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NUCLEAR POWER AND NUCLEAR BOMBS

After the final no there comes a yes
And on that yes the future of the world depends.
—Wallace Stevens

The nuclear proliferation problem, as posed, is insoluble. All policies to control proliferation have assumed that the rapid worldwide spread of nuclear power is essential to reduce dependence on oil, economically desirable, and inevitable; that efforts to inhibit the concomitant spread of nuclear bombs must not be allowed to interfere with this vital reality; and that the international political order must remain inherently discriminatory, dominated by bipolar hegemony and the nuclear arms race. These unexamined *assumptions*, which artificially constrain the arena of choice and maximize the intractability of the proliferation problem, underlay the influential Ford-MITRE report and were embodied in U.S. policy initiatives under Gerald Ford and especially Jimmy Carter to slow the spread of plutonium technologies.[1] Identical assumptions underlay the recently concluded multilateral two-year International Nuclear Fuel Cycle Evaluation (INFCE), whose lack of sympathy for those U.S. initiatives is now

[1] *Nuclear Power Issues and Choices: Report of the Nuclear Energy Policy Study Group*, Sponsored by the Ford Foundation, Administered by The MITRE Corporation, Cambridge, Mass: Ballinger Publishing Company, 1977.

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being cited as a political and technical rationale for dismantling what is left of them.[2] Unfortunately, INFCE's assumptions were widely represented as its *conclusions*, ostensibly resulting from a careful assessment of alternatives which never actually took place.

Our thesis rests on a different perception. Our attempt to rethink focuses not on marginal reforms but on basic assumptions. In fact, the global nuclear power enterprise is rapidly disappearing. De facto moratoria on reactor ordering exist today in the United States, the Federal Republic of Germany, the Netherlands, Italy, Sweden, Ireland, and probably the United Kingdom, Belgium, Switzerland, Japan and Canada. Nuclear power has been indefinitely deferred or abandoned in Austria, Denmark, Norway, Iran, China, Australia and New Zealand. Nuclear power elsewhere is in grave difficulties. Only in centrally planned economies, notably France and the U.S.S.R., is bureaucratic power sufficient to override, if not overcome, economic facts. The high nuclear growth forecasts that drove INFCE's endorsement of fast breeder reactors are thus mere wishful thinking. For fundamental reasons which we shall describe, nuclear power is not commercially viable, and questions of how to regulate an inexorably expanding world nuclear regime are moot.

We shall argue that the collapse of nuclear power in response to the discipline of the marketplace is to be welcomed, for nuclear power is both the main driving force behind proliferation and the least effective known way to displace oil: indeed, it *retards* oil displacement by the faster, cheaper and more attractive means which new developments in energy policy now make available to all countries. So far, nonproliferation policy has gotten the wrong answer by persistently asking the wrong questions, creating "a nuclear armed crowd" by assuming its inevitability.[3] We shall argue instead that acknowledging and taking advantage of the nuclear collapse, as part of a pragmatic alternative program, can offer an internally consistent approach to nonproliferation, as well as a resolution to the bitter dispute over Article IV of the Non-Proliferation Treaty (NPT).

[2] The INFCE study was published in eight volumes in February 1980 by the International Atomic Energy Agency. For critiques of the collapse of the 1976–77 U.S. policy initiatives, see Vince Taylor, "A Review of Recent Efforts to Halt the Spread of Nuclear Weapons: Lessons for the Future," typescript, January 25, 1978, available from the Union of Concerned Scientists, Cambridge; Harry Rowen and Albert Wohlstetter, "U.S. Non-Proliferation Strategy Reformulated," Marina del Ray, CA: Pan Heuristics, 1979; and, for typical recent news, R. Jeffrey Smith, "Nonproliferation Policy Challenged," *Science*, May 2, 1980, p. 178.

[3] Albert Wohlstetter *et al.*, *Moving Toward Life in a Nuclear Armed Crowd?*, report ACDA/PAB-263 to the U.S. Arms Control and Disarmament Agency, 1976, Pan Heuristics. Our intellectual debt to Professor Wohlstetter is reflected throughout this article.

On the eve of the Second NPT Review Conference, to be held in Geneva in August 1980, fatalism is becoming fashionable as the headlines show proliferation slipping rapidly out of control. Yet seeking Stevens's courage to affirm, we shall suggest that an effective nonproliferation policy, though impossible with continued commitments to nuclear power, may become possible without them—if only we ask the right questions.

II

All concentrated fissionable materials are potentially explosive. All nuclear fission technologies both use and produce fissionable materials that are or can be concentrated. Unavoidably latent in those technologies, therefore, is a potential for nuclear violence and coercion. Most of the knowledge, much of the equipment, and the general nature of the organizations relevant to making bombs are inherent in civilian nuclear activities, and are "in much of their course interchangeable and interdependent" for peaceful or violent uses.[4]

All commercial nuclear fuel cycles are fueled with uranium.[5] Natural uranium as mined contains only 0.71 percent of the fissionable isotope uranium-235. Both this concentration and the few percent of uranium-235 present in "low-enriched uranium" (LEU) are too dilute to be explosive. Practicable bombs require concentrations of tens of percent; highly efficient bombs, about ninety percent ("highly enriched uranium" or HEU). A few minor types of commercial reactors, notably the Canadian CANDU, are fueled with natural uranium. The dominant world type, the U.S.-designed light-water reactor (LWR), is fueled with LEU. One prospective commercial type (the high-temperature gas-cooled reactor) and many research reactors are fueled with directly bomb-usable HEU.

The irradiation of uranium fuel in any reactor produces plutonium, which is a bomb material regardless of its composition or chemical form. The plutonium is contained in the discharged spent fuel, highly diluted and intimately mixed with fission products whose intense radioactivity makes the spent fuel essentially inaccessible for at least a century. The plutonium is thus a

[4] This fact was recognized in the Acheson-Lilienthal report, "A Report on the International Control of Atomic Energy," U.S. State Department 2498, March 16, 1946.

[5] Experimental fuel cycles which breed fissionable uranium-233 from nonfissionable thorium differ only in detail, not in conclusions. See Amory B. Lovins, "Thorium cycles and proliferation," *Bulletin of the Atomic Scientists*, February 1979, pp. 16-22, and discussions *id.* May 1979, pp. 50-54, and September 1979, pp. 57-59.

proliferation risk only if it is extracted by "reprocessing" the spent fuel behind heavy radiation shielding—chopping up and dissolving the fuel bundles and chemically separating the purified plutonium. It is then in a concentrated, homogeneous and divisible form that can be safely handled, is hard to measure precisely, and is therefore much easier to steal undetected. Extracted plutonium can be made into bombs so quickly (in days or hours) that even instant detection cannot provide "timely warning," the cardinal principle of safeguards since the start of the nuclear age.

U.S. nonproliferation policy since 1976 has rested on distinctions between proliferation-prone fuel cycles and fuel cycles thought to be proliferation-resistant. LWRS were considered highly proliferation-resistant so long as technologies or services which could further enrich the LEU fresh fuel or extract plutonium from the spent fuel were not available to non-weapons states. It was considered possible for such states to obtain these technologies on their own, but only at high cost, with great technical difficulty, and with a large risk of timely detection. Reprocessing spent LWR fuel in conventional large plants, for example, is so difficult that no country has yet succeeded in doing it on a reliable commercial basis.

In return for an open-ended fee with no guarantee of performance (estimated costs rose thirteenfold in 1974-78 and are still rising), Britain and France are nonetheless proposing to expand their existing, rather unsuccessful, reprocessing plants to provide export services, thus relieving others of the technical difficulties. However, proposed technical measures to inhibit the use of the extracted and re-exported plutonium in bombs—chiefly by diluting or radioactively contaminating it so that further treatment would be needed—have been shown to be impracticable or ineffectual (especially against governments). International management or weapons-state siting of the reprocessing plant cannot affect how the re-exported plutonium is used.

Because commerce in plutonium therefore poses grave risks to peace, and because neither it nor the reprocessing plants supplying it can be safeguarded even in principle, the United States sought by its own example, and for a time by mild persuasion (but not by exercising its legal veto over reprocessing U.S.-enriched fuel), to discourage Britain and France from breaching the formidable barrier offered by the difficulties of reprocessing. As further recommended by the Ford-MITRE report, the United States also sought to defer as long as possible domestic and foreign commitments to widespread use of fuel cycles requiring reprocessing—

recycling plutonium in LWRS and breeding it in fast reactors. "Once-through" (no-reprocessing) LWRS, on the other hand, were encouraged for domestic use and for export because of their alleged proliferation resistance.

Advocates of reprocessing and plutonium commerce assaulted the U.S. policy on two contradictory grounds: that power reactors did not make plutonium that would be attractive to bomb-makers, and that if they did, commercial reprocessing was not the only way to extract it. The first limb of this argument claimed that the "reactor-grade" plutonium made by normal operation of power reactors—currently some 30 tons (about 10,000 bombs' worth) per year, a third of it in non-weapons states—could produce only weak and unreliable explosions, and posed exceptional hazards to persons working with it. Countries seeking bombs would therefore pass up this inferior material in favor of "weapons-grade" plutonium whose greater isotopic purity offered optimal performance. Weapons-grade plutonium could be made in existing research reactors (now operating in about 30 countries) or in "production reactors" specially built for the purpose from published designs. This route was claimed to be easier, cheaper, more effective, hence more plausible than using power reactors. Concern over power reactors was thus deemed to be far-fetched.

The technical premise behind this reasoning, however, is false. A detailed analysis of weapons physics has now shown that any practical composition of plutonium—including both "reactor-grade" plutonium and plutonium to which inseparable interfering ("denaturing") isotopes have been deliberately added—can be made by governments or by some subnational groups into bombs equivalent in power and predictability to those made from "weapons-grade" plutonium.[6] Alternatively, power reactors can be so operated as to produce modest amounts of the latter without significantly increasing costs, decreasing efficiency, or being detected.

More sophisticated bomb design is needed to achieve the same performance from reactor-grade as from weapons-grade plutonium, but this may be a small price to pay for the greater ease of obtaining the former in bulk. The power reactor has an innocent civilian "cover" rather than being obviously military like a special production reactor. It is available to developing countries at zero or negative real cost with many supporting services. It bears no

[6] The analysis may be found in Amory B. Lovins, "Nuclear weapons and power-reactor plutonium," *Nature*, February 28, 1980, pp. 817-823, and typographical corrections, March 13, 1980, p. 190.

extra cost in money or time if one were going to build a power reactor anyhow. And it produces extremely large amounts of plutonium: so large that theft of a few bombs' worth per year is within the statistical "noise" and can be made undetectable in principle, while nearly a hundred bombs' worth per reactor per year—more than from any other option—is available if overtly diverted. Power reactors, then, can be considered large-scale military production reactors with an electricity by-product rather than benign electricity producers with a militarily unattractive plutonium by-product. They are not, as INFCE held, an implausible but rather potentially a peculiarly convenient type of large-scale factory for bomb material.

