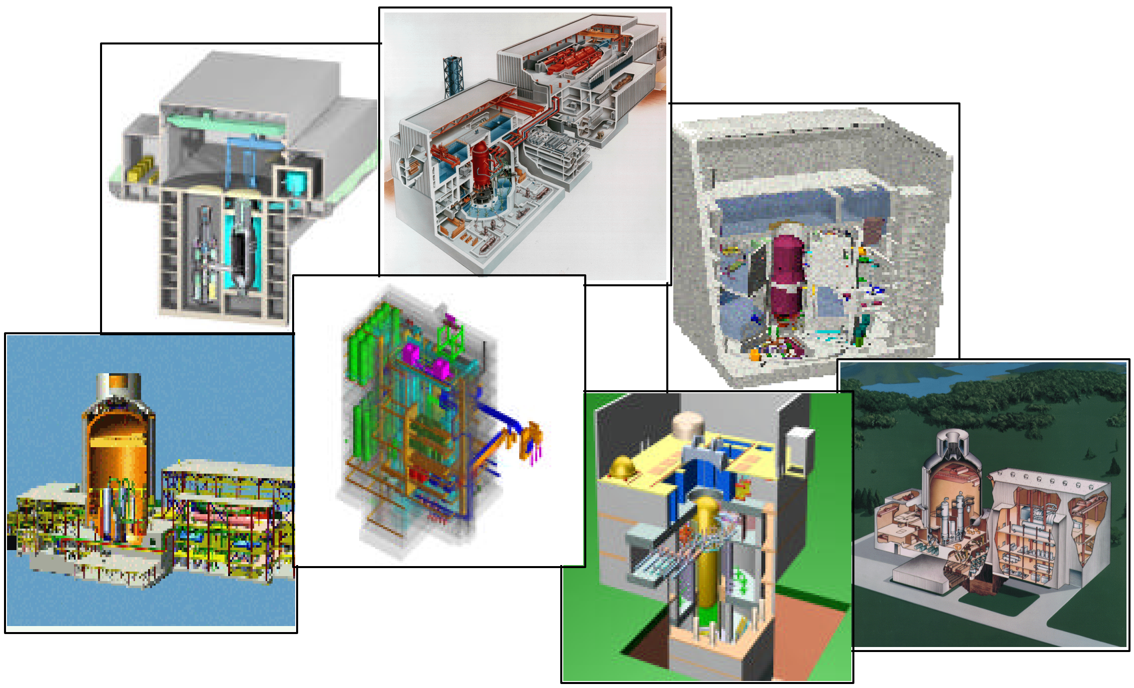
A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010

Volume I
Summary Report



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and its

Nuclear Energy Research Advisory Committee
Subcommittee on Generation IV Technology Planning

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Executive Summary

Nuclear power plants in the United States currently produce about 20 percent of the nation's electricity. This nuclear-generated electricity is safe, clean and economical, and does not emit greenhouse gases. Continued and expanded reliance on nuclear energy is one key to meeting future demand for electricity in the U.S. and is called for in the National Energy Policy. Nevertheless, no new nuclear plants have been built in the U.S. in many years, and none are currently slated for construction.

The U.S. Department of Energy (DOE) has been working with the nuclear industry to establish a technical and regulatory foundation for the next generation of nuclear plants. The DOE Generation IV (Gen IV) Program is assembling a 30-year road map for advanced plant and fuel cycle research and development. To complement Gen IV, DOE also organized a Near-Term Deployment Group (NTDG) to examine prospects for the deployment of new nuclear plants in the U.S. during this decade, and to identify obstacles to deployment and actions for resolution.

The NTDG membership includes senior and experienced personnel from nuclear utilities, reactor vendors, national laboratories, and academia. It is co-chaired by executives from Duke Engineering & Services and Southern Nuclear Operating Company.

Since commencing its work in February 2001, the NTDG has evaluated a wide spectrum of factors that could affect prospects for near term deployment of new nuclear plants as well as the readiness and technical suitability of various new plant designs identified as candidates for deployment in that time frame.

This report consists of two volumes: Volume I, this Summary Report, is a synopsis of the NTDG evaluations, conclusions and recommendations. Volume II, the Near-Term Deployment Roadmap, is a comprehensive report of the group's work, including descriptions of the candidate designs that have been evaluated, the methods of evaluation, and the institutional, regulatory, technical and economic factors considered.

Generic Gaps and Other Issues

The NTDG identified nine generic issues that could influence the viability of any new nuclear plant project. Of these, five are considered to be "gaps" warranting directed action. These are:

- Nuclear plant economic competitiveness
- Business implications of the deregulated electricity marketplace
- Efficient implementation of 10CFR52
- Nuclear industry infrastructure
- National Nuclear Energy Strategy

Four other significant issues were identified:

- Nuclear safety
- Spent fuel management
- Public acceptance of nuclear energy
- Non-proliferation of nuclear material

All of these are important. In each case, the NTDG considered the issue as it stands today, its implications with respect to near term deployment, and actions to improve prospects for near term deployment. The NTDG recommendations incorporate these conclusions.

Also, the NTDG examined the schedule implications and constraints associated with completion of a new nuclear plant construction project in the U.S. by 2010, taking into account the sequence and anticipated durations of essential siting, engineering, licensing, construction and testing work. This evaluation led the NTDG to conclusions regarding the timing of key activities necessary to support deployment of new plants in that time frame.

Reactor Design Candidates

Through DOE, the NTDG issued a Request for Information (RFI) in April 2001 seeking input from the nuclear industry and the public on nuclear plant designs that could be deployed by 2010[1]. In response to the RFI, proposals were received from U.S. and international reactor suppliers identifying the eight reactor design candidates. These include advanced boiling water reactors (BWRs), pressurized water reactors (PWRs) and gas-cooled reactors, as follows:

Design	Supplier	Features
ABWR	GE	1,350 MWe BWR, design certified by NRC and built and operating in Japan
SWR 1000	Framatome ANP	1,013 MWe BWR, being designed to meet European Requirements
ESBWR	GE	1,380 MWe passively safe BWR, under development
AP600	Westinghouse	610 MWe passively safe PWR, design certified by NRC
AP1000	Westinghouse	1,090 MWe PWR with passive safety features Higher capacity version of AP-600, not yet certified
IRIS	Westinghouse	100-300 MWe integral primary system PWR, under development
PBMR	ESKOM	110 MWe modular direct cycle helium-cooled pebble bed reactor, currently planned for construction in South Africa.
GT-MHR	General Atomics	288 MWe modular direct cycle helium-cooled reactor, being licensed for construction in Russia.

The RFI issued by DOE stipulated six evaluation criteria applicable to near-term deployment, and requested that respondents specifically address these criteria. They are:

1. Regulatory Acceptance
2. Industrial Infrastructure
3. Commercialization Plan
4. Cost Sharing Plan
5. Economic Competitiveness
6. Fuel Cycle Industrial Structure

[1]The phrase “by 2010”, as applied to near term deployment, is used throughout this report to imply deployment by the end of calendar year 2010, and has the same meaning as the phrase “in this decade”.

The NTDG evaluated each candidate design against each of the six criteria. The NTDG also identified and assessed in each case the design-specific gaps to near term deployment, based on information provided by the respondents. From these evaluations, the NTDG formed judgments regarding each candidate's potential for deployment by 2010.

Conclusions

1. New nuclear plants can be deployed in the U.S. in this decade, provided that there is sufficient and timely private-sector financial investment.

2. To have any new nuclear plants operating in the U.S. by 2010, it will be necessary for generating companies to commit to new plant orders by the end of 2003, in order to proceed with preparation of Construction and Operation (COL) applications. This will require very near term action by prospective new plant owner/operators and strong support from the government.

3. Although conditions are currently more favorable for new nuclear plants than in many years, economic competitiveness in a deregulated electricity supply structure remains a key area of uncertainty with respect to near term deployment potential. The other gaps to near term deployment require attention; in particular, implementing an efficient and effective regulatory approval process for siting and licensing of new plants is an urgent matter, and will require use of new processes in 10 CFR Part 52, that have not been demonstrated in actual practice.

4. There are excellent new nuclear plant candidates that build on the experience of existing reactors in the U.S. and around the world, and could be deployed in the U.S. in this decade. Readiness for deployment varies from design to design, based primarily on degree of design completion and status of regulatory approval. Those that are the most advanced in terms of design completion and approval status appear to be economically competitive in some scenarios, but not all. Other new nuclear plant designs, which still require licensing and engineering, show promise for improved economic competitiveness.

   The design-specific gaps that must be overcome by the gas-cooled candidates to achieve near term deployment are somewhat greater than those facing most of the water-cooled candidates.

5. Achieving near term deployment will require continuing close collaboration between government and industry. Selections of new projects must be market-driven and supported primarily by private sector investment -- but government support is essential, in the form of leadership, effective policy, efficient regulatory approvals, and cost sharing of generic and one-time costs.

Recommendations

The NTDG has formulated recommendations for actions that can significantly enhance prospects for deployment of new nuclear reactors in the U.S, in this decade. These are:

1. Implement a phased plan of action for new nuclear plants, by means of industry/government collaboration on generic and plant-specific initiatives, as follows:

Phase 1: Refine and demonstrate the 10CFR52 process, as described in Volume II, Chapters 3 and 5.
Resolve the uncertainties regarding the new plant regulatory approval process through actual use, and secure regulatory approval for several reactor design and siting applications on a time scale that will support plant deployments in this decade.

Phase 2: Complete the design of several near term deployment candidates, as reviewed in Volume II, Chapter 5.
Complete the detailed engineering and design work for at least one light water and at least one gas-cooled reactor, in time to allow start of plant construction on a schedule that could achieve deployment by 2010.

Phase 3: Construct and start up new plants.
When regulatory approvals and completed engineering are in hand, construct and deploy multiple commercially viable new nuclear plants by 2010.

All three phases should be conducted on a market-driven basis, primarily with industry funding and government cost sharing support for Phases 1 and 2. To some degree, the phases will overlap in time.

2. Put in place appropriate government financial incentives for privately funded new plant licensing, design and construction projects. Such arrangement would establish the basis for industry/government collaboration on the three-phase action plan. Government support in Phases 1 and 2 would be primarily via cost-sharing arrangements, and in Phase 3 by means of government financial incentives.

3. Conduct an assessment of the nuclear industry infrastructure and its implications on near term deployment. Determine the key areas of infrastructure weakness and the actions needed to accommodate them.

4. Develop a National Nuclear Energy Strategy that supports implementation of the National Energy Policy. This strategy would put in place a working structure for the aspects of the National Energy Policy applicable to new plant deployment, and would cover a variety of topics such as roles and responsibilities, priorities, funding principles and processes, and required administrative and legislative actions.

1 Background

1.1 Nuclear Power in the United States

Nuclear power has had a substantial role in the supply of electricity in the United States for over three decades. Currently, 103 nuclear power reactors produce approximately 20 percent of the electricity consumed in this nation.

The performance of nuclear plants in the United States is excellent. Over the past 20 years, the average capacity factor for U.S. nuclear plants has increased from about 60 percent to over 90 percent. Over this same period, nuclear safety has been excellent and there have been substantial reductions in operating and maintenance costs, worker exposures to radiation, and quantities of radioactive waste. There has been steady progress in issues such as long-term disposal of used nuclear fuel. Nuclear plants emit no greenhouse gases, an attribute of increasing importance in the U.S. and around the world. Many U.S. nuclear power plant owners have applied to NRC to extend their plant licenses.

In short, nuclear power technology has matured to the point that it is now a vital and extraordinarily valuable part of the nation's electricity supply.

Despite this excellent performance, no new nuclear plants have been ordered in the U.S. in the last twenty-three years. The extended hiatus in new plant construction is due primarily to economic factors. Nuclear plants are capital intensive, and many of the U.S. nuclear construction projects in the late 1970s and 80s were hampered by expensive delays, caused by engineering and management problems, a cumbersome regulatory process and in some cases by public opposition. At the same time, decreasing natural gas prices and general surplus in electricity supply served as economic disincentives to building new nuclear plants. Deregulation of electricity supply in the U.S. has added a level of economic uncertainty that temporarily discourages the major capital investment and long-term commitment required for new nuclear plant construction.

The rapid economic growth in the 1990s, combined with limited new power plant construction, has reduced electricity supplies to dangerously low levels in some parts of the nation. Most of the new power plants that have been built are fueled by natural gas – and volatile natural gas prices in recent years have resulted in high electricity prices in some areas of the nation. And at the same time, there is increasing societal concern regarding the emissions of airborne pollutants, and particularly greenhouse gases such as CO_2.

It is clear that an increase in nuclear-produced electricity, and therefore the design, licensing and construction of new plants, will be needed to meet the nation's growing need for safe, clean and economical electricity generation. This vital role of nuclear power is a central message of the President's National Energy Policy[2].

