U.S. DEPARTMENT OF ENERGY/NUCLEAR POWER INDUSTRY

STRATEGIC PLAN

FOR LIGHT WATER REACTOR RESEARCH AND DEVELOPMENT

FIRST EDITION

FEBRUARY 2004

Foreword

Electricity demand in the United States is expected to grow significantly in the future. Over the past decade, Americans used 17 percent more electricity, but domestic capacity rose only 2.3 percent (*National Energy Policy*, May 2001). Unless the United States significantly increases its generating capacity, the country will face an energy shortage that is projected to adversely affect our economy, our standard of living, and our national security. Coupled with this challenge is the need to improve our environment.

The *National Energy Policy*, which provides a mix of recommendations to address our Nation's energy challenges, recommends "the expansion of nuclear energy in the United States as a major component of national energy policy." Increased use of nuclear energy supports the national energy priorities because it is a safe, reliable, and affordable source of energy that does not rely on fuels from foreign countries in unstable parts of the world and, most importantly, does not emit significant amounts of air pollutants or greenhouse gases.

The United States government is committed to providing the Nation with stable, reliable, and diverse sources of domestic energy. This *Department of Energy/Nuclear Power Industry Strategic Plan for Light Water Reactor Research & Development* directly responds to the challenges noted in the *National Energy Policy* and puts the government's commitment to this policy into action.

The purpose of this strategic plan is to establish a framework that will allow the Department of Energy (DOE) and the nuclear power industry to jointly plan the nuclear energy research and development (R&D) agenda important to achieving the Nation's energy goals. This strategic plan has been developed to focus on only those R&D areas that will benefit from a coordinated government/industry effort. Specifically, this plan focuses on safely sustaining and expanding the electricity output from currently operating nuclear power plants and expanding nuclear capacity through the deployment of new plants. By focusing on R&D that addresses the needs of both current and future nuclear plants, DOE and industry will be able to take advantage of the synergism between these two technology areas, thus improving coordination, enhancing efficiency, and further leveraging public and private sector resources.

By working together under the framework of this strategic plan, DOE and the nuclear industry reinforce their joint commitment to the future use of nuclear power and the *National Energy Policy*'s goal of expanding its use in the United States. The undersigned believe that a public-private partnership approach is the most efficient and effective way to develop and transfer new technologies to the marketplace to achieve this goal. This Strategic Plan is intended to be a living document that will be updated annually.

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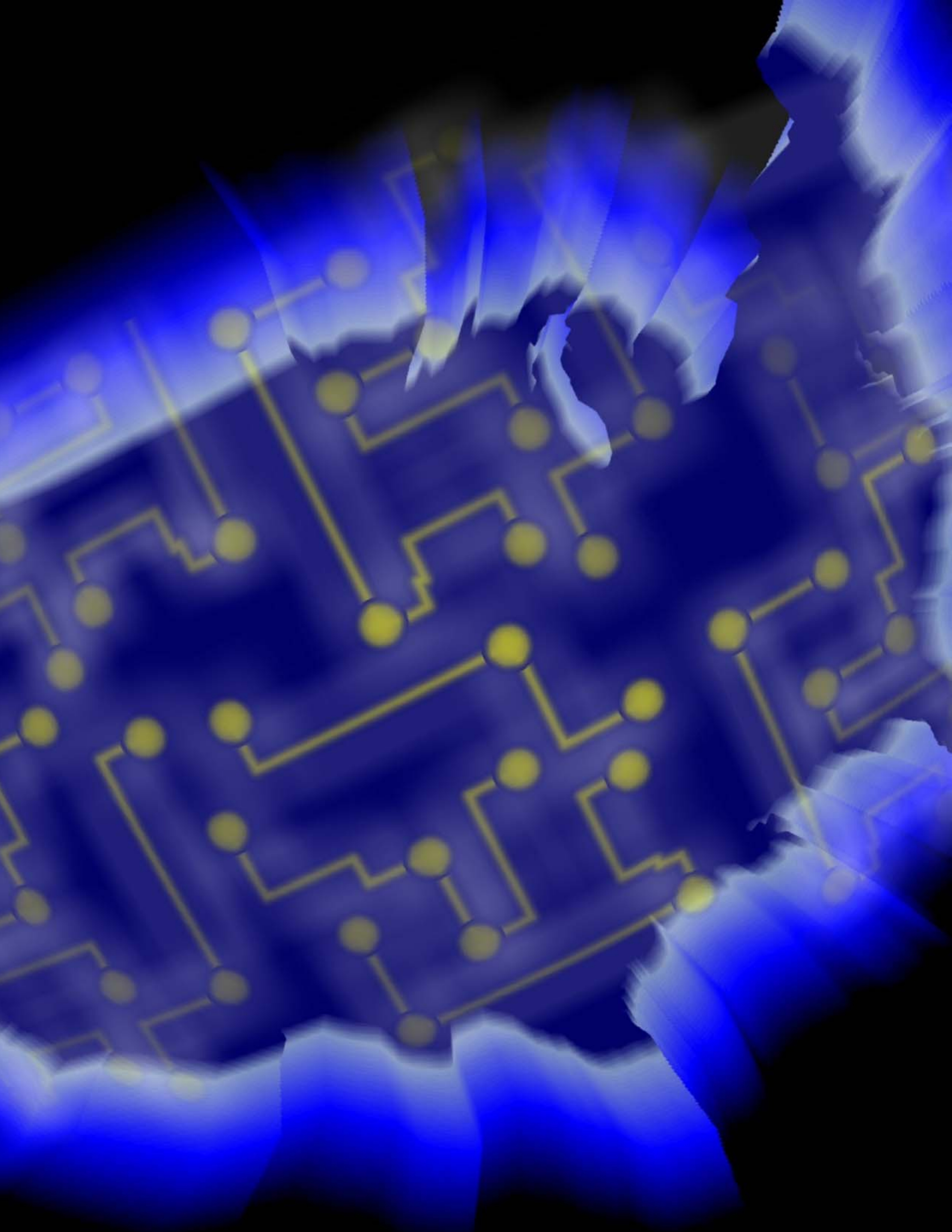