Of course plutonium in spent fuel from any kind of reactor is unusable in bombs until extracted by reprocessing, and it is here that plutonium advocates mounted their second line of attack. The official U.S. view was that reprocessing is very hard, whereas making bombs is relatively easy, so reprocessing should be inhibited. Plutonium advocates retorted that, on the contrary, making bombs is very hard but reprocessing relatively easy. To support this claim, Oak Ridge scientists developed a conceptual design for a "quick-and-dirty" reprocessing plant which could allegedly separate a bomb's worth of plutonium per week, with only a modest risk of detection during the relatively short construction time (of the order of a year).[7] Restraints on commercial reprocessing (its advocates then argued), and indeed the timely warning concept itself, were futile because any country seeking bombs could build its own crude reprocessing plant and get plutonium from its domestic spent fuel anyhow.

This double-edged argument was inconsistent, however, with the same advocates' reassurances that providing commercial reprocessing services would dissuade recipient countries from building their own plants; that international safeguards could be relied upon; and that bomb-making could be prevented by returning the plutonium "spiked" with unapproachably radioactive contaminants. (The recipient country could use its crude reprocessing plant to winnow out the plutonium from the spikants even more easily than from the original spent fuel.)

Thus the measures supposed to make reprocessing "safe" do not work. An argument meant to show there was no point discrimi-

[7] Though some details of the Oak Ridge design were criticized by other experts, the broad feasibility of its approach was confirmed by the U.S. government's official Nonproliferation Alternative Systems Assessment Program (NASAP): "Nuclear Proliferation and Civilian Nuclear Power," U.S. Department of Energy, DOE/NE-0001, December 1979, Vol. 1, p. 42 (draft).

nating against plutonium technologies showed only the wider dangers of all fission technologies. Far from showing plutonium cycles were safe, it showed only that the rival once-through cycles were nearly as dangerous. For the real implication of the Oak Ridge design was that the reprocessing barrier is not so substantial after all: that both bomb-making *and* reprocessing are relatively easy (if normal requirements of profitability, environmental control, and worker safety are greatly relaxed).

This conclusion has been reinforced by the recent invention in several countries of unconventional medium- and small-scale methods of plutonium recovery, as yet untested, that are alleged to be substantially cheaper, simpler and less conspicuous than normal reprocessing plants. If, as appears likely, at least one of these new methods or the Oak Ridge concept proves valid, then it does not mean merely the end of the old timely warning concept: it means rather that timely warning can be provided neither for separated plutonium *nor* for spent fuel, so that *all* nuclear fission will be unsafeguardable in principle.

The Ford-Carter policy that reprocessing is very dangerous, therefore, was correct but did not go nearly far enough. By emphasizing that plutonium fuel cycles are *more* dangerous than once-through cycles, it glossed over the risks of the latter. The INFCE findings that there is no technical solution to the plutonium problem, and that once-through fuel cycles are not necessarily far less proliferative than plutonium cycles, are also broadly correct; for they imply, however unintentionally, that reactors of *any* kind are significantly proliferative, and that matters are much worse than the Ford-MITRE analysis and the Ford-Carter policy supposed.

To make matters worse still, more careful scrutiny of the supposedly innocuous front end of the fuel cycle—the use of natural uranium or LEU as fresh reactor fuel—has lately suggested a similar conclusion on independent grounds. Natural uranium can be gradually enriched to bomb-usable concentrations using low-technology centrifuges. LEU can be enriched more than twice as easily. An effective centrifuge design was published 20 years ago. Better versions—much less efficient than high-technology commercial versions, but still adequate—can be, and have been, made by a good machinist in a few weeks. Non-nuclear commercial centrifuges may also be adaptable to uranium enrichment. Though tens or hundreds of centrifuges and tons of uranium would be needed for patient accumulation—perhaps requiring years—of even one bomb's worth of HEU, the centrifuges are simple, modular, concealable, relatively cheap, and highly accessible. The uranium, mined in tens of thousands of tons per year worldwide, would be even easier to get. Thus even without assuming any breakthroughs in fast-moving new enrichment technologies—simplified laser methods, or perhaps the newly discovered magnetochemical methods--old, straightforward centrifuge designs suffice to make even natural uranium, as Bernard Baruch noted in 1946, a "dangerous" material.

There are also disquieting indications that without using any conventional facilities such as LWRS or reprocessing plants, and without serious risk of detection, one unirradiated LWR fuel bundle (about a hundredth of a reactor's annual fuel requirement) could be made into one bomb's worth of separated plutonium in one year by one technician with about one or two million dollars' worth of other materials that are available over the counter and apparently subject to no controls. So far as is publicly known, this novel basement-scale method has not yet been used, but the calculations suggesting its feasibility—unpublished for discretion—appear valid. U.S. authorities were apprised of this method during 1978-79, but no published assessment mentions it. A vivid if indirect confirmation that no fuel-cycle material is officially considered "safe," however, comes from the new U.S.-sponsored Convention on the Physical Protection of Nuclear Material. This makes it an extraditable international crime (like genocide or piracy) for unauthorized persons to meddle with any fissionable material other than uranium ore or tailings, and explicitly *including* both LEU (such as LWR fuel) and purified natural uranium.

The proliferative routes just mentioned are only the latest additions to an already long list: conventional enrichment technologies, research and production reactors, direct use of bomb materials of which many tons have been exported (mainly by the United States) for worldwide research, theft of nuclear submarine fuel, theft and dismantlement of military bombs, theft of military bomb components. Collectively, both familiar and newly emerging routes to bombs imply that *every* form of *every* fissionable material in *every* nuclear fuel cycle can be used to make military bombs, either on its own or in combination with other ingredients made widely available by nuclear power. Not all the ancillary operations needed are of equal difficulty, but none is beyond the reach of any government or of some technically informed amateurs. The propagation of nuclear power thus turns out to have embodied the illusion that we can split the atom into two roles as easily and irrevocably as into two parts—forgetting that atomic energy is a-tomic, indivisible.

Can conceivable "safeguards" weaken this stark conclusion? Political arrangements for safeguards must rest on technical measures for materials accounting and for physical security. The former measures are so imprecise and *post hoc* that they cannot, even in principle, provide reasonable assurance that many bombs' worth of plutonium per year are not being removed from a good-sized reprocessing plant. Primary reliance must therefore be placed on physical security measures to limit access to materials and to deter or prevent their removal (or, if they are removed, to recover them). These measures must forestall well-equipped groups, perhaps including senior insiders acting in concert with the host government or a faction of it. Even modestly effective measures would be costly, fallible and intrusive. In the Federal Republic of Germany, for example, they would exceed the authority of the Atomic Energy Act; amending it to permit them would be unconstitutional; and amending the Constitution to permit them would conflict with human rights instruments to which the Federal Republic is a party.[8]

The institutional arrangements which rely on these inherently inadequate accounting and security measures are woven around the International Atomic Energy Agency (IAEA), the Non-Proliferation, EURATOM, and Tlatelolco Treaties, and bilateral agreements. Though these are a considerable achievement, they have well-known and collectively fatal flaws, including: non-adherence of half the world's population, including two of the five acknowledged weapons states (France, China), all three suspected ones (India, Israel, South Africa), and all major developing countries except Iran and Mexico; freedom to renounce; no prohibition on designing bombs or building and testing their non-nuclear components; unsafeguarded duplicate facilities; inadequate inspection staff, facilities and morale; virtual absence of developing-country nationals in key IAEA safeguards posts; high detection threshold; freedom of host governments to deceive, reject, hinder or intimidate inspectors or to restrict their access (especially their unannounced access); unknown effectiveness owing to confidentiality; ambiguous agreements; and unsupported presumption of innocent explanations. The IAEA has already detected diversions of quantities too small for bombs and decided they did not justify even notifying the supplier states concerned.[9] IAEA inspectors

[8] Paul Sieghart, Chapter 4.4 in the Gorleben International Review's Report, *Bericht des Internationales Gutachen Gorlebens für Niedersächsisches Sozialministerium*, Hannover, April 1979.

[9] Rudolf Rometsch, remarks in panel discussion before the Institute of Nuclear Materials Management, June 20, 1975, reprinted in *Hearings on the Export Reorganization Act of 1976* before the Senate Committee on Government Operations, Washington: GPO, 1976, pp. 1214-17.

"have found many [suspicious] indications and acts . . . , but IAEA has never taken action on any of them. This will proba continue to be true."[10] It is no wonder. All the resources of U.S. government, in more than a decade of repeated invest tions, were unable to determine whether suspected pluton thefts at the Numec plant in Apollo, Pennsylvania had occur Large HEU losses over many years at an Erwin, Tennessee p crucial to U.S. naval reactor fuel supply led in 1979 to rel accounting standards that would make the losses look "acce ble." How, then, could suspected thefts in and perhaps recalcitrant foreign country be investigated?

Finally, the momentum and bureaucratic entrenchmen nuclear programs generally prevent effective sanctions ag even an obvious, sharp violation, let alone a dimly suspec creeping one. The breach of EURATOM safeguards by the the a 200-ton shipload of natural uranium in 1968 was kept secre nearly ten years. A decade's advance knowledge of the In bomb program by the U.S. and Canadian governments prod only diplomatic murmurs, and the actual test, as Albert W stetter remarks, "inspired only ingenious apologies" from the State Department—anxious to conceal the U.S. contributio heavy water—and a congratulatory telegram from the chair of the French Atomic Energy Commission. As front pages hera the Pakistani bomb program, Pakistan was being unanim elected to the IAEA's Board of Governors.

In short, we can have proliferation with nuclear power either end of any fuel cycle. We cannot have nuclear p without proliferation, because safeguards cannot succeed eith principle or in practice. But can we have proliferation wi nuclear power?

It is true that naval reactor fuel and military bombs pr non-civilian routes to more bombs; but that means only nuclear armaments encourage their own refinement, multip tion and spread, not that there are significant civilian bomb r unrelated to nuclear power. With trivial exceptions unimpo to this argument—radioisotope production reactors, large pa accelerators, proposed fusion reactors—*every* known civilian to bombs involves *either* nuclear power *or* materials and tech gies whose possession, indeed whose existence in commerce direct and essential consequence of nuclear fission power. A gists, apparently intending to be reassuring, often state noneth

[10] David M. Rosenbaum, "Nuclear Terror," *International Security*, Winter 1977, pp. 1

that since power reactors themselves are only one of (say) eight ways to make bombs, restraining power reactors is like sticking a thumb in one of eight holes in a dike. But the other holes were made by the same drill. Arguing that reactors have little to do with bombs is like arguing that fishhooks do not cause the catching of fish, since this can also involve rods, reels and anglers.

The foregoing reasoning implies that eliminating nuclear power is a necessary condition for nonproliferation. But how far is it a sufficient condition? Suppose that nuclear power no longer existed. Again, with trivial exceptions,[11] there would no longer be any innocent justification for uranium mining (its minor non-nuclear uses are all substitutable), nor for possession of ancillary equipment such as research reactors and critical assemblies, nor for commerce in nuclear-grade graphite and beryllium, hafnium-free zirconium, tritium, lithium-6, more than gram quantities of deuterium, most nuclear instrumentation—the whole panoply of goods and services that provides such diverse routes to bombs. If these exotic items were no longer commercially available, they would be much harder to obtain; efforts to obtain them would be far more conspicuous; and such efforts, if detected, would carry a high political cost because for the first time they would be *unambiguously military* in intent.