The nuclear industry responded to the National Energy Policy with "Vision 2020", which sets the goal of 50,000 megawatts of new nuclear generating capacity added to the U.S. grid by 2020. The Nuclear Energy Institute (NEI) took a lead role in formulating Vision 2020

[2] **National Energy Policy**, Report of the National Energy Policy Development Group, May 2001

and has established an Executive Task Force on New Nuclear Power Plants to help guide near term industry activities toward that goal.

1.2 The Generation IV Program, and Near Term Deployment

The U.S. Department of Energy (DOE) has been a leader in U.S. efforts to establish a technical and regulatory foundation for future generations of nuclear plants. In 2000, DOE embarked on an international initiative termed Generation IV (Gen IV) to assemble a plan – a "Roadmap" – for the research and development needed to support new nuclear energy systems that could become operational over the next thirty years. The Gen IV Program is being implemented under the guidance of the DOE Nuclear Energy Research Advisory Committee (NERAC), and specifically by the Generation IV Roadmap NERAC Subcommittee (GRNS).

To complement Gen IV, and in recognition of the importance of relatively near term energy supplies, DOE also established a Near-Term Deployment Group (NTDG). The NTDG objectives are:

- To assess prospects for the deployment of new nuclear plants in the U.S. during this decade by identifying and evaluating available new plant designs and by examining the regulatory, technological, and institutional gaps to near-term deployment.

- To recommend specific actions that could substantially improve prospects for deployment of new nuclear plants in this decade.

The NTDG has coordinated its efforts with those of NEI and its Executive Task Force on New Nuclear Power Plants, to ensure compatibility with ongoing industry activities. The recommendations in this Roadmap are complementary to NEI efforts and are essential to achieving Vision 2020.

1.3 The NTDG Evaluation

The NTDG commenced its activities in February 2001. The evaluation has comprised several distinct (although overlapping) activities, including:

- <u>Identification and assessment of generic issues</u>
  The NTDG identified nine generic issues that could influence the viability of any new nuclear plant project. Of these, five are considered to be "gaps" warranting directed action. These are:
  - Nuclear plant economic competitiveness
  - Business implications of the deregulated electricity marketplace
  - Efficient implementation of 10CFR52
  - Nuclear industry infrastructure
  - National Nuclear Energy Strategy

  Four other significant issues were identified:
  - Nuclear safety

- Spent fuel management
- Public acceptance of nuclear energy
- Non-proliferation of nuclear material

The NTDG evaluated each of these considering its current status, its implications with respect to near term deployment, and actions that may be needed to improve prospects for near term deployment. Also, the NTDG has examined the schedule implications and constraints associated with completion of new nuclear plant construction projects in the U.S. by 2010. Section 2 of this volume describes the NTDG evaluation of these generic issues.

- Identification and evaluation of specific reactor design candidates
  Through DOE, the NTDG issued a Request for Information (RFI) in April 2001 seeking input from the public and nuclear community on nuclear power plant designs that could be deployed by 2010 and generic issues that could impede this deployment. The RFI stipulated six evaluation criteria, established by GRNS and applicable to near-term deployment, and requested that respondents specifically address each in their submittals. The six criteria are described more fully in Section 3.3.

  In response to the RFI, proposals were received from U.S. and international reactor suppliers identifying eight reactor design candidates. These candidates include advanced light water reactors of both pressurized water and boiling water design, advanced gas reactors, and more innovative light water reactors. The NTDG evaluated these candidates, both individually and comparatively, in order to determine the prospects for deployment of a new nuclear plant in the U.S. by 2010, and the steps necessary to achieve that goal. This part of the evaluation is described in Section 3.

- Development of an integrated strategy
  Taking into account the generic and the design specific actions identified in the above assessments, the NTDG developed an integrated strategy, as described in Section 4. This strategy is based on a a dual-track phased plan of action, with sequence and timing necessary to achieve near term deployment of both water-cooled and gas-cooled reactors, and it includes provisions for government/industry collaboration, with appropriate cost sharing and other support actions.

- Conclusions and Recommendations
  Based on all of these evaluations, the NTDG developed a set of conclusions and recommendations, as presented in Section 5.

The NTDG evaluation of candidate reactor designs, as outlined above, addressed primarily the question of potential for deployment by 2010. In doing so, the NTDG examined technical and other aspects of the various designs and the detailed information provided in this Roadmap Report provides important insights into the potential effectiveness and value of each design. In several cases, candidate designs judged by the NTDG to be unlikely for deployment by 2010 are being evaluated in parallel by the Generation IV Program for long-term merit.

2 Considerations Applicable to Any NTD Initiative

This section describes the NTDG assessment of common factors, including generic gaps and issues that will affect any new nuclear project, considerations related to nuclear plant economics and the schedule challenges of new plant deployment by 2010.

2.1 Key Gaps to Near Term Deployment

Many of the factors that contributed to the two-decade hiatus in nuclear plant construction are still in play and must be dealt with effectively for any new nuclear project to succeed. Additionally, this long interval itself will pose challenges to the next nuclear plant to be built, regardless of plant design. Furthermore, some new conditions must be addressed.

The NTDG considers the following to be gaps to near term deployment, in the sense that they warrant some directed action if new nuclear plants are to be deployed by 2010. However, while they are individually important, they are not wholly separable or discrete. The recommendations proposed in Section 5 collectively address these gaps.

2.1.1 Nuclear Plant Economic Competitiveness

In order to attract the substantial financial capital required to license, procure and construct a new nuclear plant, a proposed new plant must be economically competitive in the de-regulated electricity marketplace. In assessing economic competitiveness, prospective investors will consider economic factors such as cost and cost uncertainty to complete the remaining engineering, construction cost, ability to complete construction on schedule, licensing risks, plant lifetime and projected operating, maintenance and fuel costs, projections of market conditions and alternative system generation costs.

In some respects, economic viability for a nuclear plant is difficult to demonstrate because:

- Nuclear plants are capital intensive, requiring substantial financial investment and time before the investor realizes any return. The long-term (i.e., life cycle) financial advantage of a nuclear plant must be sufficiently strong (particularly in a non-regulated environment) to outweigh the capital cost disadvantage.

- Historically, nuclear plant construction and operation have been vulnerable to costly interruption because of engineering and management problems, regulatory delays and public opposition.

- The two-decade hiatus in new plant construction in the U.S. implicitly discourages new plant investment.

Implications:

This is the most significant obstacle to new nuclear plant deployment. Future nuclear plant designs must be economically competitive. They must have capital costs significantly lower than those of the plants completed in the last two decades and operating and maintenance

(O&M) costs equivalent or lower then those of the best currently operating plants. These projected cost components must be predictable with high confidence. The net effect of predictable and lower capital cost and excellent O&M costs will be overall life cycle costs that are sufficiently attractive to secure private investment in competition with fossil plant investments.

As detailed in this report, the design candidates for near-term deployment have been developed with close attention to the necessity of economic competitiveness. Also, the substantial improvements in the nuclear plant licensing and regulatory processes have addressed many of the causes of high construction costs that affected earlier projects.

However, these improvements alone are not sufficient. Additional improvements in plant economic competitiveness need to be realized, such as aggressive measures to achieve faster, more economical construction schedules. Also, effective standardization of new plant designs, now a practical objective under the 10CFR52 licensing process, can significantly improve economic competitiveness, particularly for follow-on units in a design series.

Section 2.3 of Volume I and Chapter 4 of Volume II provide more details on the issue of economic competitiveness.

2.1.2 Business Challenges of the Deregulated Electricity Marketplace

Essentially all experience in building nuclear plants in the U.S. has been under the regulated utility framework. Aside from the heightened importance of economic competitiveness, the broad-scale deregulation in the U.S. electricity supply system is a significant change that creates both new challenges and new opportunities.

Challenges:

- **Risk**. Deregulation places the financial risk of new generation projects squarely on the plant investor. No longer can a regulated utility, with mandate to serve, finance a capital-intensive plant on the strength of its own certain economic value to the stockholders (i.e., a guaranteed adequate revenue stream, paid by ratepayers and underwritten by the regulator). To secure capital, project risks and rewards will have to meet the investment community's competitive standards.

- **Time-to-market**. The electricity market is influenced by regional, national and global factors such as the economy, fuel supplies, climate and weather. The time required to license and build new nuclear generation is too long to respond to short-term changes in market conditions.

Opportunities:

- **Business flexibility**. In a deregulated environment, nuclear plant investors can manage a new nuclear project on an expedited, cost-competitive basis. They can avoid the cumbersome constraints attendant to regulated operation such as open (or extensive) bidding and procurement processes. Thus, they should be able to build a new plant faster, and at significantly lower cost, than previous projects.

- **Electricity supply**. Investors can employ new business models in negotiating and committing to long-term contracts for sale of plant-generated electricity, unconstrained by regulated service area, and in taking advantage of price stability and fuel diversity. New opportunities to provide other network related functions such as ancillary services could provide additional revenue sources.

Implications:

This fundamental change in the electricity supply business can be capitalized upon by the nuclear industry. The NTDG judges that the new deregulated environment offers substantial business opportunity for successful nuclear ventures. However, the timing and form of such ventures have not yet been developed.

2.1.3 Efficient Implementation of 10CFR52

10CFR52 was developed in direct response to the inefficiencies, difficulties and financial risks experienced by the nuclear industry in licensing and constructing plants under the previous (10CFR50) process. However, major elements of the Part 52 process have not yet been demonstrated in actual practice. Given the complexity of the overall process of designing, siting, licensing and constructing a nuclear plant, the uncertainties associated with first-time application of this new regulation represent a significant risk to prospective new plant owner/operators.

The specific areas of uncertainty are:

- Design Certification (DC). Although there have been three successful DC applications under Part 52, each took 6-8 years. That duration would be far too long to permit deployment by 2010 of any plant not already certified, and is generally untenable for any new plant project in a deregulated electricity market. The NTDG believes that new plant DCs should be completed in a much shorter time frame for designs which are mature and for which DC applications are complete and technically sound.

- Early Site Permit (ESP). This is an essential licensing step, and one likely to be on the critical path for all new plants built in the U.S. To date, there have been no applications for ESP.

- Construction and Operating License (COL). The COL is a key feature of 10CFR52 that will permit the applicant to secure, prior to construction, the license to operate the plant contingent upon meeting pre-established NRC standards and without a post construction public hearing. This is a cornerstone of the 10CFR52 process, also on the critical path for new plant projects, – and it has not yet been demonstrated.

- Inspections, Tests, Analyses and Acceptance Criteria (ITAAC). Closely linked to the COL, ITAAC are to be used by NRC as a basis of ascertaining, during plant construction, that the licensee is meeting the requirements of the COL. A common understanding has yet to be established on the scope of ITAAC required in a COL and how the ITAAC process is to be implemented during construction. This is a complex matter, with potential implications on plant construction schedule and cost.

In parallel with efforts to clarify key Part 52 licensing processes, the industry and NRC are taking the first steps toward establishing a new, risk-informed, performance-based regulatory framework for future plants, including technical/design, operational and administrative requirements. This effort will take advantage of insights and principles from the recently completed revision of the NRC reactor oversight program. This will be a long-term effort, with benefits accruing to plants being deployed in the near-term as various parts of the framework are completed and available for use.

Implications:

Together, these areas of licensing uncertainty require near-term interaction by industry and NRC, and resolution on a priority basis, prior to full implementation of the 10CFR52 process. It is imperative that substantial effort be applied, in advance, to identify and preempt unnecessary (and costly) implementation difficulties.

Industry and NRC should also pursue the development of risk-informed and performance-based regulatory framework for future plants. The NTDG believes that strong progress toward a new regulatory framework will increase confidence of prospective applicants in the regulatory environment for new plants and encourage business decisions to proceed with new nuclear projects.

2.1.4 Nuclear Industry Infrastructure [3]

There has been no real growth in the nuclear industry for many years. The practical consequence has been gradual erosion and current shortfalls in such important infrastructure elements as:

- Qualified and experienced personnel in nuclear energy operations, engineering, radiation protection and other professional disciplines.
- Qualified suppliers of nuclear equipment and components (e.g., manufacturing organizations with N-stamp credentials, part 21 QA programs). This includes fabrication capability and capacity for forging large components such as reactor vessels.
- Contractor and architect/engineer organizations with personnel, skills and experience in nuclear design, engineering and construction.

Implications

Although the Congress, DOE and NERAC have taken steps to support and restore the nuclear industry infrastructure, the infrastructure deficiencies facing those who construct and

[3] This is an issue that affects all plant deployment prospects to some degree, and some more than others. The NTDG has considered it both as a common factor and as a potential plant-specific issue, as described in Section 3.

operate new plants cannot be fully resolved in advance. Some initial steps (e.g., advance planning, long-lead personnel initiatives) can help, however, and correction will occur as a natural outgrowth of building and operating new plants[4].