Executive Summary

Nuclear Power's Promising Future

Nuclear energy has become a major source of safe, clean, economical, and reliable energy. Since 1984, nuclear power plants have generated more U.S. electricity than any source other than coal—20 percent of the country's electricity generation, without emitting air pollutants or greenhouse gases. The *National Energy Policy* recognizes the vital role that nuclear energy must play as the only large-scale energy supply option that does not produce greenhouse gasses or other harmful emissions.

The dramatic improvement in U.S. nuclear power plant performance over the last 25 years has established a strong foundation for the expansion of nuclear energy in the next two decades. According to recent data from industry, government, and international sources, nuclear plant safety has improved consistently over this period. These data also show major strides in plant capacity, reliability, and economic performance. Substantial progress has been made recently on resolving long-term spent fuel storage issues with the approval of Yucca Mountain as a long-term repository. These factors, combined with increasing concerns about the reliability of fossil fuel supplies and their associated environmental impacts, have led to increasing public support for nuclear energy and the willingness to support new plants in the United States (*Perspective on Public Opinion*, NEI, November 2003).

Goals and Objectives of the Plan for Light Water Reactor R&D

DOE and the nuclear industry have developed a strategic plan for increasing nuclear energy capacity to help meet the primary goal of the *National Energy Policy*: to increase energy supply from diverse sources, including nuclear power. This national effort could not be achieved without a strong partnership between government and industry. As work evolves, so too will this "living document." This strategic plan will be updated on an annual basis.

The mission, goals, objectives, R&D focus areas, and planned outcomes of this plan are outlined in the chart on the following page. Its objectives focus on expanding nuclear capacity through 1) deploying new plants and 2) maintaining and expanding electrical production from currently operating plants. It is based on a ten-year planning horizon.

The plan's first set of objectives encourages construction of new nuclear plants by addressing regulatory and technological issues that affect economic competitiveness and investor confidence in a deregulated generation market. Regulatory processes for licensing new plants need to be demonstrated, streamlined, and made more predictable. Effective and timely regulatory processes will reduce the "time to market" and the associated business risk, which will improve utility and investor confidence. The technological issues focus on the development of more economical, efficient reactor designs and the application of new technologies that will reduce construction times and costs.

The plan's second set of objectives focuses on improving and expanding current plant performance and achieving the longest safe and economic operating life possible. While the nuclear industry has made great strides in improving the reliability and efficiency of the existing plants, new technologies are needed to further expand and modernize existing systems while ensuring continued high degrees of reliability and operating predictability. Advanced technologies are needed to increase generating output, optimize plant performance, and assure long-term safe and secure operation. A specific R&D objective focuses on developing cost-effective security technologies to enhance the capability of existing nuclear power plants to meet newly emerging threats following the September 11 terrorist attacks. In addition to these new, advanced technologies, R&D is also needed to improve fuel reliability, achieve higher fuel burn-ups to better optimize today's longer reactor fuel cycles, and improve cost-effective management of spent fuel storage and transportation.