This ambiguity—the ability of countries, willfully or by mere drift, to conduct operations (in Fred Iklé's phrase) "indistinguishable from preparations for a nuclear arsenal"—has gone very far. An NPT signatory subject to the strictest safeguards can quite legally be closer to having working bombs than the United States was in 1947.[12] For example, precisely machined HEU spheres have recently been seen in Japan, doubtless for purely peaceful criticality experiments. But they could also be hours away from bombs.

Bernard Baruch warned in 1946 that the line dividing "safe" from "dangerous" (proliferative) nuclear activities would change and need constant reexamination. No mechanism to do this was ever set up. The variety and ease of proliferative paths expanded unnoticed to embrace virtually all activities once presumed "safe," while most of those activities were enthusiastically broadcast worldwide. Yet their direct facilitation of bomb-making was prob-

[11] The only one of substance is the use of small research reactors to make medical and allied radioisotopes. This is such a specialized small-scale operation that effective international controls could be realistically contemplated.

[12] Albert Wohlstetter, "Spreading the Bomb Without Quite Breaking the Rules," *Foreign Policy*, Winter 1976/7, pp. 88-96.

ably a less grave threat than the innocent disguise which t
pursuit lent, and lends, to bomb-making. Baruch, noting
importance of adequate "advance warning... between viola
and preventive action or punishment," had sought a technolog
monopoly so that visible operation or possession of "dangero
steps other than by a special international authority, regardles
purpose, "will constitute an unambiguous danger signal." To
with dozens of countries on the brink of a bomb capacity, suc
neat solution is temporarily forestalled. But the principle rem
sound: detection and deterrence of bomb-making require tha
be unambiguously identifiable; and for that, phasing out nucl
power and the supporting services it justifies would be bot
necessary and a sufficient condition.

Removing the present ambiguity will not make proliferat
impossible. Pakistan, both operating and planning power react
sought a French reprocessing plant rationalized as an aid
energy independence, then, when thwarted, decided to pu
bombs more directly with clandestine centrifuges whose advan
design was stolen (as predicted) from the Netherlands. Pakis
probably did not expect that effort to be accidentally unmas
at an early stage, but was presumably willing to bear the polit
cost of eventual detection (if there was one: India has not yet b
made to bear such a cost). Yet the key point is that the react
the uranium supply allegedly needed for them, the hoped
reprocessing plant, the participation of the Pakistani spy in
Dutch project, the existence of that project and of the urani
mining industry itself—all were justified and cloaked in benig
by nuclear power.

For bomb-making by any route, denuclearization would gre
increase the technical difficulty of obtaining the ingredients,
would automatically stigmatize suppliers as knowing accesso
before the fact, hence clear violators of NPT Article I in lette
spirit. By providing unambiguous danger signals, denucleariza
would make the political costs and risks to all concerned
high—perhaps prohibitively high. This does not mean tha
determined and resourceful nation bent on bombs can by
military means be absolutely prevented from getting them: m
is already out of the barn. But denuclearization would bran
military the use of those escaped resources and inhibit
augmentation and spread. It would narrow the proliferative
to exclude the vast majority of states—the latent proliferators
sidle up to the nuclear threshold by degrees, and those e
tempted.

Yet is not the complete civil (and, in due course, military) denuclearization required to remove every last shred of ambiguity a fantastic, unrealistic, unachievable goal? On the contrary, as the following sections show, that goal—and more straightforward interim steps on the way to it—would follow logically and practically from obeying the economic principles to which most governments pay allegiance.

III

Nuclear power has been promoted worldwide as both economically advantageous and necessary to replace oil. Potential proliferation, in this view, is either a small price to pay for vast economic advantages or an unavoidable side effect which we must learn to tolerate out of brutal necessity. But rational analysis of energy needs and economics strongly favors stopping and even reversing nuclear power programs. Their risks, including proliferation, are therefore not a minor counterweight to enormous advantages but rather a gratuitous supplement to enormous disadvantages.

Replacing oil is undeniably urgent. But nuclear power cannot provide timely and significant substitution for oil. Only about a tenth of the the world's oil is used for making electricity, which is the only form of energy that nuclear power can yield on a significant scale in the foreseeable future. The other nine-tenths of the oil runs vehicles, makes direct heat in buildings and industry, and provides petrochemical feedstocks. If, in 1975, *every* oil-fired power station in the industrialized countries represented in the Organization for Economic Cooperation and Development (OECD) had been replaced *overnight* by nuclear reactors, OECD oil consumption would have fallen by only 12 percent. The fraction of that oil consumption that was imported would have fallen from about 65 to 60 percent (compensated by greatly increased dependence on imported capital and uranium), and would have fallen by much more for the United States than for Japan, France, West Germany or the U.K.[13] In practice, U.S. nuclear expansion has served mainly to displace coal, not oil, by running coal-fired plants less of the time: the utilization of their full theoretical capacity dropped from 62 to 55 percent during 1973-78. In overall quantitative terms the whole 1978 U.S. nuclear output could have been replaced simply by raising the output of partly idle coal plants most of the way to the level of which they are practically

[13] See Vince Taylor, "Energy: The Easy Path," report to the U.S. Arms Control and Disarmament Agency, 1979, available from the Union of Concerned Scientists.

capable. And, contrary to the widespread assumption that nuclear shutdown would cause serious regional shortages, analysis of the balance within each regional power pool fou that in 1978 all but 13 U.S. reactors, or all but two if surp power were interchanged between regions, could have been sh down forthwith without reducing any region's "reserve margi (spare capacity) below a prudent 15 percent of the peak demand Further confirming the loose coupling between nuclear outp and oil saving, between 1978 and 1979 the United States reduc by 16 percent the amount of oil used to make electricity, wh U.S. nuclear output simultaneously *fell* by 8 percent: the oil savi came instead from conservation and coal and gas substituti Between the first quarters of 1979 and of 1980, total U.S. oil-fi generation fell 32 percent while nuclear output simultaneou fell 25 percent—hardly a substitution.

The OECD calculation above for 1975 exaggerates potential displacement by nuclear power, partly because reactors take one night but about ten years to build. Reactors order... too can replace no oil in the 1980s—and surprisingly little thereaf The example of Japan, widely considered the prime case of n for nuclear power, illustrates reactors' relatively small event contribution to total energy supply. Quadrupling Japan's nucl capacity by 1990 would reduce officially projected oil imp dependence by only about ten percent.[15] An 18-fold increase the year 2000—costing about a hundred trillion of today's and requiring a large reactor to be ordered every 20 days—co theoretically meet half of all Japan's delivered energy needs th but fossil-fuel imports would still *increase* by more than two-thi "Rate and magnitude" calculations for other countries are equa discouraging.[16]

It may be said that without nuclear power, these examp would look even worse. But even prohibitively large nucl programs cannot go far to meet officially projected energy ne The official projections reflect an inability to face the fact t nuclear power cannot physically play a dominant role in

[14] This analysis may be found in Steven Nadis, "Time for a reassessment," *Bulletin Atomic Scientists*, February 1980, pp. 37-44.

[15] Speech by Joseph S. Nye (then of the State Department) at the Uranium Inst London, July 12, 1978.

[16] The analysis concerning Japan assumes energy demand consistent with 1978 o projections, and displacing two delivered energy units with each unit of nuclear electricity details and other examples, see Amory B. Lovins, "Is Nuclear Power Necessary?", Lo Friends of the Earth Ltd., 1979; and Amory B. Lovins, "Economically Efficient E Futures," in Wilfred Bach *et al.*, eds. *Energy/Climate Interactions*, Dordrecht: Reidel, 19 press). These two essays document section III and, in part, section V of this article.

country's energy supply. Solving the oil problem will clearly require, not a nuclear panacea, but a wide array of complementary measures, most importantly major improvements in energy efficiency.

It is therefore necessary to *compare* the elements of this array in costs, rates, difficulties and risks, to ensure that one is displacing oil with the cheapest, fastest, surest package of measures. Just as a person shopping for the most food on a limited budget does not buy caviar simply for the sake of having something from each shelf, but seeks the best bargain in a balanced diet, so every dollar devoted to relatively slow and costly energy supplies actually *retards* oil displacement by not being spent on more effective measures. Nuclear power programs have been justified not by this rational test but by intoning the conventional wisdom stated in 1978 by Brian Flowers of the U.K. Atomic Energy Authority:

> Alternative sources will take a long time to develop on any substantial scale. . . . Energy conservation requires massive investment. . ., and can at best reduce somewhat the estimated growth rate. Nuclear power is the only energy source we can rely upon at present with any certainty for massive contributions to our energy needs up to the end of the century, and if necessary, beyond.[17]

Failure to assess *comparative* rates of oil displacement, as we shall do in Section V, runs the risk that, having like Lord Flowers dismissed alternatives as slow, conservation as costly, and both as inadequate, one may choose a predominantly nuclear future that is simultaneously slow, costly *and* inadequate.

Nuclear power is not only too slow; it is the wrong kind of energy source to replace oil. Most governments have viewed the energy problem as simply how to supply more energy of any type, from any source, at any price, to replace oil—as if demand were homogeneous. In fact, there are many different types of energy whose different prices and qualities suit them to different uses. It is the uses that matter: people want comfort and light, not raw kilowatt-hours. Assuming (as we do) equal convenience and reliability to the user, the objective should be to supply the amount and type of energy that will do *each task most cheaply.*

This common-sense redefinition of the problem—meeting needs for energy services with an economy of means, using the right tool for the job—profoundly alters conclusions about new energy supply. Electricity is a special, high-quality, extremely expensive form of energy. This costly energy may be economically worth-

[17] Brian Flowers, "Nuclear power," *Bulletin of the Atomic Scientists*, March 1978, pp. 21-26.

while in such premium uses as motors, lights, smelters, railways and electronics, but no matter how efficiently it is used, it cannot come close to competing with present direct fuels or with present commercial renewable sources for supplying heat or for operating road vehicles. These uses plus feedstocks account for about 90 percent of world oil use and for a similar or larger fraction of delivered energy needs. The special, "electricity-specific" applications represent typically only seven or eight percent of all delivered energy needs—much less than is now supplied in the form of electricity.

In most industrial countries, therefore, a third to a half of all electricity generated is already being used, uneconomically, for low-temperature heating and cooling. Additional electricity could *only* be so used. Arguing about what kind of new power station to build is thus like shopping for brandy to burn in the car or Chippendales to burn in the stove.

So much for prices and market-oriented corrections

The economic absurdity of new power stations is illustrated by an authoritative calculation of how much energy Americans would have bought in 1978 if for the preceding decade or so they had simply met their end-use needs by making the cheapest incremental investments, whether in new energy supply or in efficiency improvements.[18] Had they done so, they would have reduced their 1978 purchases of oil by about 28 percent (cutting imports by half to two-thirds), of coal by 34 percent (making the stripping of the American West unnecessary), and of electricity by 43 percent (so that over a third of today's power stations, including the whole nuclear program, would never have been built). The total net cost of such a program: about 17 percent less than Americans *did* pay in 1978 for the same energy services. Detailed studies of the scope for similar measures throughout the industrial world (and, where data are available, in developing countries) have given qualitatively similar results.[19]

If we did want "more electricity," we should get it from the cheapest sources first. In virtually all countries, those are, in approximate order of increasing price:

[18] See Roger W. Sant, "The Least-Cost Energy Strategy," Arlington, Va.: Energy Productivity Center of the Carnegie-Mellon Institute, 1979.