A realistic expectation for the near term is that there will be some penalties due to infrastructure weakness, in forms such as cost pressure driven by supply and demand imbalance and excessive lead times for material and equipment delivery. The challenge for the initial project leaders will be to take proactive steps to prevent or minimize the adverse effects of infrastructure limitations.

Over the longer term, substantial restoration of infrastructure will be needed to support construction and operations of an increasing number of nuclear plants. An important strategic element of this build-up should be an expansion of U.S. domestic capability in major component manufacture and assurance of competition in uranium enrichment services.

2.1.5 National Nuclear Energy Strategy

In view of the importance to the nation of a strong and growing nuclear generating capacity, and the evident difficulty in beginning new nuclear plant projects in the U.S. after a two-decade hiatus, strong and visible leadership from the Federal Government is essential. The National Energy Policy Report of May 2001 was an important first step; but it needs to be followed with a strategic plan that establishes specific nuclear energy goals, priorities and commitments for appropriate support.

Substantial effort and funding is required to bring to the marketplace a new and advanced nuclear plant design. Strong commitment and investment by industry is essential to this achievement. Consistent with the importance to the nation of a healthy and growing nuclear power capability and with the DOE overall responsibility to enable and maintain an adequate electricity supply, there is also an appropriate role for government financial and other support to the industry efforts to revive the nuclear option.

Over the last ten years, U.S. Government support for nuclear has been disproportionately low in comparison with that for other, competing electricity supply technologies. It is the NTDG view that increased and effective government support for nuclear power in the U.S. is needed.

Implications:

Section 4.1 outlines the NTDG recommended approach regarding government support for new nuclear power in the U.S. and more detailed presentation is provided in Volume II, Chapter 6. The underlying concept is that shared industry and government funding should be provided for activities necessary to satisfy safety-related design work and licensing

[4] One potential industry action that could have very positive near-term infrastructure benefit is the initiative under consideration to recover or complete existing sited nuclear power plants that have been shutdown or terminated before completion. Such projects could yield significant new nuclear capacity and would also stimulate immediate infrastructure growth, particularly in plant construction and in nuclear material and equipment supplies.

requirements for new plant construction, particularly those involving first-time implementation of new regulatory processes and or new and advanced design concepts. The recommendations in Section 5 are consistent with this approach.

Over the long term, government support is needed for research and development leading to fundamental technological advances. The Gen IV Program addresses these long-term needs.

2.2 Other Important Issues

Along with the generic gaps identified above, there are significant issues that could influence new plant deployment which require close attention. However, current industry and government actions are appropriate and no additional actions are needed to support NTD initiatives.

2.2.1 Nuclear Safety

Today's current plants are very safe and continue to improve. The certified designs have surpassed all regulatory and utility requirements for enhanced safety and are quantitatively safer than current plants. The close scrutiny of the NRC and stringent licensing requirements will ensure very high safety levels for all near term deployment plants.

Among the light water-cooled reactor (LWR) candidates considered for near-term deployment, safety approaches are comparable to or better than those of currently certified advanced reactor designs, and they will be evaluated by NRC against established and proven standards. The gas-cooled concepts employ different safety measures than light water plants[5], but it is anticipated that these will achieve safety performance at least as good as currently certified advanced LWRs. In no cases are the near-term designs under consideration expected to present significant challenges with respect to nuclear safety.

The recent attack on the World Trade Center has raised concerns about the adequacy of sabotage protection at nuclear energy plants. Industry, NRC, and other responsible federal and state agencies are addressing this issue. A number of specific short-term actions have been taken, and longer-term implications are being evaluated. New nuclear plants will benefit from this examination and will implement the actions deemed necessary for existing plants.

Implications:

All new plants will meet the current, very high NRC standards and requirements regarding nuclear safety.

[5] The gas-cooled reactors licensed by the NRC and operated in the U.S. (Peach Bottom Unit 1 and Fort St. Vrain) are no longer operating and were significantly different in design than gas-cooled reactor design candidates under consideration for near term deployment.

2.2.2 Spent Fuel Management

From a technical standpoint, the safe handling and storage of spent nuclear fuel (SNF) has been among the most successful solid waste management programs in the industrial sector. Storage of spent fuel at a reactor plant site is well understood and fully demonstrated -- its cost is moderate, licensing is straightforward, and environmental impact is minimal. On-site storage has been determined to be acceptable for the extended life of currently operating plants and can be readily incorporated in the design of any new plants.

Long-term government responsibility for spent fuel disposal remains clear, and a presidential decision is expected soon regarding the suitability of the proposed federal repository at Yucca Mountain. Nevertheless, the long-term disposition of SNF remains a contentious open issue in the U.S. and a serious concern to many regarding the efficacy of proceeding with new nuclear plants.

The SNF management situation facing all nuclear plants over the longer term still requires resolution. The U.S. government must continue to make progress in fulfilling its responsibility for SNF disposition as mandated by the National Waste Policy Act of 1982 (as amended). This will require difficult political and societal decisions regarding land use, nuclear fuel resources and SNF transportation. Disposal and storage facilities (including permanent repository and monitored retrievable storage, as applicable) will have to accommodate existing SNF as well as that generated by existing plants during their extended lifetimes and by new plants.

Although these questions may be difficult and politically divisive, the technical implications are relatively straightforward, and their resolution is not made significantly more difficult by an increase in the quantity of SNF to be managed, because of new plants[6]. In contrast to the environmental implications of expanded operation of fossil fueled plants (e.g., SO_2, NO_X, greenhouse gas emissions), SNF disposal is a more tractable, less threatening problem from the standpoints of environmental protection and public health and safety.

Advanced plant designs and fuel cycles for the next generation, as being evaluated under the Gen IV Program, are expected to reduce the spent fuel management burden.[7]

Implications:

Long-term disposition of SNF is a legacy issue -- a significant matter of national policy. It affects nuclear fuel supply, use of natural resources and land, and it involves very significant cost. However, resolution of this long-term strategic issue is not a prerequisite to new plant construction.

[6] The Nuclear Energy Agency of the OECD has concluded that "nuclear waste management is fully consistent with the principles of sustainable development, and this issue should not be considered a barrier to the continued development of nuclear power". NEA News, 2001 – No.19.1, Pp 18-20.
[7] The Gen IV Program, which primarily focuses on long-term deployment of nuclear energy, has established as a major goal that "nuclear energy systems will minimize and manage their nuclear wastes and notably reduce the stewardship burden in the future, thereby improving protection of the public health and environment".

The reactor designs for new nuclear plants must provide adequate on-site storage capability to safely accommodate with substantial margin the full quantity of spent fuel to be produced by the plant. In support of this, nuclear industry spent fuel storage and cask suppliers must ensure that their products can accommodate the full range of anticipated fuel design and operating parameters.

2.2.3 Public Acceptance of Nuclear Energy

In the past, opposition to nuclear power by some segments of the public caused significant licensing and construction delays, at substantial cost. For that reason, public acceptance of new plants is a factor that prospective owners must consider.

Many recent public opinion surveys show positive and growing public support for building new nuclear plants[8]. This trend seems to be influenced by public recognition of the need for adequate electric power generation capacity and by growing awareness of the ongoing safe, clean and economical performance of today's plants. Continued excellent performance of existing plants should result in further increase in public support.

Experience in existing plant operations shows that achieving and maintaining public trust at the local level is extremely important. Successful nuclear plant operating companies have built that trust through open, direct and proactive communication with the public in their regions.

Implications:

NTDG views public acceptance as an important issue, but one that is not likely to strongly affect near term deployment potential. Continued safety and success in nuclear operations, for current and future plants, should yield steadily improving public trust and acceptance.

Current and future nuclear plant operators must therefore continue to place highest emphasis on safe operation of their plants and on maintaining consistent, open and honest communications with their constituents. On the national level, industry and government efforts should continue to present to the public accurate and balanced information regarding nuclear power.

2.2.4 Non-Proliferation of Nuclear Materials

As noted in the NTD RFI, non-proliferation is considered to be longer-term global fuel cycle issue, and is being addressed by the Generation IV Roadmap.

Extraction of weapons-usable material from spent commercial fuel is extremely difficult and more costly than other methods, and is not an issue in the U.S. for either current plants or new plants being considered for near term deployment. All of the design candidates

[8] "A new national survey finds that the dramatic increases in public support for nuclear energy have held at high levels, despite lower public concern about energy shortages. Almost two thirds of U.S. adults continue to support definitely building new nuclear power plants. Support has grown from 42 percent in October 1999 to 63 percent in July 2001." [Bisconti, September 2001]. Gallup and other media report similar results.

considered by the NTDG for near term deployment all utilize fuel cycles that do not re-cycle fuel. Therefore they share the same strong proliferation resistance as existing U.S. reactors.

Implications

The current non-proliferation practices for operating nuclear power plants apply to NTDG plants. This issue is not relevant to near term deployment.

2.3 Cost Competitiveness – Criteria for Success

Volume II provides a comprehensive explanation of the new deregulated electricity marketplace and its implications regarding cost competitiveness of new nuclear plants, and a supporting computational model. Evaluation of the results of this study leads to the following observations regarding the necessary attributes of new nuclear designs, if they are to achieve cost competitiveness:

- Nuclear plant “time to market” is a key factor affecting economic competitiveness in the deregulated marketplace. Long lead-times prior to construction and long construction periods reduce economic competitiveness and increase project risk.

- Resolution of licensing issues before project commitment is essential to ensuring acceptably short lead-times. Resolving in advance the issues of economic need for the project, site licensing and permitting, and NRC safety regulatory approval of the design are necessary to prevent an open-ended licensing process when the plant is under construction and interest during construction accumulates.

- Depending on market conditions, project overnight capital cost (including engineering, procurement and construction (EPC) cost, owners cost, and contingencies) need be contained at about 1,500 $/KWe or less. Overnight capital costs of 1,200 $/KWe or less should secure broad market acceptance. Break-even nuclear capital costs will depend on market prices, determined in turn by the cost of fossil fuels to the marginal generating unit. Higher overnight capital cost figures could prove economic in localities with sustained high market prices, or under specially structured power purchase agreements (PPAs). Large nuclear plants will require a total as-spent investment, expressed in current year dollars, as high as $2B.

- Nuclear plant production costs (fuel and O&M expenses) should be held to 10 $/MWh or less. The major advantages of nuclear power plants are their low and stable running costs, which makes them ideal for long-term bilateral contracts. In order to allow competitively priced contracts, production costs should be kept as low as possible to provide adequate margins for capital cost recovery and profits.

- Nuclear plant lifetime capacity factors should be sustained at 85 percent or higher, in order to maximize incoming revenues and the potential for margin capture. This is a strong advantage of nuclear and another key to economic competitiveness.

- Achieving high safety performance is essential to the economic well being of the plant. Regulatory-mandated shutdowns and inspections will reduce incoming revenues, increase capital outlays for recovery and reduce plant profitability.

- Nuclear project developers and owners should locate their plants in specific locations likely to experience high and sustained market clearing prices. In general, locations where market prices can be forecasted to remain above 40 $/MWh for at least the first ten operating years, would be preferable.

- Nuclear plant owners should strive to anchor their generation in long-term bilateral PPAs, based on the prevailing local market prices (at or about 40 $/MWh). The major selling point of an operating nuclear plant is the very low volatility of its annual prices. This should allow competitively priced long-term PPAs, which will provide adequate margin capture.

- Nuclear plants should strive to obtain the best financing package possible, based on all of the above. Typical values could include containing the return on investment (ROI) requirements to 15 percent or less, allowing debt repayment periods as much longer than 10 years as feasible, and reducing equity financing to 40 percent or lower.

- The most important observation derived in this study is that the deregulation of the energy markets did not eliminate the prospects for capital-intensive base load generation options such as nuclear and coal-fired plants. Nuclear plant designers and operating companies are adjusting to the requirements of the new energy markets. The cost and performance targets discussed above are expected to be achieved in real projects, enabling the long-term role of nuclear power in the future energy markets could be sustained and enlarged.

2.4 Deployment Timeline: Major Elements and the Critical Path

This section outlines the necessary sequence of major events involved in designing, licensing and building a nuclear plant, their sequence and logical relationships and their approximate durations.