Inherent and foremost with each of these objectives is the continued assurance of public safety. Advances in risk management and safety assessment technology must accompany the advances that improve the economics and performance of nuclear power. Industry experience in dealing with unanticipated operating events and materials degradation issues highlight the importance of safety/risk

U.S. DOE/ Nuclear Power Industry Strategic Plan Summary

management as an integral part of overall plant performance improvement. Many of these needs could have been better anticipated through the use of a risk management approach. Focusing on safety/risk management is also critical for designing new plants and for resolving new plant regulatory issues in an effective manner.

A number of R&D areas have been identified that will serve as the initial focal point in implementing this strategic plan. The R&D focus areas shown on the previous figure are presented in more detail in Chapter 2 and in the tables located in Appendix A of this plan. Linked to the focus areas noted in the tables are "planned outcomes." These outcomes are specifically related actions that are performance-based and, therefore, quantifiable. The "milestones" noted in Appendix A are the ultimate measure of success for each focus area. This provides DOE and industry with preliminary metrics to assess whether the goals and objectives of this plan are in fact being met in a timely fashion.

Some of the milestones in the appendix require actions by the NRC, who is not a signatory of this plan. DOE and industry can provide invaluable assistance in helping to ensure these milestones are achieved; however, their completion ultimately is the responsibility of the NRC. Relevant information obtained from NRC sources was considered in developing these milestones.

Public/Private Partnering

With limited industry resources and the increasing demand that R&D investments be market relevant, joint planning of R&D between DOE and industry is essential to achieving highly leveraged results and avoiding duplication and gaps in respective research programs. Generally, industry's R&D priorities are shorter term in nature. Government's medium-term R&D complements industry efforts, yet must be market driven and relevant to industry's needs to be able to garner required industry cost share. Partnering with DOE allows greater focus on the medium-term R&D that industry cannot afford to fund on its own. DOE and industry have used this strategy effectively in the past, most recently in the Advanced Light Water Reactor (ALWR) program, the Nuclear Energy Plant Optimization (NEPO) program, and the Nuclear Power 2010 (NP 2010) program. This plan builds on progress already made by these programs and integrates the remaining critical R&D tasks from these programs into a more strategically focused R&D Plan.

The R&D activities under this plan will greatly benefit from joint planning and cost sharing as a means of accelerating the development of new nuclear plants and advanced technologies for current plants. Funds can be channeled to specific R&D that will expedite the development of first-of-a-kind technology, demonstrate effective new regulatory processes for licensing new plants, and develop strategically important advanced technologies for current plants. Without government support, new nuclear capacity would be added eventually, but at a much slower pace.

The Federal government has an important role in assuring that safe, economical, and reliable nuclear power technology is available to meet U.S. energy needs. By working closely with industry, the government can identify and prioritize the required R&D and share its associated costs. Joint planning and cost sharing brings balance to the scope of the plan and ensures greater value will result over the full spectrum of the R&D activities that will be pursued.

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Introduction, Background, and Scope

1

The Role of Nuclear Power in the United States

Nuclear energy is a major source of safe, clean, economical, and reliable energy worldwide, providing 16 percent of the world's electricity. Many countries rely heavily on nuclear energy for much of their electrical power. France obtains 77 percent of its electricity from nuclear energy. In China, nuclear power plays a prominent role in their energy strategy for the future, as it does in Japan, South Korea, Taiwan, and many other countries. As environmental awareness grows globally, nuclear power becomes an ever more compelling energy option.[1]

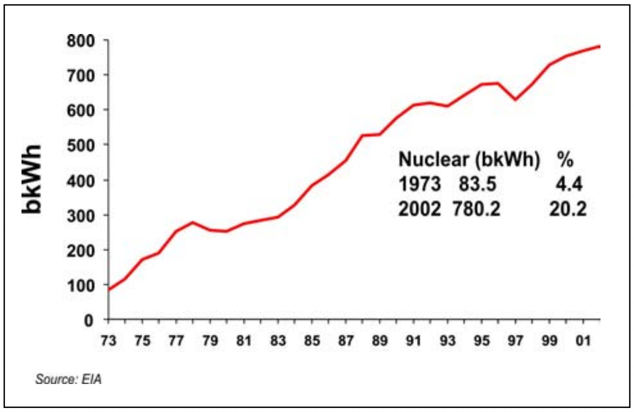

Figure 1: U.S. Nuclear Industry Net Electricity Generation (1973-2002)