[19] See, for example, Gerald Leach *et al.*, *A Low Energy Strategy for the United Kingdom*, London: International Institute for Environment and Development, 1979; David Olivier *et al.*, report to the Energy Technology Support Unit (Harwell), London: Earth Resources Research Ltd., 1980 (in press); Florentin Krause, *Wirtschaftswachstum bei sinkenden Energieverbrauch*, Freiburg i. Br. (FRG): Öko-Institut, 1980 (in press); Jørgen Nørgård, *Husholdninger og Energi*, København: Polyteknisk Forlag, 1979, CONAES Demand and Conservation Panel, "U.S. Energy Demand: Some Low Energy Futures," *Science*, April 14, 1978, pp. 145–52; and Lovins, *loc. cit. supra*, footnote 16.

1. Eliminating waste of electricity (such as lighting empty offices at headache level).
2. Replacing with efficiency improvements and cost-effective solar systems the electricity now used for low-temperature heating and cooling.
3. Making motors, lights, appliances, smelters, etc., cost-effectively efficient.[20]
4. Industrial cogeneration, combined-heat-and-power stations, solar ponds and heat engines, modern wind machines, filling empty turbine bays in existing dams, and small-scale hydroelectricity.[21]
5. Central power stations—the slowest and costliest known source.

The notion that despite all constraints—time, money, politics, technical uncertainties—nuclear power stations are at least a source of energy, and as such can be substituted for significant amounts of the dwindling oil supply, has long exerted a powerful influence on otherwise balanced imaginations. But it does not withstand critical scrutiny. It is both logistically and economically fallacious. The high cost of nuclear power *today* limits its conceivably economic role to the baseload fraction of electricity-specific end-uses: typically about four percent of all delivered energy needs. In purely pragmatic and economic terms, therefore, nuclear power falls on its own demerits.

IV

The arguments just summarized concerning the need for nuclear power might a few years ago have seemed remote and abstract. But nuclear power has in these years come under the strictest test of all, that of the market, and been found wanting. Rising costs,

[20] Typical savings for these terms are respectively about half, half to two-thirds, three-quarters, and two-fifths, with typical payback times around three, one to four, five and ten years respectively against marginal cost: primary sources are cited in Lovins, "Economically Efficient Energy Futures," *loc. cit.*, footnote 16. Combining these savings with the previous two steps typically yields total electrical savings of 60 to 80 percent or more, implying that today's U.S. economic output, and probably more, could be supplied using only present hydro, microhydro, and wind, but no thermal power stations of any kind. For documentation, see footnotes 16, 18, 19 and 36.

[21] An unlisted option in category 4, cheap solar cells (photovoltaics), will probably be on the market before anyone knows what to do with them and long before a recently ordered power station can be built. Though our analysis conservatively omits this option, the best conventional photovoltaic components already in pilot stage and scheduled for marketing in 1982-83, if combined into a single unit, would yield electricity comparable to or cheaper than that now delivered by conventional stations in industrial countries (see footnote 36, below, for documentation). Even at 1980 array prices ($6/W) photovoltaics are very attractive in most developing countries, which tend to have costlier electricity and little distribution grid: sunlight is distributed free.

falling political acceptance, and dramatically decreased prospects for electricity demand and utility finance have brought nuclear power to a virtual standstill.

Universally—in the United States and in the U.S.S.R., in France and in Brazil, under the most varying conditions of government regulation—the direct economic costs of nuclear power in real terms (corrected for general inflation) have risen unrelentingly since reactors went "commercial." The most detailed cost data available happen to be from the United States, but the same trends and conclusions apply elsewhere.

A recent detailed statistical analysis of all the U.S. data, explaining 92 percent of their variation, has revealed that during 1971–78, real capital cost per installed kilowatt increased more than twice as fast for nuclear as for coal plants and already exceeds the latter by 50 percent, despite investments that decreased coal plants' air pollution by almost two-thirds and will soon have done so by nine-tenths. The same study concludes that for nuclear plants now starting construction, excluding the possible impact of tighter federal regulatory standards in the wake of Three Mile Island, nuclear capital costs will exceed those of coal by 75 percent, "indicating that many of the 90 U.S. [nuclear] units with construction permits could be converted to coal to provide cheaper electricity."[22]

The real costs of operating the nuclear fuel cycle from uranium mining to spent fuel storage have risen even faster. Unexpectedly high estimated costs for waste management, decommissioning nuclear plants after at most a few decades, and cleaning up past mistakes (for example, burying the hazardous tailings left over from uranium mining) add many billions of dollars in liabilities. Erratic reactor performance—poor reliability, cracks in key components, maintenance problems seeming to go with scarcely a pause from the pediatric to the geriatric—has afflicted most countries. And as cumulative losses mount into the billions of dollars, no vendor in the world appears to have made a nickel on total reactor sales.

Added to these economic woes is an ever less receptive political climate, punctuated by Browns Ferry, Three Mile Island, and 19

[22] Charles Komanoff, "Cost Escalation at Nuclear and Coal Power Plants," submitted to *Science*, February 1980 (available from Komanoff Energy Associates, New York). Actual U.S. total nuclear generating costs in 1978 averaged about seven percent higher than for coal plants. Widely quoted claims to the contrary rest on selective omission of nearly all the costliest nuclear plants and cheapest coal plants; see Komanoff's "Power Propaganda: A Critique of the Atomic Industrial Forum's Nuclear and Coal Power Cost Data for 1978," Washington, D.C.: Environmental Action Foundation, 1980.

year-old news of a disaster in the Urals. Demolition by peer reviewers compelled the U.S. Nuclear Regulatory Commission to declare that its 1975 Rasmussen Report (claiming that reactors are very safe) was no longer considered reliable, and the Canadian Atomic Energy Control Board to declare its Inhaber Report (claiming that renewable sources are very dangerous) officially out of print. The classically assumed "solution" to the nuclear waste problem—reprocessing, turning the high-level wastes into glass, and burying them in salt—turned out to be technically flawed. The nuclear industry's credibility, heavily committed to these and similar premises, suffered a meltdown that seems irreversible: as Mark Twain remarked, a cat that sits on a hot stove lid will not do so again, but neither will it sit on a cold one. Efforts to repair the effects of past lack of candor or foresight have exacted a high cost in top-level managerial attention—also a scarce resource—out of all proportion to nuclear power's modest potential contribution.

As costs rise and credibility falls, the market for more electricity is quietly evaporating. With the inevitable response to higher prices beginning, forecasts of electricity demand growth in most countries have been falling steadily. Some are nearing zero or negative values. U.S. electricity demand has consistently been growing more slowly than real GNP of late, and all the trends are downward. Forecasters unfortunately responded more slowly than consumers: over the past six years, U.S. private utilities forecast that peak demand for the following year would grow by an average of 7.8 percent, but the actual growth averaged only 2.9 percent.[23] Overcapacity in the United States will probably hit 43 percent in 1980 and continue to rise (perhaps past the British level of about 50 percent). U.S. overcapacity in excess of a prudent 15 percent reserve margin is already well over twice the present nuclear contribution. It is indeed so large that if *all* U.S. power-plant construction were stopped immediately, growth in peak demand at an annual rate of 1.2 percent—twice that experienced in 1979—would still leave a national reserve margin of 15 percent in the year 2000. Growth by at least 2.2 percent per year could be accommodated if the economically advantageous industrial cogeneration potential were tapped. The market for power stations of any kind is simply imaginary.

Finally, nuclear (or fossil-fueled) power stations and their grids incur such extraordinary capital costs and take so long to build that utility cash flow is inherently unstable. Any utility, whether

[23] See *The Energy Daily*, October 30, 1978, pp. 3-4, and December 20, 1979, pp. 3-4.

public or private, regulated or not, which persists in building suc
plants will sooner or later go broke, and many are already doin
so.[24] Funding for new plants is scarce and costly; and even if it
available, building new plants is simply no longer in utilitie
financial interest.

These problems, singly and interactively, have taken their to
on industry morale, investor confidence, and resulting expecta
tions. In only six years from 1973, nuclear forecasts for 2000 fe
by a factor of five for the world, nearly four for West Germar
(no new orders since 1975), and eight for the United States (*min*
27 net orders during 1974–79). Nuclear forecasts worldwide a
still plummeting—more for economic than political reasons. T
U.S.S.R., for example, achieved only a third of its nuclear go
for the 1970s, half for the past five years. And although there ha
been essentially no procedural barriers to building reactors
Canada, the pattern of decline in nuclear capacity forecast for t
year 2000 has been all but identical in Canada and the Unit
States.

Despite intensive sales efforts and universal subsidies (often
to or exceeding total costs), the drop in expectations for nucle
power has been even faster in developing countries, paced by Ira
which projected 23,000 megawatts for 1994 and will probably g
zero, and by Brazil, which projected 75,000 megawatts for t
year 2000 and is unlikely to want more than the 2,000 megawa
that are now in serious difficulties. Total nuclear capacity in
developing countries in 1985 is now unlikely to be as much
13,000 megawatts, or about the present West German level. Ev
if giveaway offers tempt new customers (perhaps Mexico, Ken
Turkey, Zaïre) to undertake the well-known problems of integr
ing gigantic, very costly, complex units into rather small grids
countries poor in infrastructure, that extra "business" would b
tiny fraction of the loss elsewhere. It would not even be profita

[24] Capital costs are assessed in Amory B. Lovins, *Soft Energy Paths: Toward a Durable P*
New York: Harper and Row, 1979, Chapter 6, updated in "Soft Energy Technologies," *A*
Review of Energy, 1978, pp. 477–517, and in letters in *Science*: April 28, 1978, pp. 381
September 22, 1978, pp. 1077–78; December 22, 1978, p. 1242–43; and April 13, 1979
124–29. The utilities' financial problems are treated in California Public Utilities Commis
Proceedings of the Conference on Energy Efficiency and the Utilities: New Directions (April 18–19, 1
San Francisco: Public Utilities Commission, 1980 (in press); Irvin C. Bupp *et al.*, "S
Background Information on the Financial Condition of Certain Investor Owned Electric U
Companies," Harvard Business School, March 30, 1980; *The Times* (London), March 1,
p.1; Amory B. Lovins, "Electric Utility Investments: *Excelsior* or Confetti?", March 1979 p
to E.F. Hutton utility investors' conference, forthcoming in *Journal of Business Administr*
Vancouver, 1980 (in press); and "Energy: A Dark Future for Utilities," *Business Week*, Ma
1979.

business—only a way to inject export-bank funds into the vendors' ailing cash flows.

The collapse of nuclear markets has already sealed the fate of an industry tooled up to meet the inflated expectations of the early 1970s. Even with continued domestic and export subsidies, withdrawals by major firms seem inevitable. While rhetorically the world nuclear enterprise is pressing forward, in reality it is grinding to a halt and even slipping backward. The greatest collapse of any enterprise in industrial history is now underway. Thus, as Harry Rowen and Albert Wohlstetter remark,

> ...the argument sometimes shifts subtly from the needs of a robust and inexorably expanding industry to the sympathetic care required to keep alive a fragile industry that is on the verge of expiring altogether.[25]

The industry's long-term hope has been "advanced" plutonium technologies. But their first stage, recycling plutonium in conventional power reactors, was officially acknowledged in the U.K. and West Germany in 1977-78 to save too little uranium to pay for the reprocessing and other costs. Even the INFCE study, generally enthusiastic about plutonium, failed to find recycle inviting. Contrary to one of the earlier arguments advanced for reprocessing, INFCE has now concurred in the official positions of Canada, the United States and Sweden that reprocessing is not necessary for waste management. (Some experts believe reprocessing may even make it more difficult.) Similarly, one of the strongest arguments earlier advanced for reprocessing and plutonium-related technologies—that fission reactors would need so much uranium as to create shortages—is rapidly receding.