2.4.1 Timeline Elements

The activities involved in designing, licensing and building a new nuclear plant, and their approximate time frames and schedule relationships, are described in Volume II. In summary, they are as follows:

Activity	Description	Nominal Time frame
Site Licensing (ESP)	– Preparation and submittal of an application for Early Site Permit (ESP) per 10CFR52 – NRC review, interaction with applicant, public hearings (if required), and ESP Issuance	3 years total, including: – 1 year preparation – 2-year NRC review and approval This is a likely critical path

Activity	Description	Nominal Time frame
		activity for new plant projects.
Design Certification (DC)	– Preparation and submittal for Design Certification (DC) per 10CFR 52; may include extensive engineering, analysis and testing – NRC review, interaction with applicant, public hearings (if required), and rulemaking	– Preparation time: 1-3 years, depending on technical issues, precedents – 3-year NRC review and approval (2 years in some cases as discussed below) –
Plant Licensing (COL)	– Preparation and submittal for Construction and Operation License (COL) per 10CFR 52 – NRC review, interaction with applicant, public hearings, and COL Issuance – Could be combined or conducted in parallel with ESP and /or DC	– Preparation time: 1-year, presuming ESP/DC applications have been submitted – 1-year NRC review and approval, not including hearings, (with pre-existing ESP and DC) – 3-year NRC review and approval, not including hearings, for COL without pre-existing DC This is a critical path activity, in all cases.
Detailed Engineering and Testing	Includes all engineering, design, and testing needed to build the plant, beyond that needed for licensing	3-6 years – Depends on complexity of design, precedent or pre-existing design work – Presumed not to be on the critical path
Long Lead-time Procurement	Procurement of material and equipment which must be ordered in advance of start of construction to prevent critical path impact	– Reactor vessel, other large vessels are usually the pacing items, require minimum of 2 years prior to delivery – Can be kept off critical path with early (pre-COL) financial commitment

Construction	Includes: – Pre-construction and site preparation activities – Plant construction (first structural concrete to fuel load) – Fuel load and pre-operational testing	Minimum of 4 years for a large single unit site, 3 years for first module of a modular plant, for critical path work (plant construction, fuel load and testing). – Site preparation, ~1-2 years, not on critical path – Some previous U.S. project construction time frames have exceeded 10 years; recent overseas construction times have been in the 4-5 year range.

2.4.2 The Nominal Schedule for Near-Term Deployment

Based on the main elements outlined in the table above and target of commercial operation by the end of 2010, the NTDG offers the following general observations regarding schedule:

1. Critical path construction must start by the beginning of 2007 at the latest, for any realistic potential to achieve commercial operation in 2010. Therefore, the COL must be in hand by that time.

2. For designs already certified, and assuming two to three years for ESP and COL (from first submittal to full NRC approval), initial application must be submitted to the NRC by the end of 2003 or early 2004, depending on degree of ESP and COL overlap, in order to obtain the COL in time for construction start in early 2007.

   NTDG considers this three-year time frame for ESP and COL approval for a certified design to be achievable. It is based on the assumption of an uncontested COL (no formal hearings), since all design and siting issues would have been previously resolved with hearing opportunity at the time of resolution. With significant overlap of the ESP and COL processes, the ESP/COL processes could be completed in less than three years. For example, with simultaneous ESP and COL submittals, the time required for NRC approvals is likely to be controlled by the ESP process, the longer of the two. Thus simultaneous ESP/COL processes could be completed in two years, exclusive of hearings.

3. For designs not yet certified, it may be possible to combine the Final Design Approval (FDA) phase of the DC and/or ESP with the COL process, and to secure COL in a four to five year time frame (that is, by the end of 2006), assuming significant overlap between ESP and COL applications. In this scenario, the COL includes essentially all of

the NRC design review and approval process that would otherwise be part of the FDA phase of the DC, but would not include the rulemaking phase of the DC. This allows construction and operation of an approved design, with DC proceedings undertaken at a later date, after plant operation, so that the design that is finally certified for standardized construction has the benefit of any lessons learned from the first construction project. However, this is a significantly more challenging licensing approach, and success (in that time frame) will depend on such factors as technical completeness and quality of licensing submittals, timeliness of both NRC and applicant resolution of emerging issues, and a smooth and conclusive hearing process.

4. For any new plant design, it is NTDG's view that the activities that precede site-specific licensing (e.g., business decisions, site selection, selection of NSSS, and preparation of licensing applications) must be largely concluded in the 2003 time frame to achieve high confidence that the plant can be placed in service by 2010.

2.4.3 Timeline Variations and Opportunities for Acceleration

The above depicts a nominal or baseline schedule for near-term deployment and identifies realistic constraints and interim milestones. However, the actual sequence and duration of engineering, licensing, procurement and construction activities could follow any number of alternate scenarios as discussed in Volume II, Section 5. Some key factors affecting the likelihood that a given plant can be completed by 2010 are:

- The licensing preparation and approval durations could be longer or shorter than the nominal case, depending primarily on the degree of pre-application work needed (e.g., engineering, testing and analysis). These will vary from design to design.

- The willingness of the plant owner/operator and/or the plant investors to finance expensive critical path activities on a risk basis, prior to full licensing (particularly COL), will affect the total schedule. Lower risk approaches (such as deferring non-licensing engineering and long-term procurement until after receipt of COL) would add several years to the overall time frame (compared to the nominal case), and in some cases could preclude operation by 2010.

- Critical path construction time frames for the smaller plants, and particularly for modular designs, could be shorter than the nominal case assumption (four years). On the other hand, actual construction experience in the U.S. suggests that significantly longer construction periods are quite possible as well.

- Variations permitted within the 10CFR52 licensing process (such as pursuing a COL without a DC, as is under consideration for the PBMR and GT-MHR) could decrease the total licensing time, but entail more licensing risk.

3 Evaluation of Reactor Designs for NTD Potential

3.1 Near Term Candidates

The reactor designs considered in this evaluation of near term prospects for new nuclear generation were those identified in response to the RFI issued by DOE in April 2001. The intent of the NTDG evaluation was to determine those sufficiently mature in design and licensing to support deployment in this decade, and to assess their respective advantages, disadvantages and readiness for near term deployment.

In all, eight plant designs were assessed. Their key features are summarized on the following table:

Design	Supplier	Size and Type	Key features
ABWR	GE	1,350 MWe BWR	Advanced evolutionary LWR, design certified by NRC and built and operating in Japan.
SWR 1000	ANP Framatome	1,013 MWe BWR	Advanced BWR design; to meet European Requirements
ESBWR	GE	1,380 MWe BWR with passive safety features	Based on earlier passive SBWR design, but higher in capacity and decreased in physical size per installed KWe.
AP600	Westinghouse	610 MWe PWR with passive safety features	Advanced passive PWR, design certified by NRC
AP1000	Westinghouse	1,090 MWe PWR with passive safety features	Higher capacity version of AP-600; not yet certified
IRIS	Westinghouse	100-300 MWe PWR	Integral primary system plant design; eliminates classic LOCA accidents.
PBMR	ESKOM	110 MWe modular pebble bed gas-cooled reactor	Modular direct cycle helium-cooled pebble bed design, currently planned for construction in South Africa.
GT-MHR	General Atomics	288 MWe prismatic graphite moderated gas-cooled reactor	Modular direct cycle helium-cooled reactor being licensed for construction in Russia, for power production and disposition of excess Russian weapons-grade plutonium.

The following sections provide additional information on the eight candidates.

3.1.1 ABWR

General Electric (GE) developed the 1,350 MWe Advanced Boiling Water Reactor (ABWR) in cooperation with the Tokyo Electric Power Company and Hitachi and Toshiba. The ABWR incorporates design features proven in many years of worldwide BWR operating experience, along with advanced features such as vessel-mounted reactor recirculation pumps, fine-motion control rod drives and a state-of-the-art digital, multiplexed, fiber-optic control and instrumentation system.

The ABWR design was reviewed and certified by the NRC in 1996, under the provisions of 10CFR52. It is the only one of the reactor designs evaluated for near term deployment for which all engineering is complete and there is actual construction and operating experience. Two ABWRs, Kashiwazaki-Kariwa Units 6 and 7 went into commercial operation in Japan in 1996 and 1997 and are currently in their fifth cycle of operation. More recently, two ABWR units received regulatory approval and are now under construction in Taiwan.

3.1.2 SWR 1000

SWR 1000 is a 1,013 MWe BWR developed by Framatome Advanced Nuclear Power (F-ANP) in conjunction with German electric utility companies and European partners. The SWR 1000 design combines proven, conventional BWR features with passive safety features to provide enhanced safety benefits. The plant is designed to meet European requirements, including relevant requirements in Germany's nuclear codes and standards and other recommendations proposed by German and French reactor safety commissions for the European Pressurized Water Reactor (EPR).

A four-year design phase for the SWR 1000 was completed in 1999 and included the development of a site-independent safety analysis report, a probabilistic safety analysis report, and projected construction costs. FANP advises that in parallel with efforts to market the SWR 1000 in Europe, they may consider entering the U.S. market. However, to date, no action has been taken to adapt the design to meet U.S. standards or to prepare for submittal to the NRC for design certification.

3.1.3 ESBWR

ESBWR is a 1,380 MWe, natural circulation, passively safe boiling water reactor developed by GE, in concert with several international utilities, designers and research organizations. The design is based on its predecessor 670 MWe passively safe SBWR, initially developed in the early 1990's with DOE support, and it also utilizes many design features of the ABWR. The substantially higher plant power, combined with extensive reconfiguration and simplification of the reactor systems and containment structure, make possible very significant cost reduction in comparison with both SBWR and ABWR.

Although the ESBWR offers attractive advantages, GE is not yet moving ahead with detailed engineering and design certification of the plant. GE's current plan is to proceed with ESBWR in a "step-wise" fashion -- first with design certification, as funding becomes available, and then with detailed engineering, but only with the commitment and financial support of a plant customer.

3.1.4 AP600

The AP600 is a 610 MWe PWR. The core, reactor vessel, internals, and fuel are essentially the same design as for present operating Westinghouse PWRs. Fuel power density has been decreased to provide more thermal margin. Canned rotor primary pumps, proven in the naval program and in fossil boiler circulation systems, have been adopted to improve reliability and maintenance requirements. The innovative aspect of the AP600 design is its reliance on passive features for emergency cooling of the reactor and containment, provided by natural forces such as gravity, natural circulation, convection, evaporation, and condensation, rather than on AC power supplies and motor-driven components.

Extensive testing of the AP600 passive cooling systems has been completed and supported by independent confirmatory testing by NRC to verify the design and analyses of the passive emergency cooling features. NRC has certified the AP600 design. Additional detailed design work would be needed before the plant would be ready for construction.

3.1.5 AP1000

The AP1000 is a 1,090 MWe PWR of the same basic design as the AP600, but up-rated in power to achieve economy of scale. The AP1000 passive safety systems are essentially the same as those for the AP600, except for some changes in component capacities. The power up-rate has been achieved by increasing the length and number of fuel assemblies, by increasing the size of the reactor vessel and primary components, and by increasing the height of the containment and the size and capacity of the secondary plant energy conversion components. The AP1000 generating cost is estimated to be 30 percent less than that of AP600, because the additional power rating is achieved with a only a small increase in capital cost.

AP1000 application to NRC for design certification is scheduled for submittal to NRC by January 2002. Pre-application reviews with NRC are already underway. As with the AP600, additional detailed design work must also be done before the plant will be ready for construction.

3.1.6 IRIS

IRIS is an innovative small (100-300 MWe) pressurized water reactor under development by Westinghouse. The key feature of the IRIS design is the integrated primary system – that is, all primary system components, including the steam generators, coolant pumps and pressurizer are housed along with the nuclear fuel in a single, large pressure vessel. As such, IRIS offers potential safety advantages, primarily related to the elimination of any potential for large-break loss of coolant accident; and its small size and modular design may simplify on-site construction and be deployable in areas not suitable for large nuclear plants.

IRIS is currently in the conceptual engineering stage, and is being developed by an international consortium and with some support from the DOE via the NERI Program[9]. The

[9] The U.S. DOE Nuclear Energy Research Initiative (NERI) annually awards funding to selected promising nuclear projects.

integral primary system configuration introduces significant design and licensing challenges that will be difficult to overcome, particularly in the relatively short time frame established for this near term deployment assessment. In key design details, IRIS is fundamentally different from any reactor licensed and operating in the United States. For that reason, extensive analysis and testing will be needed as a prerequisite to NRC licensing and commercial deployment in the U.S. The IRIS sponsors' response to the NTDG RFI identifies this needed development and testing.

3.1.7 PBMR

The Pebble Bed Modular Reactor (PBMR) is a 110 MWe graphite-moderated, helium-cooled reactor. Heat generated by nuclear fission in the reactor is transferred to the helium and converted into electrical energy in a gas turbo-generator via a Brayton direct cycle. The PBMR core is based on the German high temperature gas cooled technology and uses spherical fuel elements. The fundamental objective of the gas-cooled reactor design concept is to achieve an exceptional level of nuclear safety, via fuel design that effectively precludes the possibility of a core melt accident.