Since 1984, nuclear energy has generated more U.S. electricity than any source other than coal (Figure 1). The U.S. produced 780 billion kilowatt hours of electricity from nuclear power in 2002—20 percent of the country's electricity generation, without emitting significant air pollutants or greenhouse gases (Figure 2).[2] The average production

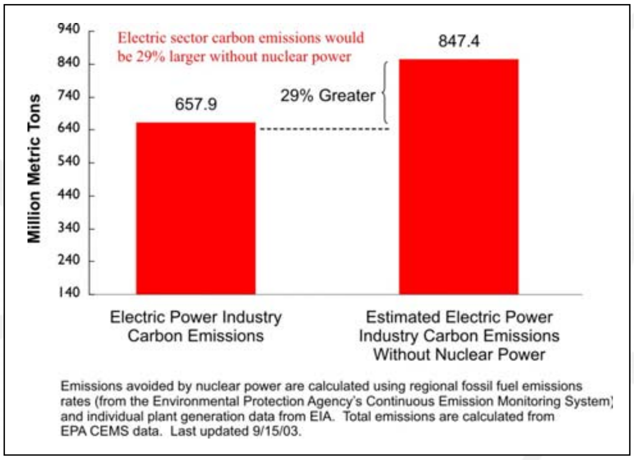

Figure 2: Nuclear Power's Contribution to Limiting Carbon Emissions (2002)

[1] *U.S. NRC Information Digest*, 2003 Edition, NUREG-1350, Volume 15, Figure 14.
[2] Ibid., p 28.

cost of this electricity was the lowest of all fuel sources at 1.71 cents per kilowatt hour.[3]

However, while other nations are building new reactors and increasing the electricity contribution from nuclear energy, not a single nuclear power plant has been ordered by an electric utility in the United States since 1978, and no plant ordered after 1973 has been completed.[4]

Nuclear energy is an integral part of the United States' electricity supply and therfore is essential to the Nation's economy. A strong and growing nuclear generation capacity is important to the Nation. After a two-decade hiatus in nuclear plant construction, government support is necessary to ensure that nuclear energy remains an essential part of our country's energy future. However, as nuclear power plants are commercial enterprises, built and operated by electric utilities, it will be their ultimate responsibility to utilize and implement the results derived from the R&D scope addressed by this plan.