In short, the economics of fast breeder reactors look ghastly until far into the next century.[26] There are indications that prospects for funding and finding acceptable sites for the extremely costly next-stage breeder projects range from only fair (in France and the U.S.S.R.) to poor (in West Germany, Japan, the United States and the U.K.) Even sympathetic officials are realizing that the 50-fold potential improvement in uranium utilization that successful breeders might produce cannot in fact be achieved for well over a century because of the time it takes the breeder's fuel cycle to come to equilibrium; for the next 50 to

[25] Rowen and Wohlstetter, *op. cit.*, footnote 2.

[26] See Brian G. Chow, "Economic Comparison of Breeders and Light Water Reactors," report AC8NC113 to the U.S. Arms Control and Disarmament Agency, Pan Heuristics, 1979; also see Michael J. Prior's analysis prepared for the November 1978 South Bank Polytechnic conference, available from the author at NCB-IEA Services, 1415 Lower Grosvenor Place, London SW1.

80 years, the modest uranium savings that could be reali
through breeders could be achieved much more cheaply
surely through uranium-efficient thermal reactors instea
Costly, difficult breeder programs are thus looking increasin
like a commercial blunder, akin to pushing the Concorde w
others developed jumbo jets. Further attempts to deploy bree
reactors in an already hostile political climate could indeed je
ardize the limited acceptance now enjoyed by thermal reacto

The loss of momentum for the breeder, and for the nuc
program which it was to culminate, is reflected at the hig
political levels in all the main nuclear countries of OECD
beneath the surface throughout the Soviet scientific commun
At various times in the past few years, the British, French,
West German cabinets have been sharply split over whether
whole electronuclear program makes sense.[28] Chancellor Hel
Schmidt has even speculated that 20 billion marks may have b
thrown out the window.

How has U.S. policy affected the foreign nuclear debate at
political levels? U.S. technological dominance of the nuc
arena, though still preeminent, is no longer hegemonic; but
political dominance of world energy policy effectively is. So f
has been exercised in exactly the wrong direction.

U.S. policy pretends that the nuclear collapse is not happen
or that if it is, it shouldn't be and deserves no encouragem
The Energy Secretary has just committed two-fifths of his bu
for the next five years to nuclear power. The State Departm
says that *not* using nuclear power would make proliferation w
Presidential confirmations of the necessity and the large en
potential of nuclear power have bolstered sagging program

[27] See Harold A. Feiveson *et al.*, "An Evolutionary Strategy for Fission Power," *S*
January 26, 1979, pp. 330-37.

[28] The French program, widely portrayed as robust, is in reality fragile. It is proceedin
the moment, with a heavy mortgage. See Jean-Claude Derian and Irvin C. Bupp, "Ru
Water: Nuclear Power on the Move in France," September 6, 1979, available from Pro
Bupp at the Harvard Business School. To continue for long, the program must fin a
fix the growing cracks in the reactors; make the Cap La Hague reprocessing plant w
the waste problem; find reactor export markets to support the monopoly vendor Frama
find markets for more electricity to keep Électricité de France solvent (the recent forgive
five milliard francs of EdF's debt helps only temporarily); find politically acceptable r
sites; make a truce with the main nuclear union; and win public acquiescence by means
lasting than mere autarchy. Each of these problems may be soluble in isolation, but the c
of solving them all look slim. See also Sadruddin Aga Khan, "The Nuclear Power Deb
Western Europe," *Bulletin of the Atomic Scientists*, September 1979, pp. 11-12; for p
analogies, see Luther Gerlach, "Energy Wars and Social Change" and "Can Indepe
Survive Interdependence?", Department of Anthropology, University of Minnesota, M
apolis 55455, 1979; Amory B. Lovins, "Democracy and the Energy Mobilization Board
Man Apart, February 1980, pp. 14-15, Friends of the Earth, San Francisco.

countries poorer in fuels. Promotional rhetoric has given the nuclear industry a license to present in Europe a false but largely uncontested image of a flourishing American nuclear program (and vice versa). The State Department does not know, and seemingly does not want to know, that however monolithic the policy front presented by other countries (an appearance carefully orchestrated by the U.S. nuclear industry), every national nuclear policy is riven from top to bottom by doubt and dissent. Whatever the United States has done, in policy or in rhetoric, has helped one side of those internal debates and hurt the other. Yet the State Department, maintaining a meticulously lopsided neutrality, has never appreciated that the most powerful U.S. lever for affecting foreign nuclear policies in either direction was not blunt instruments like fuel supply, but rather the *political example* of stated and applied U.S. energy policy in its broadest terms.

Ignoring this influence on domestic energy politics abroad, advocates of continuing subsidized nuclear exports have argued that if the United States does not supply sensitive nuclear technologies, others will, so the United States might as well—and that since others can, the United States has no "leverage" to justify abstention. As Harry Rowen and Albert Wohlstetter put it, "We can retain our leverage only if we never use it. A lever is a form of abstract art rather than a tool giving us a mechanical advantage." Today the United States proclaims itself anxious to be seen as a "reliable supplier," spends five billion dollars on a gratuitous expansion of a centrifugal enrichment capacity to take on new fuel export commitments, and seeks to make those commitments irrevocable; yet at the same time it asks itself, half aloud, how much "leverage" it can obtain by exporting more U.S.-fueled reactors as hostages to later sanctions. Both kinds of exports leave the United States in the unpalatable position of vigorously proliferating in the name of nonproliferation, sacrificing for a weak and counterproductive physical leverage a strong and positive political leverage.

How real is that political leverage? The political vulnerability of nuclear projects was strikingly illustrated in 1979 by the West German government's firm commitment, allegedly crucial for national survival, to build an enormous reprocessing and waste-disposal plant at Gorleben in Lower Saxony. The State Department, citing sensitive alliances, had passed up low-cost opportunities to scuttle analogous projects nascent in the U.K., France, and Japan before still-fluid political commitments to them had solidified. In the German case, they seemed solid already, but inwardly there were doubts, and to defuse local opposition the governor of Lower Saxony commissioned a technical review by an ad hoc panel of 20 independent experts from 5 countries.[29] Their report was so comprehensively devastating that neither the Chancellor's party in Lower Saxony nor, privately, the project's own promoters could defend it, and Bonn had to cancel it outright. If a mere report and hearing with no official resources behind them can be the catalyst that reverses a supposedly irrevocable national commitment, what political leverage might a country—especially the United States—apply by the example of its whole energy policy?

In sum, the forces of the market—in combination with new and more searching analysis of other factors—have made the future of nuclear power so precarious that a change in policy by the United States, or by several other countries, would greatly hasten the dawning realization that nuclear power has no valid future either in industrialized or developing countries. The issue is not whether to maintain a thriving enterprise, but rather whether to accept the verdict of the very calculations on which free market economies rely.

V

To this point we have been balancing the dangers of nuclear fission power's crucial contribution to the spread of nuclear bombs against its necessarily limited role in the total energy picture and against the mounting evidence that even in that limited role nuclear power simply does not make economic sense (as well as raising serious safety and social issues, on which it is hardly necessary to dwell). The balance is overwhelmingly negative, and should in itself suffice to conclude that it is time to phase out nuclear fission power once and for all.

But, to make a fully rounded presentation, we need to consider what is needed affirmatively to meet the world's energy needs. It is sometimes argued that nuclear expansion is necessary, in the words of W. Kenneth Davis of the Bechtel Corporation, "to minimize the risks of war in a world struggling for growth in the face of inadequate and poorly distributed sources of energy." In fact, the balance on this criterion would be even more decisive: nuclear power creates its own set of international conflicts—over uranium, fuel cycle services and technologies—and it unavoidably

[29] See Gorleben International Review, *op. cit.* footnote 8, for details. The report and adversarial hearings on it are summarized in Hermann Graf Hatzfeldt *et al.*, eds., *Der Gorleben Report*, Frankfurt/M.: Fischer, 1979. See also *Rede-Gegenrede: Symposium der niedersächsischen Landesregierung zur grundsätzlichen sicherheitstechnischen Realisierbarkeit des integrierten nuklearen Entsorgungszentrum.* Niedersächsische- und Landesregierung, Jan./Feb. 1980.

and incontinently spreads bombs, innocent disguises for bombs, and the ambiguous threat of bombs that motivates rivals to acquire them.

Yet there *is* a danger of international conflict for sources of energy, and it revolves primarily around oil. How then can the oil saving so central to security and peace be achieved? Broadly speaking, the important oil-saving measures are distressingly simple: stop driving Petropigs and stop living in sieves.

Cars use about half of all U.S. oil, about a sixth of European and Japanese oil.[30] An average car today gets, in round numbers, about 15 miles per U.S. gallon in North America, about 20 to 25 in Europe and Japan. The average new domestic car sold in the United States in 1979 got about 19, the average import about 32—a sixth better than the congressionally mandated level for 1985 models. A diesel Rabbit, with only a tenth less interior space than the average U.S. model-year 1978 car, averages about 45 miles per gallon, its successor model about 64. Volkswagen has already tested a four-passenger advanced diesel car with measured EPA composite efficiency of 70 to 80 mpg. A big, comfortable car using either an infinitely variable transmission or a diesel-electric series hybrid drive would readily do better than that (as European prototypes have done) even without using existing technologies for very lightweight but crashworthy body design.[31]

For any country, accelerated turnover of the car and light truck stock would provide major, quick and cheap relief of oil import dependence—and great benefits to domestic industry. The car stock normally takes about ten years to turn over, and the collapse of trade-in value for North American gas-guzzlers has only accelerated their filtering down to poor people who can least afford to run or replace them. Rather than building synthetic-fuel plants, it would be much quicker and cheaper to save oil by using the

[30] In Europe, most of the oil is used for low-temperature heating (which is, for example, half of all delivered energy needs in West Germany) and for industrial heat. In Japan, industry dominates, and oil must be saved chiefly by efficiency improvements there—for which there is surprising scope, since energy has been subsidized even more heavily in Japan than in the United States, and cost less in Japan until 1973. The main transitional role of coal, too, is to replace oil and gas under industrial boilers (especially with cogeneration), not in new power stations, and this will not entail a vast expansion of world coal mining or trade if cost-effective efficiency improvements are done first.