The first PBMR is planned for construction in South Africa, under a joint venture led by ESKOM. The plant design is currently in the detailed engineering stage and is preparing licensing application material for review by the South Africa regulatory authorities. Exelon, the largest nuclear utility in the U.S., is a member of the joint venture and anticipates a follow-on PBMR project in the U.S. The U.S. PBMR project is in the early stages of preparation for application to the NRC for an ESP and a COL under 10CFR52.

Of the reactor designs evaluated by NTDG, the PBMR is the only one for which there is currently a potential customer actively involved and investing in the plant's development. Although Exelon's continued involvement is not assured, this is a significant factor in the PBMR potential for deployment in the U.S. by 2010.

3.1.8 GT-MHR

The Gas Turbine – Modular Helium Reactor (GT-MHR) is a graphite-moderated helium cooled reactor. Each unit generates 288 MWe, with up to four units comprising a complete plant. Heat generated by nuclear fission in the reactor is transferred to the coolant gas (helium) and converted into electrical energy in a gas turbo-generator via a Brayton direct cycle. The fuel consists of spherical fuel particles; each encapsulated in multiple coating layers, formed into cylindrical fuel compacts and loaded into fuel channels in graphite blocks. The GT-MHR design offers very high thermal efficiency (approximately 48 percent) and outstanding nuclear safety.

The GT-MHR is being developed under an international program in Russia for the disposition of surplus weapons plutonium. Government and private sector organizations from the U.S., Russia, France, and Japan are sponsoring the development work. General Atomics (GA) has the lead responsibility for providing U.S. technical support. The Russian GT-MHR demonstration plant is planned to be operational in 2009.

A parallel GT-MHR commercial plan has been assembled and could lead to adaptation of the design to utilize uranium fuel. The detailed design produced in Russia would be converted to U.S. standards and revised as necessary for the U.S. application. At this point, GA is actively seeking a U.S. owner/operator.

3.2 Other Candidates (not evaluated by NTDG)

The NTDG evaluated those candidate reactor designs submitted per the requirements of the DOE Request for Information, as described above. For completeness, it is noted that other designs may also be deployable by 2010. However, these were not evaluated and the NTDG offers no judgment as to their feasibility as near term deployment candidates.

3.2.1 EPR

The European Pressurized water Reactor (EPR) is a very large (1,545 MWe or 1,750 MWe) design developed in the 1990s as a joint venture by French and German companies, Framatome and Siemens. The basic design was completed in 1997, working in collaboration with other European nations, and conforms to French and German laws and regulations. As the EPR design was being developed, there was substantial cooperation between the European utilities developing EPR user requirements and the U.S. utilities leading the US ALWR Program and its Utility Requirements Document. The EPR was not submitted to the NTDG in time to support an assessment. Further, as with the SWR 1000, the designer, Framatome ANP, has not made a decision regarding entry into the U.S. nuclear market.

3.2.2 System 80+

The System 80+ is a 1,350 MWe PWR design developed by ABB-CE (now merged with Westinghouse). It conforms to the ALWR Utility Requirements Document and was certified by NRC in May 1997. Plants based on the System 80+ design have been built in Korea. However, as of this time Westinghouse has chosen not to market the System 80+ design in the U.S.

3.2.3 CANDU

Canada's CANDU reactor designs use multiple pressure tubes containing nuclear fuel assemblies in the active core region, which permit on-line refueling. Heavy water is pumped through the pressure tubes to remove heat and is also used to moderate neutrons in a low-pressure vessel (the Calandra) that surrounds the pressure tube region. CANDU reactors have been deployed outside Canada (e.g., Romania, South Korea). Recent advances to this design use light water cooling but retain heavy water moderation in the Calandra. This approach holds significant promise for improved maintainability and economics. Most CANDU designs are in the medium (500-1,000 MWe) size range.

3.3 Design Evaluation and Comparison

The following sections summarize the NTDG evaluation of the eight candidate reactor designs. These include assessment of each candidate's compliance with the six criteria established by GRNS for the NTDG, identified design-specific gaps, projected cost performance, schedule considerations, and overall potential for deployment by 2010.

In each of these evaluation categories, the NTDG conclusions for all eight candidates are summarized in tabular form. Tabular summaries are intended to provide a concise comparison of the relative merits and demerits of the reactor designs evaluated. The underlying individual evaluations, in much more detail, are presented in Volume II, Chapter 5.

3.3.1 Criteria

The six evaluation criteria established by the GRNS as a basis for near term deployment, as stated in the NTD RFI, are as follows:

1.	**Regulatory Acceptance**	Candidate technologies must show how they will be able to receive either a construction permit for a demonstration plant or a design certification by the U.S. Nuclear Regulatory Commission (NRC) within the time frame required to permit plant operation by 2010 or earlier.
2.	**Industrial Infrastructure**	Candidate technologies must be able to demonstrate that a credible set of component suppliers and engineering resources exist today, or a credible plan exists to assemble them, which would have the ability and the desire to supply the technology to a commercial market in the time frame leading to plant operation by 2010 or earlier.
3.	**Commercialization Plan**	A credible plan must be prepared which clearly shows how the technology would be commercialized by 2010 or earlier, including market projections, supplier arrangements, fuel supply arrangements and industrial manufacturing capacity.
4.	**Cost Sharing Plan**	Technology plans must include a clear delineation of the cost categories to be funded by government and the categories to be funded by private industry. The private/government funding split for each of these categories must be shown along with rationale for the proposed split.

5.	**Economic Competitiveness**	The economic competitiveness of candidate technologies must be clearly demonstrable. The expected all-in cost of power produced is to be determined and compared to existing competing technologies along with all relevant assumptions. (Includes plant capital cost, first plant deployment cost, other plant costs)
6.	**Fuel Cycle Industrial Structure**	Candidate technologies must show how they will operate within credible fuel cycle industrial structures, i.e., they must utilize a once-through fuel cycle with LEU fuel and demonstrate the existence of, or a credible plan for, an industrial infrastructure to supply the fuel being proposed.

3.3.2 Compliance with NTDG Criteria

The NTDG evaluation of the degree to which each of the candidate reactor designs meets the intent of the six criteria for near term deployment is summarized on Table 3.4.1-1. The NTDG judgments in each case are based on the information submitted by the respondent, on additional information provided (including presentations at NTDG meetings) and on the experience and judgment of the NTDG team members.

Details of the RFI responses and the NTDG evaluations are provided in Volume II, Section 5.

Table 3.4.1-1: Criteria Conformance Comparison

Design	1 Regulatory Acceptance	2 Industrial Infrastructure	3 Commercial-ization Plan	4 Cost Sharing Plan[10]	5 Economic Competitiveness	6 Fuel Cycle Industrial Structure
ABWR	Meets criterion. Design is NRC Certified.	Meets criterion. International infrastructure exists and has been demonstrated on Asian ABWR projects.	Can meet criterion. ABWR has been successfully commercialized in Japan and Taiwan.	Meets criterion. No design-specific government funding requested.	Can meet criterion. ABWR costs have high certainty (based on actual experience), but U.S. economic competitiveness is uncertain because of relatively high capital cost; ABWR may be competitive in some market scenarios.	Meets criterion. ABWR utilizes conventional fuel of proven design.
SWR 1000	Can meet criterion. SWR 1000 design developed to meet European requirements; translation/revision to U.S. requirements will be difficult but could be achieved in time for 2010 deployment if initiated very soon.	Meets criterion. Strong international infrastructure is in place.	Indeterminate. Plan not provided; SWR 1000 commercialization in the U.S. is contingent upon FANP decision re U.S. business strategy.	Indeterminate. Cost sharing requested for design certification only. (Source and amount of funding to complete first-time engineering is not identified.)	Can meet criterion. Projected costs are attractive, but they are highly uncertain, particularly under U.S. conditions.	Can meet criterion. SWR 1000 will utilize new fuel assembly design, but requires development and qualification.

[10] Consistent with the requirements established by NTDG (see Section 3.3.1), the statements in this column address primarily the completeness of the proposed cost-sharing plans. They do not reflect NTDG judgment regarding the appropriateness of the requested level of government support and the likelihood that it will be available. These questions are addressed in Volume II, Chapters 5 and 6.

Design	1 Regulatory Acceptance	2 Industrial Infrastructure	3 Commercial-ization Plan	4 Cost Sharing Plan[10]	5 Economic Competitiveness	6 Fuel Cycle Industrial Structure
ESBWR	Can meet criterion. ESBWR design incorporates ABWR and SBWR design features, both previously reviewed by NRC.	Meets criterion. Same international infrastructure as demonstrated on Asian ABWR projects would support ESBWR.	Does not meet criterion. ESBWR commercialization plan is predicated on prior successful commercialization of ABWR. Therefore it is not likely to support deployment by 2010.	Meets criterion. Cost sharing requested for design certification and detailed design.	Can meet criterion. GE did not provide cost projections; however, based on GE design economic targets and GE preliminary estimates of material quantities, ESBWR would likely be economically competitive.	Meets criterion; ESBWR utilizes conventional fuel of proven design (same fuel as ABWR).
AP600 and AP1000	AP600 meets criterion. Design is NRC Certified AP1000 can meet criterion. AP1000 is not yet certified, but is based on AP600 and AP1000 pre-application steps are in process.	Both meet criterion. Strong international infrastructure in place.	Both can meet criterion. Both are mature designs, but require substantial financial investment to complete the detailed design. Because it is already certified, AP600 design completion costs are somewhat (~10%, as estimated by Westinghouse) lower than AP1000.	Both meet criterion. The Westinghouse plan proposes cost sharing and supporting rationale for design certification and detailed design.	Both can meet criterion. Because of smaller capacity, AP600 has higher capital and operating costs than AP1000. Based on Westinghouse projected costs, AP-600 may be competitive in some U.S. market scenarios; AP1000 would be competitive in today's market	Both meet criterion. AP600 and AP1000 will utilize conventional nuclear fuel.
IRIS	Does not meet criterion. Design certification in time frame needed to support 2010 deployment is very unlikely, because of extensive analysis and testing required.	Can meet criterion. International IRIS design team, which includes manufacturing capability, has been assembled.	Does not meet criterion. Commercialization plan (in time to support 2010 deployment) is unrealistic.	Meets criterion. Identified cost sharing would support IRIS engineering, testing and licensing.	Indeterminate. Westinghouse projections on IRIS costs are highly conjectural; if true, IRIS would be economically competitive, but there is not yet a sufficient basis for confidence.	Meets criterion, for initial fuel loads. However, more highly enriched fuel loads, proposed to be used in later years, would require new manufacturing capability.

Design	1 Regulatory Acceptance	2 Industrial Infrastructure	3 Commercial-ization Plan	4 Cost Sharing Plan[10]	5 Economic Competitiveness	6 Fuel Cycle Industrial Structure
PBMR	Can meet criterion, provided that several challenging technical issues (including fuel issues) can be resolved and demonstrated to NRC satisfaction in the time frame needed for 2010 deployment. U.S licensing submittal information must be adapted from the German / South African design and test work. Pre-application steps with NRC are in progress.	Can meet criterion. International team is being assembled. Design contracts are in place for major equipment.	Can meet criterion. PBMR already has a potential US customer (Exelon) with substantial - albeit conditional - commitment. Presuming successful continuation of the South African project and Exelon decision to proceed with a U.S. project, PBMR commercialization plan is credible.	Meets criterion. Proposed government cost sharing is primarily for licensing activities, including the NRC confirmatory fuel characterization and test programs.	Can meet criterion. However, projected PBMR economics are preliminary and have high uncertainty. Satisfactory economics rely on deployment of multiple modules and successful development of the design.	Can meet criterion. PBMR safety and reliability hinge on successful fuel development and high quality fuel manufacture. Current plan includes ambitious program to develop, test, license and produce PBMR fuel, and presumes that initial U.S. fuel loads will be procured from a foreign supplier.
GT-MHR	Can meet criterion, provided that several challenging technical issues (including fuel issues) can be resolved and demonstrated to NRC satisfaction in the time frame needed for 2010 deployment. U.S licensing submittal information must be adapted from the Russian design and test work.	Can meet criterion, provided that the Russian industrial infrastructure can be qualified as a commercial supplier in the U.S. This may be difficult to achieve in the time frame required for deployment by 2010.	Can meet criterion. However, this presumes continued U.S. government support to the Russian project, timely identification of U.S. customer and industry partners, and technical success with Russian project.	Meets criterion. Cost share proposal is predicated on continued U.S. Government support to Russian project and presumes substantial private sector participation for commercialization.	Can meet criterion. However, projected GT MHR economics are preliminary and have high uncertainty. Satisfactory economics rely on deployment of multiple modules and successful development of the design.	Can meet criterion. GT MHR safety and reliability hinge on successful fuel development and high quality fuel manufacture. Current plan includes ambitious program to develop, test, license and produce GT MHR fuel.