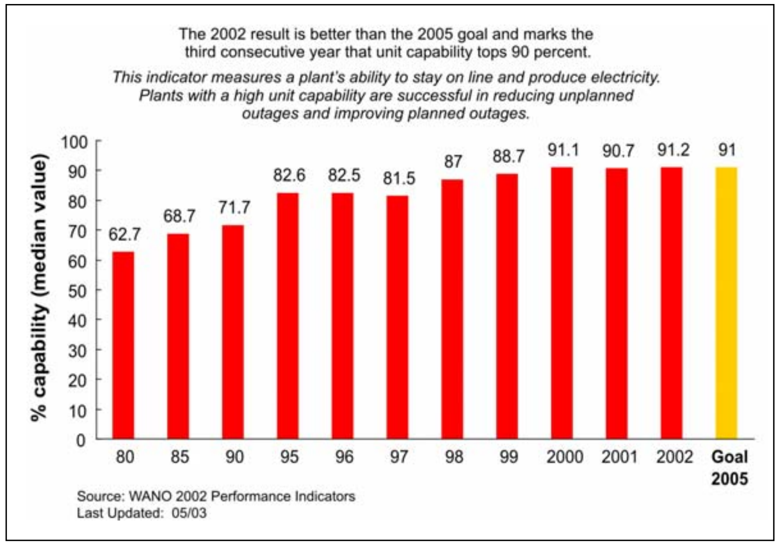

Figure 3: Unit Capability Factor

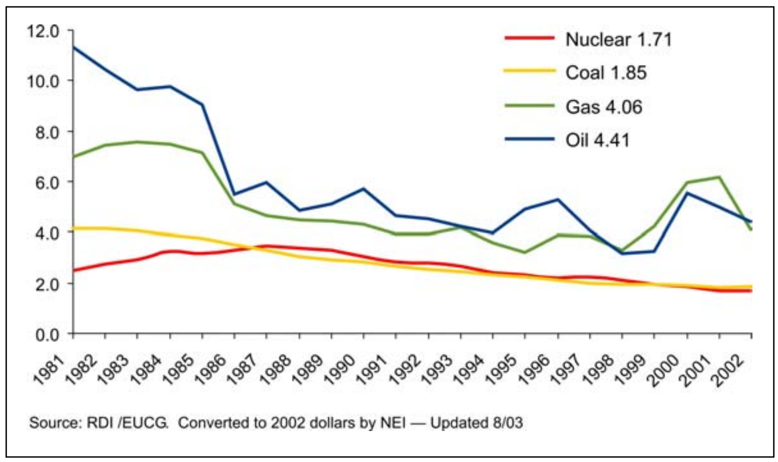

Figure 4: U.S. Electricity Production Costs (1981-2002) (in 2002 cents per kilowatt-hour)

Nuclear Energy: Trends in Performance Improvement

Despite the lack of new plant construction, the nuclear power industry has made great strides in plant safety, efficiency, and increased capacity to keep up with the ever-growing demand for electricity. Nuclear power plant performance in the United States has improved dramatically since 1990[5]; the increased electricity output has compensated for nine older plant retirements since that date, and added the equivalent of 13 new 1,000-megawatt power plants to the national grid (Figure 3). These improvements have also lowered the cost of nuclear generation, making it competitive with other sources of electricity, as noted in Figure 4.

A Commitment to Secure, Clean Energy

World events such as the oil embargoes of the 1970s and the political unrest in the Middle East have influenced energy consumption in the United States. Environmental concerns also have a growing impact on the energy choices made by nations worldwide. The United States has taken these

[3] RDI/EUCG, August 2003.
[4] IEA, *Nuclear Power in the OECD*, Page 132, 2001.
[5] *U.S. NRC Information Digest*, 2003 Edition, NUREG-1350, Volume 15, Table 7 and Figure 25.

concerns into account in developing its own energy policy, which reflects the country's concern with securing an energy future that is less dependent on foreign sources, promotes fuel diversity, minimizes price fluctuations, and addresses environmental impacts.

Several important planning documents have strongly urged the expansion of nuclear energy in the United States. A key recommendation in the *National Energy Policy*[6] is to "expand nuclear energy in the United States as a major component of our national energy policy." Almost immediately after the *National Energy Policy* was issued to the American public, the Nuclear Energy Institute announced the industry's *Vision 2020*. This latter document outlines an approach to meeting future electricity demand while maintaining the current percentage of non-emitting generation, by adding 50,000 megawatts of new nuclear generating capacity to the U.S. grid by 2020, along with an increase of 10,000 megawatts from existing nuclear units.[7]

Through these documents, both government and industry have individually committed to the expansion of nuclear energy. This joint R&D plan defines the work necessary to support this commitment, especially in those areas where government and industry have mutual interests.

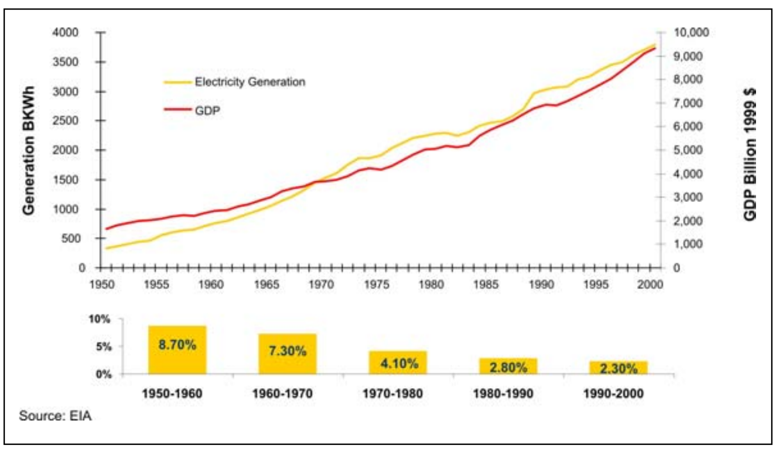

Figure 5: Electricity Generation and Economic Growth (1950-2000)