[31] In the series hybrid design, a diesel engine (or fuel cell) runs a generator which charges a few ordinary batteries which run drive motors. The batteries power acceleration and recharge with deceleration. The diesel, meeting only the average load at constant speed and torque, is small, clean and extremely efficient. It can also be replaced by a fuel cell. For a fuller account of more conventional approaches to super-efficient cars, see Robert H. Williams, "A $2 a Gallon Political Opportunity," PU/CEES-102, and Frank von Hippel, "Forty Miles a Gallon by 1995 or Bust," PU/CEES-104, Center for Energy and Environmental Studies, Princeton University, 1980.

same funds to pay anywhere from half to all of the cost of giving people *free* diesel Rabbits or Honda Civics (or an equivalent American car if Detroit would make one) in return for scrapping their Brontomobiles. Alternatively, it would be quicker and cheaper to save oil by giving cash grants approaching $200 for every mile per gallon by which a new car improves on a scrapped gas-guzzler.[32] For once, what's good for General Motors might be good for the world. Replacing all U.S. cars with hybrids getting a modest 60 miles per gallon (achievable now using off-the-shelf components in a big, two-ton car) would save nearly four million barrels of oil per day—half the present rate of U.S. net oil imports, greater than imports from the Gulf, two and a half North Slopes, 80 big synfuel plants, or several Irans. Precisely the same logic applies in other countries.

Even an elementary program of systematically applied building "retrofits" (making old buildings efficient), cost-effective at present prices, would save half to two-thirds of space-heating energy, whether in the United States, United Kingdom, or Denmark, without coming anywhere near technical or economic limits.[33] (Doing that would reduce space heating needs to approximately zero even in a subarctic climate.) In the United States alone, half the space-heating energy could be saved by the mid- to late-1980s, equivalent to two and a half million barrels of oil per day.[34] Improved heat-tightness so far—17 percent better for American gas-heated dwellings during 1972–79, 20 percent for West German oil-heated single-family dwellings during 1973–79—illustrates the thesis but improvements so far have barely scratched the surface.

In short, just the two largest single terms in improved U.S. energy productivity, just in the 1980s, and pursued to a level far short of what is technically feasible or economically optimal, would together displace four-fifths of U.S. net oil imports. They would "supply" energy at nearly five times the rate deliverable by the maximum U.S. nuclear capacity physically achievable in the same period—at a small fraction of the cost. And they would do

[32] An average U.S. car annually goes about 10,000 miles and uses about 17 barrels of crude oil equivalent. A marginal one-mile-per-gallon improvement saves about one barrel per year and gives, at a $200 cost, a five-year payback against delivered synfuels (over $40/bbl). The worst cars would pay back faster; better ones, more slowly. A bounty should also be offered, based on efficiency and expected lifetime, for scrapping gas-guzzlers without replacing them.

[33] See Arthur H. Rosenfeld et al., "Building Energy Compilation and Analysis," LBL-8912, Lawrence Berkeley Laboratory, Berkeley, California, 1979; also see Sant, Leach, Krause, and Nørgård, cited in footnotes 18 and 19.

[34] See Marc Ross and Robert H. Williams, "Drilling for Oil and Gas in Our Buildings," PU/CEES-87, Center for Energy and Environmental Studies, Princeton University, 1979.

this before a reactor ordered today could deliver any energy whatsoever.

Such energy-saving measures in all sectors can form the keystone of a coherent "soft" energy strategy if combined with transitional fossil-fuel technologies and with a steady shift, over 50 years or so, to reliance on diverse renewable sources, matched in scale and in energy quality to their tasks.[35]

The four years since the emergence of this concept of a "soft" energy strategy have seen astonishingly rapid analytic and practical progress. As a result of thousands of studies and experimental projects, what was controversial has become widely accepted. Economic claims once made with caution can now be made with confidence. Findings extrapolated from early analyses in a handful of countries are now bolstered by dozens of far more detailed studies in about 15 countries and many localities—and, increasingly, by practical demonstrations on a significant scale.

At the same time, projections of future needs for energy, and hence for major facilities to supply it, have dropped strikingly. Today the highest official estimates of U.S. energy needs in the year 2000 are below the lowest, most heretical unofficial estimates made in 1972. The lowest official estimates, still assuming a two-thirds increase in real GNP, are less than half as large, and more than a quarter *below* today's level.[36] The downward trend continues as new studies incorporate greater detail (identifying more opportunities for saving) and rapid recent technical progress in raising energy productivity to an economically efficient level. This

[35] See Amory B. Lovins, "Energy Strategy: The Road Not Taken?", *Foreign Affairs*, October 1976, pp. 65-96, expanded in *Soft Energy Paths*, cited in footnote 24. Besides such technical elements as we mention here, a soft energy path is defined by its avoidance of the political costs that characterize a "hard energy path": centrism, autarchy, vulnerability, technocracy. Its policy instruments are noncoercive and market-oriented. It neither assumes nor requires that car efficiency, for example, be improved by the particular means mentioned herein. Our soft-path analysis assumes rapid, undifferentiated, and worldwide economic and industrial growth; no significant changes in social goals, composition of economic output, or patterns of settlements, political organization, or behavior; and implementation only through "technical fixes"—that is, presently proven, presently economic technical measures with no significant effect on lifestyles. Readers who consider today's values or institutions imperfect are welcome to assume some mixture of technical and social change which would simplify implementation, but as a conservatism, we have not done so; we assume a "pure technical fix."

For a good example of the progress made in this area, and the degree to which soft energy strategies have become common coin, see Robert Stobaugh and Daniel Yergin, eds., *Energy Future*, New York: Random House, 1979. It is interesting that the illustrative 95-quad demand for energy in the year 2000 shown in 1976 in "Energy Strategy: The Road Not Taken?" was precisely the forecast published two years later by Energy Secretary Schlesinger (for a real oil price of $32/bbl).

[36] These estimates may be found in Solar Energy Research Institute, "Sustainable Prosperity: An Efficient Solar Future," draft report to the U.S. Department of Energy, May 26, 1980 (to be published by the Institute, Golden, Colorado).

level is at least several times that now prevailing in the most energy-efficient countries: at least a fourfold improvement in West Germany, sixfold in the U.K.[37]

Far from being uselessly slow, efficiency improvements are the fastest growing energy source today. Of all new energy "supplies" to the nine EEC countries during 1973–78, about 95 percent came from more efficient use and only 5 percent from all supply expansions combined, including North Sea oil and nuclear power—a ratio of about 19 to 1 in favor of conservation. In Japan, the corresponding ratio rose to about 10. In the United States, it averaged about 2.5; but in 1979, real GNP rose 2.3 percent while total energy use *declined* 0.2 percent—remarkable progress in view of the more than $100 billion in annual tax and price subsidies which underprice fuels and power by more than a third. During 1973–78, total U.S. efficiency gains yielded twice as much energy-"supplying" capacity, twice as fast, as synthetic-fuel advocates claimed they could do—except that their option, if it worked, would have cost 10 times as much. Even this 10 percent gain in national energy efficiency was less than a third of what would have been worthwhile at 1978 energy prices.[38] The 1973–78 efficiency gains in U.S. industry alone yielded twice the 1978 "supply" of Alaskan oil, but left the oil in the ground. By 1979, total post-embargo savings were at least five million barrels of oil equivalent per day, nearly two-thirds of 1979 net oil imports.

In a crisis the normal reflex is to abandon competition among many solutions in favor of single but dramatic nonsolutions (as in the 1979 post-gas-line White House hysteria for synthetic fuels). But these examples show that the centrally managed supply programs are being far outpaced by millions of individual actions in the market. There are three further structural reasons why efficiency gains and soft technologies can displace oil far faster than other methods:

—The soft-path investments have construction times per unit measured in days, weeks or months, not ten years.

—They diffuse into a vast consumer market, rather like citizen's-band radios, snowmobiles and pocket calculators, rather than requiring tedious "technology delivery" to a narrow, specialized and dynamically conservative utility market.

[37] See Krause and Olivier, *loc. cit.* footnote 29.

[38] See Vince Taylor, "The Easy Path Energy Plan," 1979, available from the Union of Concerned Scientists; and Sant, *loc. cit.* footnote 18. The energy "supplies" from conservation calculated in this paragraph are the difference between the energy actually used to produce economic output in a given year and the energy that would have been needed to do so at previous levels of technical efficiency.

—The institutional barriers that hold back their dozens of technological categories are largely independent of each other: microhydro is held back by regulatory problems, air-to-air heat exchangers by the need to retread the building industry. Because these and analogous problems are not generic—like the major-facility siting problems that hold back all hard technologies everywhere at once—dozens of relatively slowly growing individual wedges of soft technologies and efficiency improvements can independently add up by strength of numbers to very rapid total growth.

Desubsidization, tariff reform, replacement-cost pricing (or equivalent rules for allocating capital), and purging of institutional barriers are difficult problems—though easier than the alternative. Their solution, though no longer mysterious, is still at an early stage. Yet price incentives have already accelerated soft-path implementation. Still faster implementation could be achieved by reinventing and adapting the institutional innovations used in the past for major national adaptations, such as the changes of electrical voltage in Sweden or frequency in Toronto and Los Angeles, the advent of North Sea gas and smokeless fuels in Britain, right-hand driving and district heating in Sweden. It is chastening to recall that when the Swedish government in 1767 commissioned development of the Cronstedt recirculating stove, five times as efficient as the open fires that were causing a firewood crisis, the solution was perfected and published within eight years; mandatory conversion was rapid throughout Sweden; and soon the stoves were all over Northern Europe.

Developing countries should be able to achieve the same ultimate efficiencies as industrialized countries, but faster and cheaper, because they can use the most energy-efficient technologies from scratch (the world's most efficient steel mill is said to be in Kenya), rather than having to install them by slow and costly retrofit of existing plants. On this basis, preliminary estimates suggest that a completely industrialized world of eight billion people, with a standard of living somewhat above today's West European average, need use no more total energy than the world uses today.[39] This energy need—less than a tenth electricity, about

[39] See Lovins, "Economically Efficient Energy Futures," *loc. cit.*, footnote 16. (Such a future may be impossible or undersirable on grounds other than energy availability.) Third World analysts are right to attribute the world's energy crisis to the North, but the absolute amount of waste in the North is irrelevant to the merits of efficiency-improving investments in the South. Their scope and attractions are immense; see, for example, Lovins, "Economically Efficient Energy Futures," pp. 9–13, and the sources in footnotes 37 through 41; World Bank Staff Working Paper 346, "Prospects for Traditional and Non-Conventional Energy Sources in Developing Countries," 1979; Elizabeth Cecelski *et al.*, "Household energy and the poor in the third world," Washington, D.C.: Resources for the Future, 1979.

a fifth liquid fuels for vehicles, the rest heat—lends itself to supply entirely from well-known soft technologies.

Carefully selected and efficiently used, the best soft technologies already in or entering commercial service, and matched to local needs and climates, are sufficient to meet virtually all long-term energy needs in every country so far studied, including the United States, Canada, U.K., the Federal Republic of Germany, France, Denmark, Sweden and Japan—a suggestive list, as it includes countries that are simultaneously cold, cloudy, densely populated, and heavily industrialized. This assumes no technologies yet to be developed, but only the best *present* art in passive and active solar heating, passive solar cooling, high-temperature solar heat for industry (collectable even in cloudy winters), converting farm and forestry wastes to liquid fuels for vehicles, present and small-scale new hydroelectricity, windpower, and in some cases other simple devices such as woodburners, biogas plants, and low-temperature heat engines. The appropriate mix of sources (each containing a vast array of subcategories and hybrids) varies between and within countries, but even countries poor in transitional fuels, such as Japan, appear to be amply rich in renewable energy if each kind is intelligently used to do the tasks it does best.[40]

Given careful shopping for clever designs, efficient marketing structures, and cost-effective efficiency improvements done *first* (thus making renewable supply smaller, simpler, cheaper and more effective), soft technologies can be—though not all are—cheaper than today's oil. More important, they are consistently cheaper in capital cost, and several times cheaper in delivered energy price, than the power stations or synfuel plants which would otherwise have to be built to replace the oil and gas. This comparison is conservative, is based on empirical cost and performance data, and omits all "external" costs and benefits. Thus, as the Harvard Business School energy study recently found, the cheapest energy investments are the efficiency improvements, then soft technologies, then synfuels, and last—costliest—power stations. Most countries have so far taken these options in reverse order, worst buys first.