3.3.3 Design Specific Gaps

The following are the design-specific gaps identified by each of the RFI respondents and/or by the NTDG review teams:

Design	Design Specific Gaps
ABWR	– Economic competitiveness, under some scenarios
SWR 1000	– Commitment by Framatome ANP – Licensing to U.S. regulatory and industry standards
ESBWR	– Design certification and completion of detailed design
AP600	– Financial support for completion of detailed design – Economic competitiveness, under some scenarios
AP1000	– Design Certification – Financial support for completion of detailed design
IRIS	– Steam generator design, control, and accessibility for inspection and maintenance – Integrated system safety performance, including transient response and primary system/containment interaction – Internal CRDM development (and/or adequacy of conventional CRDMs with long drive trains)
PBMR	– Continued commitment by Exelon, to support South African project and to proceed with U.S. project – Fuel development, characterization, manufacture, testing and regulatory acceptance – Performance of in-reactor high temperature materials – Power conversion system uncertainties with respect to components, materials and reliability
GT-MHR	– Conversion of Russian prototype information and analyses, into documentation suitable for US application. – Successful continuation of Russian project – Fuel development, characterization, manufacture, testing and regulatory acceptance – Performance of in-reactor high temperature materials – Power conversion system uncertainties with respect to components, materials and reliability

3.3.4 Economic Competitiveness of Reactor Designs Based on Vendor-Specific Data

As detailed in Volume II, the NTDG performed an economic analysis of the generation costs of several reactor designs, based on design-specific cost data provided by the vendors in response to the DOE RFI and subsequent communications. The submitted cost data are based on the assumption of success in the development, design and licensing activities of the various designs. The results of the analyses are summarized below.

1. The total generation ("busbar") costs of all the reactor designs considered by the NTDG fall within the range of 36$/MWh to 46 $/MWh. (Generation costs in this range correspond to overnight capital costs that meet the economic competitiveness criteria presented in Section 2). These costs are well within the range of expected market prices, which are estimated by the NTDG to vary between 35 $/MWh and 55 $/MWh or higher. Thus, nuclear plants are expected to be generally competitive on a total cost basis, with market prices likely to prevail in the U.S. in the future. As such, nuclear plants should be included as potential supply options in utility generation expansion studies.

2. The deregulation of the energy markets did not price new nuclear plants out of the market. Given the low production costs of 10 $/MWh, adequate margins exist between nuclear production costs and market prices to allow an appropriate return on the investment. Should the nuclear designs reviewed here achieve the cost/performance data reported in Volume II, they should be able to compete in the deregulated energy markets.

3. Nuclear plants should represent economic power supply options in specific market situations. More detailed and localized economic analyses will have to be performed to clarify whether a specific reactor design would prove a long-term competitive choice in a local market under specific contracting arrangements.

4. Nuclear plants, at the low end of their lifecycle generation costs, present costs lower than the likely range of future market prices. Nuclear plants at the high end of the cost uncertainty range still fall within the band of likely market prices.

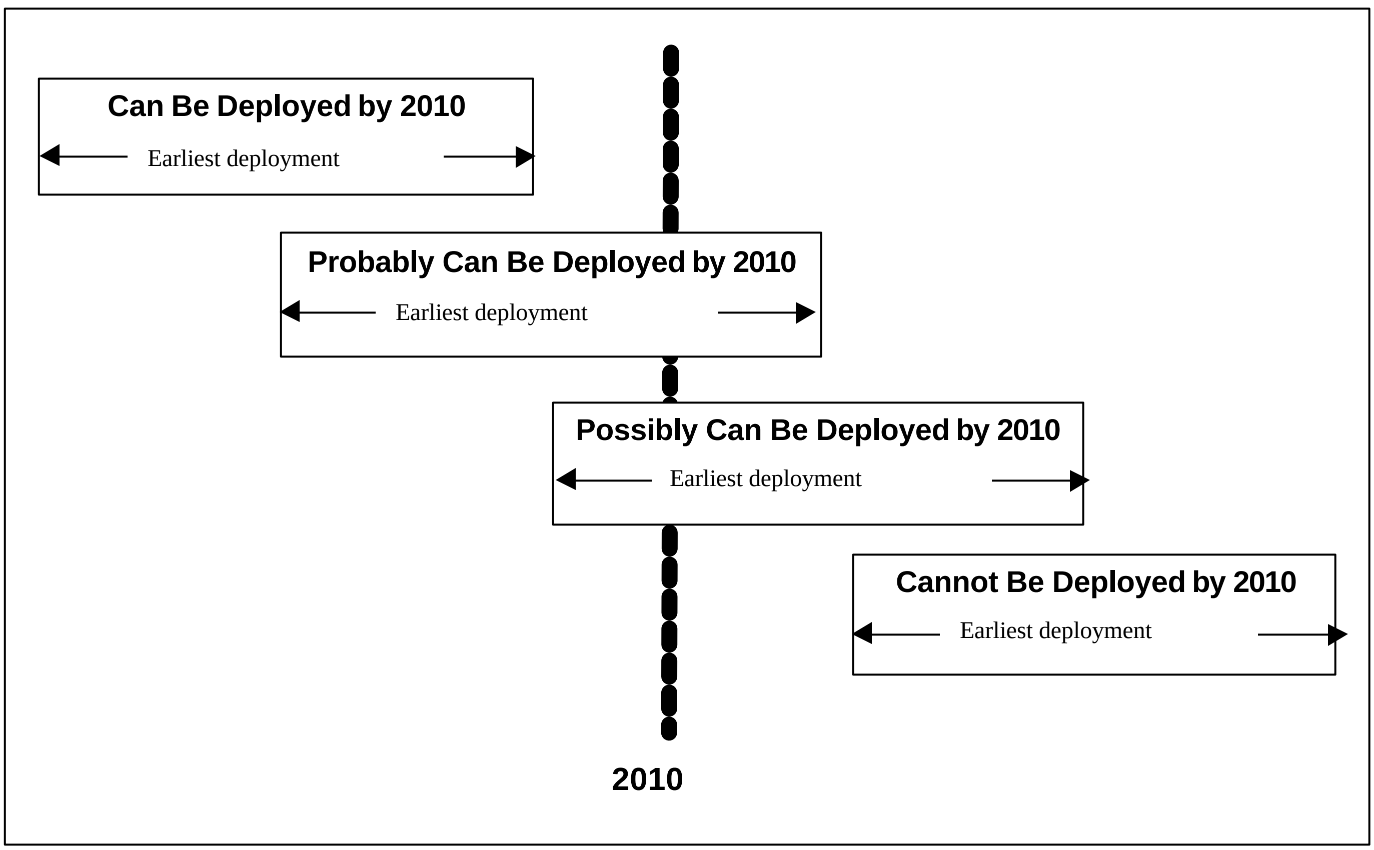
5. The issue of first years of life costs should be further evaluated. It is possible that some reactor designs will be competitive in their specific markets from the first year of operation going forwards. In other cases and based on local conditions, a specially structured Power Purchase Agreement (PPA) may have to be devised, to allow recovery of a substantial fraction of the costs in the early years of life.

3.3.5 Potential for Deployment by 2010

This section summarizes the potential for deployment by 2010 of each of the eight candidates evaluated. Potential is addressed primarily in terms of *readiness* – that is, such factors as the amount of prerequisite engineering and certification work already completed, the cost and time needed to perform that which is not already complete, and the potential for timely commitment of the funding (as indicated by expressions of interest by prospective customers) necessary to perform the siting, licensing, early procurement and other work needed.

For any candidate, the *likelihood* of deployment by 2010 also depends on factors such as the proponents' business and financial strategies, regional and national electricity supply and cost of alternative fuels. It may be that for reasons of economic competitiveness, some of the candidates judged to be higher in readiness are less likely to be deployed by 2010 than others that require more front-end investment but have potentially more attractive cost performance.

In this evaluation, the terms "can be deployed", "probably can be deployed", "possibly can be deployed" and "cannot be deployed" reflect the judgment as to whether the work necessary to deploy the plant in this decade could realistically be accomplished. In the case of those candidates designated as "probably can be deployed" and "possibly can be deployed", substantial and timely private sector investment, and very successful and timely completion of technical and regulatory work would be required (to an extent that varies from case to case) to achieve near term deployment. These determinations are not quantifiable and in each case represent NTDG collective judgment of potential along a continuum of possibilities, as shown in the following graphic.



The Figure above depicts graphically the NTDG judgments regarding each of the designations used to connote potential for deployment. The horizontal dimension in each box represents graphically a range of plausible deployment dates for the evaluated design candidates; the designations "can be", "probably can be", etc. reflect the position of the box relative to the 2010 target schedule. In all cases, these are largely qualitative judgments, backed by the assessment of actions required to achieve near term deployment.

Following are synopsis statements of potential for deployment, for each of the candidates:

Design	2010 Deployment Readiness
ABWR	The ABWR can be deployed in the U.S. by 2010. NRC has certified the ABWR design, and all detailed design (except site-specific) is complete. The construction time frame has been demonstrated in Japan. Although ABWR construction and operating costs should be highly predictable, economic competitiveness in the U.S. is uncertain based on current trends in the electricity market.
SWR 1000	SWR 1000 possibly can be deployed in the U.S by 2010. Given the resources and capability of the international sponsors, it is *possible* that an aggressive initiative to deploy an SWR 1000 in the U.S. by 2010 could be successful – however, the challenges of translating and refining the design to meet U.S. requirements and licensing the plant on an accelerated schedule would require very early commitment and major financial investment. At present, FANP has not yet decided to enter the U.S. new plant marketplace and has not provided a commercialization plan, suggesting that it is unlikely that SWR 1000 will be deployed in the U.S. by 2010.
ESBWR	ESBWR possibly can be deployed in the U.S. by 2010. The ESBWR conceptual design is relatively mature and offers the promise of economic competitiveness and excellent safety and reliability. However, GE currently is planning a "step-wise" ESBWR development, in which design certification could proceed initially but detailed engineering would not proceed until after certification is in hand and only if commercial support is available – and potentially not until there have been several ABWR orders. On that basis, ESBWR deployment by 2010 would not be possible. However, if GE chooses (in the relatively near future) to accelerate that schedule, deployment by 2010 can be achieved.

Design	2010 Deployment Readiness
AP600 and AP1000	AP600 or AP1000 probably can be deployed in the U.S. by 2010. Westinghouse plans to pursue AP600 or AP1000, but not both. NRC has certified the AP600 design. However, detailed engineering remains to be completed and the plant's economic competitiveness in the U.S. is uncertain, based on current trends in the electricity market. The AP1000 design has promise for economic competitiveness and is relatively mature, based on the certified AP-600 design. To be deployed by 2010, however, the following will be required: – Sufficient near-term financial support for detailed engineering and licensing – A successful NRC design certification (based on the already-certified AP600)
IRIS	IRIS cannot be deployed in the U.S. by 2010. The design is still highly conceptual and it includes innovative features that will require extensive testing and analysis. The schedule submitted by Westinghouse does not support deployment by 2010.
PBMR	PBMR probably can be deployed in the U.S. by 2010. PBMR is unique among the NTDG candidates in that it has a potential customer (Exelon), participating in the South Africa project and actively pursuing this design for U.S. application. Nonetheless, deployment by 2010 would require: – That the South Africa project continues successfully – That Exelon decides to proceed with a U.S. PBMR project, and commits to early (prior to COL) procurement of long lead-time plant components[11]. – A successful, expedited ESP/COL schedule – Resolution of several challenging technical issues, including those related to fuel reliability, energy conversion system and in-reactor high temperature materials.

[11] Subsequent to the NTDG evaluation, Exelon announced that it intends to delay its decision to proceed with the PBMR by a year, and that one or two technical issues that create uncertainty with regard to PBMR licensability will need to be resolved for Exelon to proceed. The South African demonstration plant has also been delayed by one year. Exelon advises that it still plans to proceed with its ESP application in 2002, but will delay the COL schedule. This recent development is an example of the uncertainty inherent in the NTDG judgments regarding deployment potential.

Design	2010 Deployment Readiness
GT-MHR	GT-MHR possibly can be deployed in the U.S. by 2010. For deployment by 2010, the following will be required: – Success in the Russian GT-MHR project (in turn, requiring continued U.S. Government support). – GA must secure, in the near future, adequate investment from prospective customer(s) to fund engineering and licensing applications for the U.S. plant. – A successful, expedited ESP/COL schedule – Resolution of several challenging technical issues, including those related to fuel reliability, energy conversion system and in-reactor high temperature materials. While these conditions could be met, it is unlikely that all will be done in time to support 2010 deployment.

4 Achieving Near Term Deployment – an Integrated Strategy

This section presents an integrated strategy to achieve the goal of near term deployment, addressing the generic gaps and other issues outlined in Section 2 and the design-specific gaps and implementation needs outlined in section 3.