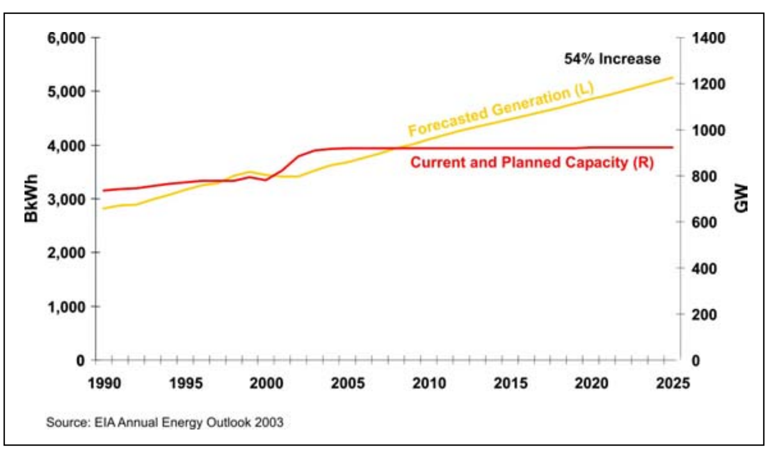

Figure 6: Forecasted Electricity Demand and Current and Planned Capacity (final consumers)

Nuclear Power and U.S. Energy Policy

The United States' economy and standard of living depend on the production, transmission, and distribution of adequate, reliable, and clean electricity (Figure 5). Over the past two decades, there has not been sufficient planning for the addition of new electricity capacity to sustain our growing economy, expanding population, and rising standard of living. Increasing generation capacity margins as well as transmission capacity can help meet growing electricity needs, handle the increased traffic resulting from deregulation, and improve grid reliability.

According to the *National Energy Policy*, America is facing an uncertain energy future. As Figure 6 illustrates, if production of electricity only grows at the current rate, then within 20 years electricity demand will significantly outpace production. To meet projected demand over the next two decades, America must invest in 1,300 to 1,900[8] new electric plants. Much of this new generation is

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[6] *National Energy Policy,* May 2001.
[7] *Vision 2020: Nuclear Energy and the Nation's Future Prosperity,* Nuclear Energy Institute, May 2001.
[8] *National Energy Policy,* May 2001.

expected to be fueled by natural gas; however, gas prices are highly volatile. Such a scenario could create regional energy shortages and escalating electricity prices.

The National Energy Policy outlines a balanced energy portfolio that emphasizes stable, reliable, and diverse sources of domestic energy to reduce our dependence on imported fossil fuels. These sources include electricity supply from alternative energy sources, such as renewable energy. However, an uncertainty in future fossil fuel prices and the environmental impacts of these fuels have created increased attention to the role of nuclear energy. In addition, while renewable energy fuels offer hope for America's energy future with improvements in energy conservation and energy efficiency, improvements are still needed in the transmission, storage, reliability, and economics of these technologies. Accordingly, the *National Energy Policy* called for expanding the role of nuclear energy.

The Expansion of Nuclear Energy: Facing New Challenges

The greatest challenge in our energy future is increasing electricity supply without adversely impacting the environment or the economy. Nuclear power plants, which serve millions of American homes and businesses, emit no pollution or greenhouse gases into the atmosphere. Yet, despite an excellent record for safety and reliability, expansion of nuclear energy in the United States has been slow. Industry and the NRC expect virtually all nuclear power plants to apply for a 20-year license renewal to help meet future energy demands, but no new nuclear plants have been brought on-line since 1996. To keep up with the growing demand of electricity, the nuclear energy industry has made great strides in improving the efficiency of existing plants in order to expand capacity.

This plan addresses several challenges that need to be overcome to further expand nuclear energy in the United States. The two-decade-long hiatus in nuclear plant construction has been caused by a combination of many factors, most of which are no longer of high significance. These included overcapacity, high interest rates, marginal operational performance of a few nuclear plants, an unpredictable licensing process, and public concerns about the safety of nuclear technology and the disposal of spent nuclear fuel. Some of these issues no longer remain, and progress in resolving the others have been steady and encouraging. Most of these factors no longer dominate the challenges that investors must consider when making decisions about new generating capacity.

As nuclear energy expands in the 21st century, it faces new and different challenges. The two most significant obstacles to constructing new nuclear plants are lack of assurance that new nuclear plants can achieve adequate return on investment in today's deregulated electricity marketplace, and lack of investor confidence in the effectiveness of NRC's new, unproven licensing process, coupled with related utility concerns about the impact of that licensing process on construction cost and schedule.