The early debate over the technologies and costs of the soft path gave way, as critics verified the references, to a residual philosophical debate: Will people do it?[41] No analyst's view of what is

[40] See Haruki Tsuchiya's supply data in *Soft Energy Notes*, May 1980 (in press). Topical technical studies are reported bimonthly in *Soft Energy Notes* by the International Project for Soft Energy Paths; the first seven issues are reprinted free by the Office of Solar Policy, U.S. Department of Energy, as DOE/PE-0016-1.

[41] See Hugh Nash, ed., *The Energy Controversy: Soft Path Questions and Answers*, San Francisco: Friends of the Earth, 1979.

important or tolerable to people can substitute for asking them. The debate reduces to the Jeffersonian (and market economics) view that people are pretty smart and, given incentive and opportunity, can choose wisely for themselves, versus the Hamiltonian view that these complex issues must be centrally decided by a technocratic elite. Under the latter philosophy, energy policy requires massive central planning and intervention which, under the former, it cannot tolerate.

Recent experience of what works is empirically resolving this dispute in favor of the Jeffersonians. Under a no-strings grant program, Nova Scotians weatherized half their houses in one year. The people of Fitchburg, Massachusetts, by door-to-door citizen action, did the same in seven weeks, saving a quarter of the town's heating oil. Of the roughly 200,000 U.S. solar buildings, half are passive and half of those are retrofits (greenhouses added to existing buildings). In the most solar-conscious communities, from a quarter to all of the 1978-79 housing starts were passive solar. More than 150 New England factories, and half the rural households in many areas, switched from oil to wood. Over half the states have active fuel alcohol programs. Small-scale hydro reconstruction is flourishing. More than forty manufacturers of wind machines share an explosively growing market whose two biggest commercial commitments in 1979 totalled $230 million. The size, dispersion, rate and diversity of soft-path activities are now so great that national authorities are only dimly aware of how fast their own targets are being overtaken.[42]

Governments face special institutional barriers internally. Reactors can be ordered from Bechtel, KWU, Framatome, Mitsubishi; but the centers of excellence in soft technologies are scattered, unprestigious, impecunious, all but unknown. Historic patterns of reward and prestige make bureaucracies safe for incompetence, bypass vision, and scorn technologies that are sophisticated not in their complexity but in their simplicity. But in national terms soft technologies, by contrast, are politically efficient, for they are correctly perceived to be relatively benign; their impacts are in general directly sensible and susceptible to common-sense judg-

[42] Hundreds, probably thousands, of North American counties, cities and towns are consciously seeking to implement most or all of the elements of a soft energy path. See *Proceedings of the First Annual Conference on Community Renewable Energy Systems* (Boulder, August 1979), Golden, Colo.: Solar Energy Research Institute, 1980 (in press); *Renewable Energy Development: Local Issues and Capabilities*, DOE/PE/0017, Washington, D.C.: U.S. Department of Energy, 1980; James Ridgeway, *Energy-Efficient Community Planning*, Emmaus, Pa.: JG Press, 1979; Office of Consumer Affairs, *Energy Consumer*, Washington, D.C.: U.S. Department of Energy, February/March 1980; and project lists from the Center for Renewable Resources in Washington, D.C., the Institute for Local Self-Reliance in Washington, D.C., and the Institute for Ecological Policies, in Fairfax, Virginia.

ments; they are chosen in the marketplace and at a democratically accountable political level; and they give their costs and benefits to the same people at the same time, so the recipients can decide how much is enough.

Some will think that permitting nuclear power to die is a drastic gamble, prematurely sacrificing an insurance policy which we may desperately need if alternatives do not work.[43] But the real insurance policy, besides present overcapacity, is the well-proven, completely conventional efficiency improvements and transitional fossil-fuel technologies (such as cogeneration) which can each unquestionably provide more electricity faster and cheaper than nuclear power but were left out of official projections. The need for nuclear power is not established by merely raising doubts about the capacity of renewable sources to take over quickly. Nor is nuclear need "during the transition" established by citing a scarcity of transitional fuels, for this begs the question of what will fuel the even longer transition to nuclear dependence. Whether or not a country has indigenous fossil fuels has nothing to do with whether nuclear power or soft-path investments can displace that country's oil use faster.

It is neither necessary nor desirable to do everything at once, and some options exclude others. Keeping the nuclear industry alive, even in a semi-comatose state, is not like offering vitamin tablets; it demands heroic measures to resuscitate and artificially sustain the victim of an incurable attack of market forces. Of our finite resources, only crumbs would remain. Countries wanting to shift to reliance on renewable sources—both the adequate ones already available and the improved ones being rapidly developed—must do so before the relatively cheap fossil fuels, and the relatively cheap money made from them, are gone. They are going fast. In this transition, nuclear power does not complement but devours its rivals. It is a long, irreversible step in the wrong direction.

VI

The section just concluded has focused largely on the potential of the soft energy path for industrialized countries. What of the

[43] It is also often argued that the cost of writing off nuclear plants now operating or being built would be prohibitive. But in fact, their extra electricity can in general be used only for low-temperature heating and cooling. The cheapest ways of doing those tasks—efficiency improvements and passive solar measures—cost less than the running costs alone for a newly built nuclear plant, so it is cheaper to write off such a plant and never operate it. Under U.S. tax law, this saving plus the saved future utility profits and tax subsidies would probably suffice to recoup the plant's capital cost too. Similar arguments apply to partly built, partly amortized, and fossil-fueled power stations.

developing countries? And what, in particular, of the statement of purpose of the International Atomic Energy Agency, which in 1957 undertook to promote the spread of nuclear energy for exclusively peaceful purposes, especially in developing countries—and of the obligation stated in Article IV of the Non-Proliferation Treaty of 1970, under which all the parties to that treaty undertook "to facilitate" and have a right "to participate in, the fullest possible exchange of equipment, materials . . . and information for the peaceful uses of nuclear energy," with an "inalienable right" to peaceful uses "without discrimination"?

The first thing to be said about Article IV is that it is, by its own terms, subject to conformity with the primary obligations of the same Treaty: Article I, in which nuclear weapons states promise not to transfer bombs or "in any way to assist [or] encourage" the acquisition of bombs by others, and Article II, in which non-weapons states promise not to seek or acquire bombs.

The ambiguity inherent in this compromise between promoting reactors and prohibiting bombs has been well exploited. Some nations, for varying reasons, adopt the nuclear industry's view that Article IV legitimates or even mandates the supply to all NPT adherents of plants that yield pure bomb materials, or of those materials themselves, so long as they have some civilian use. Suppliers' declarations of "restraint" in making "sensitive" transfers (code for "unsafeguardable in principle") have not said that such transfers would breach the Article I obligation "not . . . in any way to assist," but have accompanied reaffirmed commitments to export more reactors.

Any attempt to resolve this ambiguity seems to some parties a discriminatory abrogation of their own hallowed interpretation. Tempers are running high. But the impasse results from misstating the problem. Denial—of bombs to states lacking them—is the central purpose of the NPT. The compensatory rewards to non-weapons states were stated in terms of nuclear power because of the nuclear context and background of the negotiators, not as an expression of the essential purpose of Article IV.

As conventionally construed, Article IV is an obligation to facilitate a transfer which is in fact now a liability for its ostensible purpose of providing energy, but is singularly useful for its forbidden purpose of providing bombs. Nuclear power is something which under Article I the givers mustn't give and under Article II the recipients shouldn't ask for. The time is therefore ripe to reformulate the bargain in the light of new knowledge. Instead of denying or hedging their obligation, the exporting nations should fulfill it—in a wider sense based on a pragmatic reassessment of what recipients say their real interests are. When Eisenhower spoke in the fading glow of FDR's rural electrification program, and when the NPT was negotiated at the zenith of cheap oil, nuclear power was expected to be cheap, easy, and abundant. Now that everyone knows better, recipients should insist on aid in meeting their declared central need: not nuclear power per se but rather *oil displacement and energy security.*

The arguments that efficiency improvements and available soft technologies can displace oil and meet energy needs better than nuclear power are in fact strongest in developing countries, where capital, delivery systems, infrastructure, and income are most limited.[44] By enhancing resilience, self-reliance, and economic strength, a soft path aids national security. It can serve equally well, we shall suggest, another legitimate motive: prestige. It does not serve the illegitimate motive which NPT adherents have disavowed: getting bombs. It thus isolates legitimate from illegitimate motives and makes proliferators explicitly reveal their intentions.

To the extent that developing countries seek reactors for prestige, the West's bad example is to blame. But prestige is normally defined in terms of an accepted theory of national welfare. Reality has debunked the fantasy that nuclear power would make deserts bloom, cities boom, and villages prosper. Enormous diversions of national resources for pitiful ends may comfort nuclear bureaucrats, but not a finance minister facing massive oil debts, a district commissioner fighting deforestation, or a prime minister whose people still cannot cook their rice. Clay stoves, biogas plants, and cogeneration may lack sex appeal for technocrats, but a practical politician has more to gain from thousands of small, successful projects than from a single ribbon-cutting. Romantic images can have a long half-life, but ultimately market forces will work, and investment in pyrolyzers and windmills, solar cells, and solar stills, will become commonplace and "respectable." To hasten the demise of decisions based on bad economics and false glamor, the industrialized countries need simply to ask that buyers of nuclear power pay for it—and to provide a psychological lead, as when 81 percent of Swedes voted in 1980 to stop reactor ordering and phase out nuclear power within about 25 years.

Some leaders may see short-run glamor in bombs. But as the Vietnam debacle showed a decade ago, prestige comes from a

[44] See materials cited in footnote 39.

leader's ability to influence events, not from mere technology or troop strength. In the long run, a policy of self-denial, recognizing the near-irreversibility of a peek over the nuclear threshold, has often been a policy of shrewd self-interest. The costs of nuclear "strength"—more nervous and better-armed generals at home and abroad, more entanglement in superpower rivalries, more reluctant allies—outweigh the benefits (putative deterrence and distraction from internal problems). Bomb programs have probably always decreased their patrons' security. The first act in the worldwide nuclear arms race began, chillingly, with the misperception that a rival (Nazi Germany) was about to develop bombs. A nuclear force possessed by, say, India or Japan cannot deter neighbors' nuclear attacks (which may arrive anonymously by oxcart or fishing boat); and far from deterring first strikes by the great powers, it is an attractive nuisance inviting them.

