended to the report are some additional technical comments by Dr. Michael Corradini.

Based on its review of data gathered by the DOE and the Center for Nuclear Waste Regulatory Analyses, the Board believes that all the conditions necessary to initiate localized corrosion of the waste packages will likely be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse. Corrosion experiments indicate that localized corrosion is likely to be initiated if waste package surface temperatures are above 140°C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present. Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence. (Crevices are widespread on the waste packages, arising from their design as well as from contacts between the metal and dust particles.)

Thus, the Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides.

The Board is aware that the DOE believes that the conditions in the repository will not promote significant corrosion. The DOE points to data, gathered using thermogravimetric apparatus (TGA), to demonstrate that the conditions necessary to initiate localized corrosion will be present only briefly. The Board has evaluated these data and finds them inadequate to support the DOE's claim for the following reasons.

- Brines used in the TGA experiments may not be representative of those that would form on the waste packages because of deliquescence.
- The metallic coupons used in the experiments did not contain crevices.

- The TGA experiments have been run only over narrow ranges of temperature and relative humidity.
- The experimental apparatus is an "open" system that may not approximate short-term behavior of the microenvironment associated with crevices.
- The results from other experiments conducted by the DOE seem contradictory.

The DOE also holds that the conditions under which localized corrosion might occur are extreme and unlikely. The information provided to the Board to date, however, does not form a compelling basis for that contention. For example, the DOE maintains that the presence of nitrates and an insufficient amount of calcium chloride in the proposed repository tunnels will limit localized corrosion. The DOE's own data, however, indicate that nitrate may not be protective at temperatures higher than 140°C. Furthermore, as noted above, the Board has concluded that more than enough chloride would be present in the dust from the tunnels to lead to widespread localized corrosion.

Thus, the DOE's belief that the geochemical environment on the waste package surfaces *will not* lead to corrosion lacks a strong technical basis. Absent that basis, the Board cannot ignore the clear and unambiguous implications of the corrosion and deliquescence experiments.

As stated in our October 21 letter, the Board realizes that decision-makers must take into account considerations beyond technical and scientific ones when making program decisions. However, because of the significance of the waste packages to the proposed repository system, the Board believes that the potential for localized corrosion during the thermal pulse should be addressed. From a technical perspective, the problems related to localized corrosion that are described by the Board in the enclosed report could be avoided if the repository design and operation were modified. The data currently available indicate that perforation of the waste packages caused by localized corrosion is unlikely if their temperatures are kept below 95°C.

The Board looks forward to continuing its review of the DOE's investigations at Yucca Mountain, including those dealing with the integrity of the waste packages.

Sincerely,

Michael L. Corradini, Chairman	Mark D. Abkowitz
Daniel B. Bullen	Thure E. Cerling
Norman L. Christensen, Jr.	Paul P. Craig
David J. Duquette	Ronald M. Latanision
Priscilla P. Nelson	Richard R. Parizek

placed, and the saturated zone beneath the underground facility. Each of these barriers, or a combination of them, will likely play some role in isolating and containing the radioactive waste. Nevertheless, the Board believes that two of the primary barriers, the waste package and the unsaturated zone above the repository horizon, could be less effective than indicated by the DOE's analyses.

V. Overall Board Conclusions

Conclusions regarding the likelihood and extent of localized corrosion

On the basis of the DOE's temperature and relative humidity calculations and salts in dust deposited on waste package surfaces, all the conditions necessary to initiate localized corrosion of the waste packages will likely be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse. Furthermore, in the Board's opinion, the DOE has not firmly established its conclusion that corrosion would not be caused by water seeping into drifts during the thermal pulse. Localized corrosion is likely to propagate during the remainder of the thermal pulse and is likely to continue even after the thermal pulse at temperatures below 95°C. Because of the high temperatures of the current repository design and operation, this localized corrosion will result in the perforation of the waste packages. The data currently available to the Board indicate that perforation caused by localized corrosion is unlikely if waste-package surface temperatures are kept below 95°C.

Conclusions regarding the existence of multiple barriers and defense-in-depth

If the Board's interpretation of the data and analyses presented by the DOE is correct, an important engineered element of the DOE's current repository design, the waste package, will be susceptible to corrosion during and following the thermal pulse. There also may be more seepage, and thus potentially more and earlier transport of at least some radionuclides, than the DOE now projects. The contribution of the other natural barriers to radionuclide isolation depends on complex modeling calculations whose uncertainties are high and will remain high for many years. Therefore, although some combination of multiple barriers will be operating at various times in the repository, the capability of those barriers to provide meaningful defense-in-depth—that is, redundancy—in isolating and containing radionuclides is unclear with the DOE's high-temperature design.

Do the Board's technical conclusions have significant effect on performance calculations for the repository system *as a whole*? Although a precise statement about whether, or how much, dose might be increased or the safety margin decreased cannot be made given the existing uncertainties, the Board believes that the implications of the Board's conclusions for repository system performance could be substantial.[45] Therefore, it is incumbent on the DOE to demonstrate unambiguously the reliability and safety of any design concept for Yucca Mountain.