At the center of this integrated strategy is a phased approach to project planning and execution for new plants that aggressively pursues regulatory approvals and design completion, leading to construction and startup of multiple new plants by 2010. Success of this strategy, and therefore to near term deployment of new plants, requires effective industry/government collaboration.

4.1 Two Tracks – Water and Gas

As described in Section 3, candidates for near term deployment include both water-cooled and gas-cooled reactor designs. Carrying both tracks forward is essential to a prudent national energy strategy.

Most commercial reactor experience in the U.S. and around the world is with light water cooling[12]. U.S. regulatory process, plant engineering, design, safety analysis, construction and operational experience are based in large measure on the more familiar light-water reactor (LWR) technology. However, it is generally accepted that LWRs are most competitive economically in large (1,000 MWe, or larger) plant sizes and, as outlined above, such large projects involve very high initial capital expenditure and for that reason have not been attractive to prospective investors. In contrast, the new gas-cooled designs are smaller modular units and therefore pose substantially lower investment risk and better flexibility to serve regions with lower electricity demand, and they allow suppliers to add incremental capacity and better match increasing demand.

Near term deployment efforts should be pursued on a dual-track basis, providing maximum potential for success of both water-cooled and gas-cooled designs.

Two tracks are necessary because water and gas-cooled plants offer very different (and complementary) advantages, because they are likely to be attractive to different customers in different regions of the country, and because they are distinctly different in terms of readiness for deployment and the actions necessary to achieve near term deployment.

The dual-track strategy would include some generic activities, particularly those involving the licensing process, which would provide common support to water and gas-cooled candidates. For design-specific work, activities to support the development and near term deployment of designs of both types (several, if market interest is sufficient to support) should be carried out in parallel.

[12] All 103 commercial power reactors in the U.S. are LWRs. Two gas-cooled plants – Peach Bottom Unit 1 and Fort St. Vrain – were licensed by NRC but are no longer in operation. The new gas-cooled candidates, as described in Chapter 3, are significantly different in design from these early gas-cooled reactors.

4.2 Phased Plan of Action

Achieving the goal of near term deployment will require timely and successful actions in several different areas. In order to apply properly prioritized emphasis and support as the work proceeds, the NTDG recommends a phased plan of action that reflects not only the steps needed to achieve near term deployment but also their required timing and sequencing. The phased approach will also permit ongoing measurement of progress and validation or adjustment of the work, as needed to achieve the end objective.

The action phases to achieve new plant deployment in this decade are as follows:

- Phase 1: Regulatory Approvals
- Phase 2: Design Completion
- Phase 3: Construction and Startup

Phased actions by industry and government would accomplish, in a coordinated way, the essential regulatory and technical work, both generic and design-specific, to make possible new nuclear plants in this decade. Work in Phases 1 and 2 would be supported by a combination of private and public investment. The number of parallel project activities and the pace of the work would be driven by the marketplace; in no case would work proceed and federal funding be applied without the commitment of substantial private investment.

4.2.1 Phase 1: Regulatory Approvals

Phase 1 includes a broad set of actions, both generic and plant-specific, related to application of the 10CFR52 regulatory process:

- Preparation and submittal of early site permit (ESP) applications, and follow-up interactions with NRC, as necessary to demonstrate the ESP process for a range of siting scenarios and to secure multiple ESPs
- Preparation and submittal of applications for reactor design certifications (or FDAs for gas reactors), and follow-up interactions with NRC, as necessary to demonstrate an efficient DC/FDA process and to secure multiple design approvals
- Preparation and submittal of applications for combined construction and operating license (COL) for each NTD design to be supported in Phases 2 and 3
- Development of generic guidance to ensure efficient, safety-focused implementation of key Part 52 processes, including ESP, COL and ITAAC. This may include application of certain elements of the new regulatory framework, as it is developed and parts are judged “ready for use” by applicants.

4.2.2 Phase 2: Design Completion

In Phase 2, the detailed testing, engineering, and planning necessary to permit start of construction would be completed for those designs with sufficient private sector investment to proceed to deployment, contingent on DOE cost sharing. Phase 2 is a dual track effort, involving parallel government/industry collaboration in support of at least one ALWR design and at least one gas-cooled reactor design. In each case, the work would include:

- Detailed design and evaluation, including first-of-a-kind engineering
- Nuclear and component and plant system testing
- Plant materials testing, if needed
- Fuel development and testing, if needed
- Balance of plant/power conversion system testing, if needed

4.2.3 Phase 3: Construction and Startup

Phase 3 covers the actual construction and startup of new nuclear plants selected by the marketplace, including associated activities such as site work, plant structures, equipment procurement and installation, quality assurance, construction testing, and the like.

Phase 3 will continue as a dual track effort:

- For the ALWR(s), conventional and fully commercial construction project approaches are envisioned.
- For the gas-cooled reactor(s), given the level of testing required to confirm regulatory compliance and commercial performance, the best path to success may involve a demonstration project. DOE and potential private sector investors should evaluate the feasibility, practicality, and commercial objectives of such a project. The evaluation should include consideration of siting such a demonstration project on federal land.

Phase 3 funding is primarily through private financing, with government support provided in the form of environmental credits and other financial incentives of the kind already being provided to other (non-nuclear) electricity generating systems.

4.3 Aggressive Schedule

To achieve deployment by 2010, the phased plan of action must be implemented on an aggressive schedule, taking maximum advantage of coordinated efforts by industry consortia (or “family of plant” entities) working together and with government to achieve earliest possible deployment of each design with sufficient market support to achieve commercial operation.

Measures to achieve aggressive project schedules will include:

- Parallel efforts on regulatory approvals for siting, design approval, and combined license. All of the timelines for NTD designs shown in Volume II of this Roadmap propose significant overlapping of these activities. In many cases, the optimum schedules have been discussed with NEI and/or NRC for feasibility.
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- Parallel efforts on Phases 1 and 2, such that detailed engineering work is completed concurrently with (or very soon after) regulatory approvals, in order to support construction start as soon as site permits and COL approvals are in hand. Again, all of the timelines for NTD designs shown in Volume II of this Roadmap propose significant overlapping of these Phase 1 and Phase 2 activities.

- Early procurement of many plant components, to ensure timely delivery of long lead-time items (e.g., large vessels), to support completion of detailed engineering, and to support early construction start soon after COL approval.

- Early actions to secure all necessary state and local approvals from all entities as needed. These actions include environmental and other investigations, and preparation and submittal of permit applications.

These aggressive project schedules necessarily require more up-front investment than would be required with more conservative, sequential project planning and execution. As such, projects implemented on aggressive schedules will require innovative business arrangements, such as consortia among designers, constructors, NSSS and major equipment suppliers, and plant owner/operators, with strong and common incentives to successfully build and operate new plants. Such consortia could include multiple future owner/operators, each willing to build one or more plants, which pool resources and expertise behind a chosen design. This enables cost and risk sharing within a broader investor base, and greater benefits from standardization of common engineering and programmatic efforts, state-of-art construction and operational management systems and equipment to optimize the cost and schedule of multiple plant projects. These teams of owner/operators are referred to within the industry as “family of plant” organizations.

The government’s role in making such projects succeed is important, and includes the essential element of cost-sharing the one-time costs associated with the phased approach, as well as providing economic incentives (e.g., federal tax credits) as discussed below to encourage industry investment.

4.4 Funding Requirements

Volume II of this report presents a number of recommendations for industry and government funding, in support of near term deployment. The estimated funding requirements for all of the design candidates as well as for generic and site-specific needs are tabulated in aggregate in Appendix J of Volume II. Actual funding levels will depend on which activities secure adequate private investment to meet DOE cost sharing criteria.

Among the NTDG recommended actions, the primary funding needs will be for the dual-track, three phase activities described above. A summary of the estimated funding for that work is as follows:

Phase 1: Regulatory Approval

All above activities are to be cost-shared equally by industry and DOE. The total resource requirements over a four-year period are estimated to be:

Activity	Estimated Cost
Generic regulatory tasks including resolution of issues and development of guidance for ESP, COL, ITAAC verification, and construction inspections, and development of a risk-informed regulatory framework	$13M
ESP Demonstrations for an adequate range of siting scenarios	$30M
DC completion for designs based on previously certified or NRC-reviewed designs	$30M per application
COL completion for approved sites and designs	$10-15M per application
COL completion for designs that defer design certification and seek NRC design approval via COL (e.g., gas reactors)	$100M to $150M[13]

Phase 2: Design Completion

The funding requirements for Phase 2 vary widely, depending on design-specific needs. This work has been completed for one certified design, and significant work has already been completed for some of the uncertified NTD designs. The cost to complete NTD designs that are not yet certified range from roughly $150M to $300M per design. In some cases, private sector investors are willing to fund design completion at a funding rate significantly above the 50/50 cost share formula applied to Phase 1.

Phase 3: Construction and Startup

Phase 3 will be funded primarily through private financing, with government support provided in the form of environmental credits and other financial incentives of the kind already being provided to other (non-nuclear) electricity generating systems, as described in Section 4.5 and in Volume II, Chapter 6.

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[13] Because this regulatory approval involves substantial engineering work, this funding estimate bridges into Phase 2 activities and could extend beyond the Phase 1 completion schedule above

The above funding recommendations address site-specific, generic and design-specific needs. For the design-specific applications, in cases where there are several candidates for government funding that could meet the above criteria, priorities for funding allocation should be market-driven, based on:

1. Realistic potential for successful deployment (as indicated by commercial interest and financial support in place)

2. Concept merit/added value (i.e., credible likelihood that the design will achieve significant improvement over today's reactors)

3. Maturity of technology and the developers' stated needs

Based on their assessment of the work needed and the projected availability of private investment, NTDG estimates that the typical yearly DOE total funding requirement will be approximately $100 million from 2003 to 2007, for phases 1 and 2. Details are provided in Volume II.

4.5 Industry/Government Collaboration

4.5.1 Formalizing a National Nuclear Energy Strategy

The National Energy Policy establishes the importance of nuclear power in meeting the nation's current and future energy needs. This formal statement by the government is an extremely important underpinning for the actions required to revitalize and expand the use of nuclear power in the U.S.

The logical next step in implementing aspects of the Policy related to nuclear power is to formulate an implementation strategy. This strategy would put in place a working structure for the aspects of the Energy Policy applicable to new plant deployment, and would cover a variety of topics such as roles and responsibilities, priorities, funding principles and processes and required administrative and legislative actions.

With respect to near term deployment of new plants, the NTDG envisions the strategy as codifying the principles, methods and actions presented in this Roadmap. A recommendation to that effect is included in Section 5.

4.5.2 Industry/Government Cost-Sharing

As described above, successful execution of the phased approach demands a commitment by industry and government to share in the one-time costs to achieve near term deployment. In a de-regulated electricity supply system, nuclear energy must be economically viable on a stand-alone basis. Prospective nuclear plant owner/operators must be able to secure project financing on the strength of the demonstrated business value of that investment – otherwise, investors will go elsewhere.

At the same time, reinvigorating the nuclear option is a matter of national importance. Yet the obstacles to be overcome in doing so are substantial. In particular, the initial costs of designing and licensing the next plants, after the long hiatus and utilizing untried new licensing processes, will be very high and could preclude nuclear plant reentry to the U.S. marketplace on a purely competitive basis. In light of government's responsibility to ensure a stable, safe and self-sufficient energy supply for the nation, some level of government financial support on a cost-sharing basis with the nuclear industry for these up-front efforts -- many of which are applicable to all designs -- is therefore appropriate.

NTDG envisions an appropriate model for shared industry and government funding based on several principles:

- Industry should carry prime responsibility for attracting and committing the substantial investment required to build new plants, and for all aspects of the life-of-plant (after construction) financial support. For any cost-sharing scenario, viability and value-added is first indicated by availability of private sector investment.

- Government funding should be applied in areas where government actions have added cost or uncertainty to the licensing process. For example, implementation of 10CFR52 will involve unpredictable and potentially high costs for the first users, costs that should be offset by government financial support.

- With respect to new plant development, government funding should be applied primarily in areas involving one-time costs or generic costs needed to ready new plants for the marketplace, and only where there is evident value-added by the new plant options.

- Over the longer term, government should support research and development necessary to achieve fundamental improvements in such areas as sustainability, compatibility with the environment and nuclear safety. The basic objective of the Gen IV Program is to identify such opportunities for long-term improvement and the R&D needed to realize them.

4.5.3 Cooperative Agreement

The U.S. Advanced Light Water Reactor (ALWR) Program experience with significant government-industry cost sharing demonstrated the value of a cooperative agreement in establishing an efficient and effective cost-sharing process that supports marketplace needs.

Cost sharing must be administered in a way that permits timely and flexible management of resources. The normal manner in which private sector cost sharing is implemented is by turning over invested funds (either in cash or in-kind work) to an industrial entity to utilize on its authority and within its assigned scope of responsibility. In such arrangements, the participants share the risks and the return on the investment is obtained through royalties, and profit sharing.