Many developing countries are eager to avoid these costs and to advance their people's welfare by indigenous, appropriate, nonviolent energy policies. As an impressive literature attests, centrally aided decentralized action toward a soft energy path can benefit enormously from a few simple tools:

—"Classic designs" that can spread rapidly and attract local refinements, like Chinese biogas plants (nine million installed in 1972–78), New Mexican greenhouses, Indian bamboo tubewells, and Saskatchewan superinsulation. The incredibly rapid flowering of clever, accessible designs worldwide is a tribute to the most powerful known tool in the universe: four billion minds wrapping around a problem.

—Fieldworkers, extension services, wandering gossips/minstrels/cross-pollinators, staff exchanges, networking newsletters, appropriate-technology and self-help groups.

—Small-grants programs at national and regional levels. With low unit cost, low overheads, high volume, high dispersion, and willingness to take risks, these have been among the richest sources of rapid innovation. The money needed to build a single reactor, spread among a million groups and individuals, could hardly avoid dispersing a hundred thousand successes where people can see and imitate and improve them. Thousands would probably yield innovations each more important to national welfare than the initial foregone reactor.

—Reliance less on specialized technical institutions, high technologies, and credentials than on smart people, who are to be found everywhere. Technical skills and facilities are valuable but have been overrated as prerequisites. Many of the best soft technologies can be made in any vocational high school or by a good blacksmith.

—Small-business soft-energy credit systems and marketing infrastructures analogous to farm credit systems and co-ops. An Indian family might save upwards of $3 a year in kerosene with a $10 stove, but a 30 percent annual return on capital is not compelling for people with no capital.

—Soft-path lending by national energy development banks oriented toward farming, small-business, and household needs, complementing finance (mainly in industry, and ensuring that fledgling industries buy the most energy-efficient technologies) by utilities, national fuel companies, and existing public and private banks.

—"Investment balancing tests" by international lending agencies, which now fund hard technologies generously and cheaper, softer ones penuriously.[45] The World Bank has apparently not even studied industrial energy saving—a major opportunity in many developing countries.

—Soft-technology transfer concessions, including mutual exchanges, licensing of public-sector patents for home and regional markets, and international financing of local production.

—International ad hoc advisory networks organized by biogeographical province.

—Humility by "advanced" countries: many countries they consider backward are far ahead of them, leaders on a world scale in truly advanced technologies.

Currently there are many forums for Northern nations to exchange energy views and data, none for Southern. The International Energy Agency's oil-sharing plans exclude the South. New global and regional energy and financial institutions will undoubtedly emerge, and NPT adherents, especially non-weapons states, deserve substantive preference, a strong voice, and preferably a guiding role in them. To reinforce success in energy policies that make the NPT effective, or ultimately unnecessary, countries displacing oil most effectively with inherently non-violent technologies should be entitled to special financial or oil guarantees by weapons states.

The global urgency of displacing oil and uranium—like the reconstruction urgency that gave rise to the Marshall Plan, World Bank, IMF, and OECD—offers a good case for a Fund for Renewable

[45] These simple tests allocate investment to the cheapest ways of meeting end-use needs, and can largely avoid the energy pricing problem: see Lovins in *Journal of Business Administration* and concluding address in California PUC, *loc. cit.*, footnote 24.

Energy Enterprise (FREE), analogous to the International Fund for Agricultural Development and funded perhaps by a tax on oil sales, oil or fossil-fuel use, uranium mining, arms budgets, or megatonnage of bomb inventories. FREE would aggressively finance distribution, site testing, training, and institution-building for soft technologies (limited by charter to decentralized systems). It would complement existing institutions, work closely with appropriate non-governmental organizations, substitute broad social accounting for narrow profitability tests, take risks, be at least half-controlled by recipient states, and operate via semi-autonomous regional centers maximizing their dispersion of staff, decisions and money. As one of the many complementary mechanisms needed to address the full spectrum of developing-country energy needs at which Article IV was aimed, this concept could be explored and refined at the NPT Review Conference and at the 1981 U.N. Conference on New and Renewable Sources of Energy.

VII

The proliferation problem has seemed insoluble primarily because vast worldwide stocks and flows of bomb materials were assumed to be permanent. Policy never looked beyond the nuclear power age because there was no beyond. But that age may be ending, with proliferation—given pragmatic planning—arrestable just short of total unmanageability.

To abandon nuclear power and its ancillary technologies does not require any government to embrace anti-nuclear sentiment or rhetoric. It can love nuclear power—provided it loves the market more. Governments need merely accept the market's verdict in good grace and design an orderly terminal phase for an unfortunate mistake. That should include the least unattractive and most permanent ways to eliminate from the biosphere (via interim internationally controlled spent-fuel storage) the hundreds of tons of bomb materials already created, and helping nuclear technologists to recycle themselves into work where their talents are more needed. Phasing out reactors by the means suggested in Sections III and V would take about a decade and reduce both political tensions and electricity prices.

While collective leadership by other countries is desirable and sufficient, the U.S. example alone would deprive other countries of the domestic political support that an exorbitantly costly bail-out of their nuclear industries would require. Interdependent political illusions would quickly unravel. In a period of tight budgets and narrow electoral margins, explicit U.S. recognition that the market has cut short the nuclear parenthesis in favor of more effective means of oil displacement would focus the accelerating swing of public and professional opinion worldwide. To allow the nuclear industry to die without noting and politically capitalizing on its passage would be a signal failure of international leadership.

Second, as efforts to make the market more efficient hasten the recycling of nuclear resources into the soft path, the United States unilaterally, and interested states (especially nonaligned non-weapons states) multilaterally should freely, unconditionally, and nondiscriminatorily help any other country that wants to pursue a soft path—especially developing countries, on the lines suggested in the previous section. Nuclear fuel security initiatives should be turned into energy security initiatives.

Third, these efforts must be psychologically linked to the slower and more difficult problem of mutual strategic arms reduction—treating them as interlinked parts of the same problem with intertwined solutions. All bombs must be treated as equally loathsome, rather than being considered patriotic if possessed by one's own country and irresponsible if by others. A vigorous coalition of non-weapons states to this end is urgently needed. But the key missing ingredient for promoting a psychological climate of denuclearization, in which it comes to be seen as a mark of national immaturity to have or want reactors *or* bombs, is a reversal of the political example now set by the weapons states.

These combined actions may succeed only if they are taken together and explicitly linked together. Our thesis is certain to be misrepresented as "trying to stop proliferation by outlawing reactors." We have not said that. We have presented three main elements, and many sub-elements, of a coherent market-oriented program, and emphasize that they have a mutually reinforcing psychological thrust—a synergism—essential to their success. Their linkage is also pragmatic, as illustrated by the common and valid argument that if one phased out nuclear power and did nothing else instead, oil competition could worsen. Although the fight against the "vertical" nuclear arms race will be far more difficult than against the "horizontal" spread of bombs, their interlinkages with each other and with nuclear power are so inextricable that they must be pursued jointly and thought of jointly.

Nonproliferation policy addresses the increase of bombs, not their existence. If human life, and perhaps any life, is to persist on our planet, the *present* level and dispersion of bombs cannot be tolerated. We have no special insight into how the underlying political problems of the world can be solved, nor special optimism that they can be. Yet we place some small hope in the gathering portents of a fundamental transformation of human values such as has not been seen for centuries. As terrible global pressures—oil, a half-trillion dollars' uncollectable debts, ecological constraints, North-South and East-West tensions, the failure of the old development concepts, tyranny, poverty, the numbing weight of military spending—all converge to crush us, a greater spiritual energy that can inwardly rework human attitudes is starting to be pressed out of the cracks. In the next decade it may become a flood, profoundly extending the ways we care for the earth and for each other. No one can say if this will happen; but knowing that it might be starting to happen can alert us to grasp the lifelines of new awareness that our increasingly cornered psyches may throw out. The ego is strong, but the love of life may yet prove stronger.

Nor can we long survive if that hope proves illusory. Many nuclear physicists, in reflective moments, have wished for a magic wand that would make all nuclear fission impossible; they would wave it instantly. Yet if such a wand were waved, but if we did not also reverse the psychic premises of eons of homocentric, patriarchal culture, then the time bought might only be used to devise other ingenious ways of killing each other. The United States dropped on and around Vietnam the explosive equivalent of one Nagasaki bomb per week for seven and a half years. There are nerve gases, napalm, fuel-air explosives, submunition clusters, cruise missiles, germ warfare, now high-powered lasers. What next? Nonproliferation, however successful, can only buy time before some other holocaust unless we also come to grips with the central problems: power without purpose, tribalism, human aggression, injustice. A soft energy path would foster a social framework in which to address these problems. but it cannot solve them. Indeed, Carl-Friedrich von Weizsäcker suggests that as artillery made city walls and hence the city-state obsolete, so nuclear weapons may make both the nation-state and the institution of war obsolete—a necessity so alien that governments turn to the diversion of "deterrence" to avoid facing it.

Bernard Baruch's choice between the quick and the dead is still before us, with a new potential resolution that has every justification in rational calculations of cost, of security, of economic and political interest. But people and governments are not purely rational—as Baruch found when his 1946 plan fell victim to the cold war. Our ideas, or the refinements we seek, may work—if many decisions now made irrationally are brought expeditiously within the confines of the criteria which are claimed to guide them, or if political instincts rest on a wise perception of self-interest.

Need we have proliferation without nuclear power? Not if we do it right. The methodical collapse of the greatest cause and facilitator of proliferation offers, briefly, the chance to start afresh, to start to unravel the web of hypocrisy and doublethink that has stalled arms control and nonproliferation alike. Perhaps the same promotional skill that spread reactors around the world can now nurture alternatives to them and so place prohibitive political obstacles in the way of making bombs The same ingenuity and goodwill that managed, against all odds and inconsistencies, to obtain the small measure of international nuclear agreement we have today can now, freed from commercial imperatives that have proven vacuous, find ways to divert trend before it becomes destiny.

In 1946, the Acheson-Lilienthal report proposed a technological monopoly to prevent proliferation in an inevitably nuclear-powered future: mere treaties and policing, it reasoned, would prove weaker than national rivalries, some national instabilities, and human frailties. In 1980, with nuclear power no longer inevitable or even pragmatically attractive, the same political logic leads to quite a different policy prescription. Yet as we frame our different answers to different questions, the same prescient Acheson-Lilienthal conclusions seem apposite:

> We have outlined the course of our thinking in an endeavor to find a solution to the problems thrust upon the world by the development of the atomic bomb—the problem of how to obtain security against atomic warfare, and relief from the terrible fear which can do so much to engender the very thing feared.
>
> As a result of our thinking and discussions we have concluded that it would be unrealistic to place reliance on a simple agreement among nations to outlaw the use of atomic weapons in war. We have concluded that an attempt to give body to such a system of agreements through international inspection holds no promise of adequate security.
>
> And so we have turned from mere policing and inspection by an international authority to a program of affirmative action . . . . This plan we believe holds hope for the solution of the problem of the atomic bomb. We are even sustained by the hope that it may contain seeds which will in time grow into that cooperation between nations which may bring an end to all war.
>
> The program we propose will undoubtedly arouse skepticism when it is first considered. It did among us, but thought and discussion have converted us.

It may seem too idealistic. It seems time we endeavor to bring some of our expressed ideals into being.

It may seem too radical, too advanced, too much beyond human experience. All these terms apply with peculiar fitness to the atomic bomb.

In considering the plan, as inevitable doubts arise as to its acceptability, one should ask oneself "What are the alternatives?" We have, and we find no tolerable answer.