The need for future baseload plants is becoming increasingly apparent. Baseload plants face economic challenges because of the combined effects of their large size, long lead time for construction, and high capital cost.

A History of DOE and Industry Efforts in Nuclear Energy R&D

Despite the country's need for new power generation, several factors in today's marketplace are discouraging the construction of new nuclear power plants. These include uncertainties associated with the Federal regulatory processes; the high initial capital cost of a new, first-of-a-kind nuclear plant; and related business risks. Since 1980, industry and government have worked, both individually and together, to develop new technologies and practices that improve the operating efficiency of current and future nuclear power plants, to develop new regulatory processes for licensing future plants, and to assess the business risk associated with building new nuclear power plants in the United States.

Following the accident at Three Mile Island in 1979, DOE and the nuclear industry recognized that performance issues existed at operating nuclear plants but that the nation's energy and environmental needs necessitated retaining the option to build future nuclear plants. The industry initiated major efforts to improve the performance of its plants, assisted by the Institute of Nuclear Power Operations (INPO). This effort was vital to improving safety, and to increasing the Nuclear Regulatory Commission's (NRC's) confidence in the industry's capability and commitment. This effort was also a necessary prerequisite to building new plants.

Other central organizations sponsored by electric utilities worked to improve nuclear plant safety, reliability, and performance, interaction with the NRC, spent fuel management, public information on nuclear energy, and Congressional relations. These organizations included the Nuclear Energy Institute (NEI) and its predecessor organizations responsible for nuclear energy policy and all the above issues, and the Electric Power Research Institute (EPRI, the utility industry's R&D arm). NEI, EPRI, and INPO operate jointly today under a Memorandum of Agreement (MOA) to coordinate their efforts.

In 1983, DOE and industry embarked on a program to retain a nuclear power option and to lay out the conditions under which nuclear plants could be built again. This grew into the Advanced Light Water Reactor (ALWR) Program, which ran from the mid 1980s to the late 1990s. European and Asian nuclear utilities also participated in the program and helped fund it. This public/private partnership conducted specific engineering activities for four advanced designs by three U.S. reactor vendors. A major outcome of this effort was the "ALWR Utility Requirements Document." The work done in that program has provided a critical foundation for current DOE and industry programs to deploy new, standardized reactor plants.

In the late 1980s, NRC streamlined the licensing process for new plants. With input from Congress, industry, DOE, and other stakeholders, NRC implemented a new regulation, 10 CFR Part 52, which provided an improved process for early site permitting (ESP), standardized design certification (DC), and a combined construction and operating license (COL). This new regulation increases public involvement in the early stages of the process and improves its predictability and effectiveness. Ultimately, the NRC certified three standardized designs for construction in the United States. These certified designs are an important step in the eventual deployment of new nuclear power plants.

Much of the institutional framework and R&D program foundation that forms the basis for this integrated strategic plan was created during the 1990s. The ALWR program continued as a successful R&D partnership between DOE and industry, as did various joint initiatives that ensured the viability of nuclear plant life extension through a license renewal process at NRC. During this time, DOE also conducted three landmark energy studies: one called for a major expansion of public/private partnerships and the others served as the basis for two new DOE nuclear R&D programs, the Nuclear Energy Research Initiative (NERI) and the Nuclear Energy Optimization (NEPO) program.

These Federal initiatives have given rise to other DOE nuclear R&D programs such as the Generation IV Nuclear Systems Initiative, the Advanced Fuel Cycle Initiative, the Nuclear Hydrogen Initiative, and the Nuclear Power 2010 Program. These programs support the national priorities of domestic electricity supply diversity and security and the development and deployment of clean energy technologies.

Uncertainty over the cost and schedule for deploying new baseload plants is a critical factor in the business decision to go forward with constructing a new plant. Thus, R&D efforts need to focus on reducing capital costs and on reducing the time required to both license and build new plants. Demonstrating successful licensing and construction is key to investor confidence.

Existing nuclear plants face different challenges. To allow expansion of nuclear power, the current plants must continue to operate safely and efficiently. The most significant obstacles to continued high performance and extended life of the current fleet of nuclear energy plants are:

- Age-related degradation of systems, structures, and components.
- Nuclear fuel reliability under increased performance demands.
- The high cost associated with maintaining plant security.
- Equipment reliability and obsolescence, particularly of instrumentation and control systems and other active components, both of which are amenable to applications of advanced digital and telecommunication technologies already developed by other industries.