Such an arrangement can serve a wide scope of needs for public-private partnership, including a broad-based consortium to address industry wide needs (e.g., ESP and COL process development and improvement) as well as design-specific consortia dealing with DC or design-specific COL matters.

For design-specific consortia, such agreements give authority to the lead industrial organizations (e.g., reactor suppliers) to use the shared funds at the discretion of each consortium and within its procurement procedures, to achieve the mutually agreed-upon objectives of the assigned scope of work. Joint management committees are established, composed of executives representing the government and the industrial cost-sharing organizations, to define the objectives and the overall plan for the effort to which the lead organization must adhere. This avoids overlapping cumbersome procurement and management efforts by both the government and the lead industrial organization.

An approach along these lines is recommended for near-term deployment activities.

4.5.4 Other Mechanisms for Government Financial Support

Along with cost sharing of generic or plant-specific activities, the Government can provide effective and appropriate financial support to nuclear plant near term deployment activities, consistent with the national importance of continuing reliance on nuclear energy. These include:

Tax and other incentive arrangements:

The Federal Government routinely establishes financial incentives – typically in the form of investment tax credits – to encourage private sector investment in areas considered important to the national interest. Examples in the energy sector are tax credits for generating systems utilizing renewable fuels and for non-emitting technologies. Actions that serve to make possible continued and expanded reliance on safe, clean nuclear energy clearly merit such incentive treatment, particularly in light of the deregulated electricity marketplace that effectively discourages such investment. Other tax-related approaches that should be considered are accelerated depreciation, access to tax-exempt state government financing, and encouragement of long-term power purchase agreements.

Government support to the energy industries should maintain a reasonably "level playing field". In a deregulated marketplace, inequitable support – for example, higher tax credits for avoided emissions to some kinds of electricity producers than to others – creates a cost penalty that can aggravate the already difficult challenge of achieving economic competitiveness.

As a general principle, incentives for new nuclear plants should be equivalent to comparable incentives elsewhere in the energy industry. For example, incentives for major capital investments in the oil and gas industry, or for coal generation would be appropriate for new nuclear energy plants. Similarly, incentives in place to encourage renewable energy sources are a good model for non-emitting nuclear energy.

Risk Management Support

The next nuclear plants to be built will be, in effect, first-of-a-kind ventures, both in terms of the detailed plant design (certified, but never built) and the regulatory process (10CFR52, in place for years but never used for an actual construction process). Inevitably, first-of-a-kind projects involve some level of programmatic risk and uncertainty.

These financial risks represent an obstacle to any commercial entity seriously considering such an approach. The Federal Government could choose to augment the above tax-based incentives with additional measures to encourage nuclear plant construction. These more aggressive steps might be offered on a temporary basis to get initial plants built, then diminished as experience allows. Such augmented incentives might include reduction of business risk by providing loan guarantees for a portion of the private investment, to cover overruns or delays that may result from the implementation of new licensing processes.

4.6 Alternate Scenarios and Contingencies

It is quite possible that future unanticipated events or circumstances could dictate changes in priorities or approaches to energy planning in the U.S., including changes to the preferred approach to near term deployment. For example, the recent attack on the USA by terrorists and the subsequent war on terrorism could place energy resources in the Middle East at risk.

An energy crisis, brought about by problems in the Middle East or elsewhere, could stress the nation’s fossil energy resources and create increased pressure to achieve greater energy independence and a higher level of electrification of our commercial, industrial, and transportation infrastructure. Under such circumstances, the nation would probably shift to higher reliance on electricity and natural gas in the transportation sector, and place greater reliance on coal and nuclear energy for power generation. To accelerate such a change in energy strategy, the federal government might take action to encourage attendant actions (such as new plant installations) on an accelerated schedule.

Similarly, other scenarios could alter the implementation strategy for new nuclear plants. These might include higher than anticipated fossil fuel prices, severe delays in NRC licensing of new designs, major shifts in national or global economic conditions, significant changes in direction regarding economic deregulation of electricity, and greater prominence of health and safety issues related to fossil fuel consumption. Each of these would present challenges to a national nuclear energy strategy and could dictate more rapid action to build new nuclear plants.

If there were a need for accelerated nuclear energy plant construction, several actions are possible. The NRC could accelerate the licensing process as much as possible, consistent with safety requirements. Investment incentives would focus on rapid market response. Design choices for new plants would trend more toward proven technology and choices with very high assurance of rapid deployment and minimum chance of project delays. In such situations, it is likely that designs that are already certified or are near completion of NRC certification would be chosen for installation. It is also likely that existing nuclear sites would be preferred for new plant siting, particularly those previously evaluated for the addition of one or more nuclear plants.

Under such urgent circumstances, and with special treatment, new nuclear plants could be deployed on the shortest possible time frame. Achievable deployment dates would depend primarily on when such a national need was identified.

5 Summary Conclusions and Recommendations

5.1 Conclusions

The following is a summary of the most significant conclusions drawn by the NTDG in the course of their assessment, and as described in this report:

1. New nuclear plants can be deployed in the U.S. in this decade, provided that there is sufficient and timely private-sector financial investment.

2. To have any new nuclear plants operating in the U.S. by 2010, it will be necessary for generating companies to commit to new plant orders by the end of 2003, in order to proceed with preparation of COL applications. This will require very near term action by prospective new plant owner/operators and strong support from the government.

3. Although conditions are currently more favorable for new nuclear plants than in many years, economic competitiveness in a deregulated electricity supply structure remains a key area of uncertainty with respect to near term deployment potential. The other gaps to near term deployment require attention; in particular, implementing an efficient and effective regulatory approval process for siting and licensing of new plants is an urgent matter, and will require use of new processes in 10 CFR Part 52, that have not been demonstrated in actual practice.

4. There are excellent new nuclear plant candidates that build on the experience of existing reactors in the U.S. and around the world, and that could be deployed in the U.S. in this decade. Readiness for deployment varies from design to design, based primarily on degree of design completion and status of regulatory approval. Those that are the most advanced in terms of design completion and approval status appear to be economically competitive in some scenarios, but not all. Other new nuclear plant designs, which still require licensing and engineering, show promise for improved economic competitiveness.

   The design-specific gaps that must be overcome by the gas-cooled candidates to achieve near term deployment are somewhat greater than those facing most of the water-cooled candidates.

5. Achieving near term deployment will require continuing close collaboration between government and industry. Selections of new projects must be market-driven and supported primarily by private sector investment, but government support is essential, in the form of leadership, effective policy, efficient regulatory approvals, and cost sharing of generic and one-time costs.

5.2 Recommendations

1. Implement the phased strategy for new nuclear plants, by means of industry/ government collaboration on generic and plant-specific initiatives
This recommendation comprises three time-staggered phases, as follows:

1a. Demonstrate and refine the 10CFR52 process

Objective: Resolve the uncertainties regarding the new plant regulatory approval process through actual use, and secure regulatory approval for several reactor design and siting applications on a time scale that will support plant deployments in this decade.

Action: Develop generic guidelines for ESP, COL and ITAAC verification, and proceed with a series of industry/government cost shared generic, site and/or design-specific initiatives including:

- Early site permit (ESP) applications,
- Applications for reactor design certifications (or FDAs for gas reactors),
- Combined construction and operating license (COL) applications,
- Continuing development of a risk-informed, performance based regulatory framework.

These are all Phase1 activities, as defined in Section 4. Only those initiatives capable of obtaining sufficient private sector funding support to complete the initiative, assuming DOE cost sharing, should proceed.

Responsibility: NEI, NRC, DOE and applicants.

Timing: 2002 – 2006. The schedule for each Phase 1 activity will be dictated by the overall objective of new plant deployment by 2010. Although individual timeline requirements will vary for different sites and reactor designs, much of this work is on the critical path to deployment and it is therefore important that Phase I work commence in year 2002 or early 2003. Based on the timeline constraints discussed in Section 2 the bulk of Phase I work must be complete by 2006. The exception is the new plant regulatory framework, which can proceed as a continuing, parallel activity.

1b. Complete design of several near term deployment candidates

Objective: Ensure that the detailed engineering and design work for at least one light water and at least one gas-cooled reactor is completed in time to allow start of plant construction on a schedule that could achieve deployment by 2010.

Actions: Proceed with Phase II work as follows:

ALWR Track: Industry / government cost share for at least one market-selected initiative for the engineering, testing and design, to the degree that permits plant order and construction.

Gas Reactor Track: Industry / government cost share for at least one market-selected initiative for the engineering, testing and design, to the degree that permits plant order and construction.

Note: only those initiatives that secure private sector funding support sufficient to complete the work, assuming DOE cost sharing, should proceed.

Responsibility: DOE and applicants.

Timing: 2003-2007. In order to support deployment by 2010, Phase 2 work must be complete for both the ALWR and gas reactor tracks by 2007. Earlier completion may be possible for some design options.

1c. Construct and start up new plants

Objective: Complete construction and deploy multiple commercially viable new nuclear plants by 2010.

Action: When regulatory approvals and design work are in place, proceed with plant construction work and associated activities. This work should be privately funded, but supported by government incentives as discussed in Section 4.

For ALWR(s), this could entail conventional and fully commercial construction project approaches. For gas-cooled reactor(s), this action may involve evaluation, and potentially implementation of a demonstration project, perhaps at a federal facility.

Responsibility: Owner/operators of new plants, with government involvement as necessary.

Timing: 2005 – 2010

2. Put in place appropriate government financial incentives for privately funded new plant licensing, design and construction projects.

Objective: Assist prospective owners/investors in dealing with the financial challenges and risks of the deregulated electricity marketplace.

Action: Identify and implement actions by the federal and state governments to reduce the risks associated with private sector investment in capital-intensive new nuclear plants. These could include accelerated depreciation; investment tax credits; access to tax-exempt state government financing; negotiated long-term power purchase agreements; and, federal and state tax incentives for diversity in fuel supply and/or emission-free generation.

Responsibility: DOE should take the lead in formulating and proposing the appropriate government actions, with support from industry via NEI.
The Administration, and the Congress to implement, as appropriate.

Timing: 2002-2003

3. Conduct an assessment of nuclear industry infrastructure.

Objective: Determine the key areas of infrastructure weakness and the actions needed to accommodate them.

Action: Assemble a team comprising experts from industry, government and academia to assess methodically and quantitatively the various elements of infrastructure that could affect design, construction and operation of new nuclear plants in this decade, and to identify solutions to adverse conditions.

Responsibility: NEI leadership, with DOE participation and support.

Timing: 2002

4. Develop a National Nuclear Energy Strategy for implementation of the National Energy Policy.

Objective: To fulfill the vision for nuclear power articulated in the National Energy Policy

Action: Put in place a comprehensive strategy for industry and government, with priorities and action plans. The Strategy should:

- Clearly explain why our national security, economic strength, and environmental quality require – and will benefit from – greater reliance on nuclear energy.
- Commit the federal government to embracing the nuclear energy industry's Vision 2020, which has as its goal the addition of 50,000 MWe of new nuclear generation by 2020.
- In the near term, commit the federal government to a nuclear energy supply R&D investment strategy that is in balance with that for other energy supply options.
- Reaffirm the commitment of the Administration to expedite applications for new plants through the NRC, consistent with safety regulations, as called for in the National Energy Policy.
- Commit DOE to enter into market-driven, public-private partnerships to execute those new plant initiatives that garner the necessary industry support for cost sharing with DOE.
- Commit DOE to undertake a stronger leadership role in forging a consensus among the relevant DOE Offices, scientific and energy policy leaders, and government contractors, toward an integrated and effective national policy on nuclear fuel cycle issues, focused initially on establishing centralized used fuel management.
- Develop a plan of action to expand this Vision 2020 milestone to greater reliance on nuclear energy in the 2030 to 2050 timeframe, based on further advances in nuclear technology, developed under DOE leadership in partnership with industry.
- Seek broad support from Congress for a national nuclear energy strategy.

Responsibility: DOE, with input and support from the industry

Timing: 2002

5.3 Closing the Gaps

The NTDG recommendations discussed above address all of the key gaps identified in Section 2 of this report. The linkage between recommendations and gap closure is shown graphically as follows:

Recommendations		Gaps				
		Economic Competitiveness	Deregulated Marketplace	10CFR52 Implementation	Industry Infrastructure	National Nuclear Energy Strategy
1a	Phase 1: Regulatory Approvals	X		X		
1b	Phase 2: Design Completion	X		X		
1c	Phase 3: Plant Construction	X	X			
2.	Government Financial Incentives	X		X		
3.	Infrastructure Assessment		X		X	
4.	National Nuclear Energy Strategy	X	X	X	X	X

In each case, the symbol "**X**" indicates that the recommended action could address the identified gap in a meaningful way.