Today's Most Relevant, Nuclear-Related Policies, Reports, and Programs

The *National Energy Policy*

One of the first goals of the Bush Administration was to develop a national energy plan. The *National Energy Policy*, issued in May 2001, developed a comprehensive long-term strategy that uses leading edge technology to produce an integrated energy, environmental, and economic policy. It recommends improving conservation, modernizing our infrastructure, and increasing our energy supplies. It recognizes the vital role that nuclear energy must play, as the only large-scale energy supply option that does not produce greenhouse gases or other harmful emissions. Much of the related work being funded today is based on the *National Energy Policy's* call to support the expansion of nuclear energy in the United States as a major component of our nation's energy policy.

Nuclear Energy Institute's *"Vision 2020"*

Shortly after the National Energy Policy was issued, the Nuclear Energy Institute announced the nuclear energy industry's "Vision 2020": an approach to meeting future electricity demand growth while simply maintaining the current percentage of non-emitting generation. This forward-looking document postulates that to meet these challenges, the nation would need to add 50,000 megawatts of new nuclear generating capacity to the U.S. grid by 2020. This vision of building new nuclear plants—roughly 50 of them, assuming an average size of 1,000 MWe each—is modest in comparison to the forecasted energy supply needs. The entire 50,000 megawatts, along with an increase of 10,000 megawatts from existing nuclear units due to power uprates and other efficiencies, is predicted to only slightly expand the total percentage of U.S. electricity generation from nuclear energy, from about 20 percent to about 23 percent.

The Near-Term Deployment (NTD) Roadmap

In October 2001, the Nuclear Energy Research Advisory Committee (NERAC) approved and DOE published *A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010*. The NTD Roadmap identified three phases of activities to assist in the deployment of new nuclear power plants in the 2010 timeframe. Phase I addressed refinement and demonstration of the 10CFR52 process; Phase II addressed completing the design of viable nuclear plant options; and Phase III addressed construction and start-up of new plants. The implementation of these phases would be market-driven, with industry and government cost sharing activities in Phases 1 and 2, and industry paying for Phase 3. The plan also assessed the regulatory, technical, and economic challenges to building new nuclear plants and provided recommendations for addressing these challenges.

By developing and applying new technologies, existing nuclear plants can continue to deliver clean and affordable electricity, enhance their reliability, availability, and productivity, while maintaining high standards of safety.

Building on the excellent safety, environmental, and economic progress of U.S. nuclear plants over the last twenty years, industry and DOE now have the responsibility to demonstrate to Americans the policy implications of this performance record and its relevance to meeting the Nation's future energy needs. Also, recent progress toward licensing a permanent repository at Yucca Mountain will allow the Nation to begin the safe disposal of spent fuel at that site in the next decade.

The Importance of Government Leadership

The Federal government has a long history of using public-private partnerships to augment and optimize the use of limited Federal funds, inject market forces into government R&D prioritization, and encourage technology transfer of its R&D investments into the marketplace. The Federal government has an important role in assuring that safe, economical, and reliable nuclear power technology is available to meet U.S. electricity needs. In view of the importance to the nation of a strong and growing nuclear generating capacity, strong and visible leadership from

The Nuclear Power 2010 Program

The NP 2010 program is a DOE/industry cost-shared effort to reduce the regulatory, technical, institutional, and economic uncertainties associated with the licensing and construction of new nuclear power plants. Its initial effort is focused on implementing key elements of Phase I of the NTD Roadmap. Activities under this program focus on exploring sites that could host new nuclear power plants, demonstrating untested NRC regulatory processes, developing Generation III+ nuclear reactor technologies, and implementing appropriate strategies to enhance the business case for building new nuclear power plants with the intent to obtain an industry decision by 2005 to order at least one new nuclear plant for deployment in the 2010 timeframe.

The NP 2010 program supports the national priorities of ensuring domestic electricity supply diversity and security, developing and deploying emission-free and clean energy technologies, and enhancing and encouraging economic development. Additionally, the program makes a significant contribution towards achieving the President's global climate change goal of reducing greenhouse gas intensity by 18 percent by 2012. Through successful completion of the NP 2010 program activities, competitive Generation III+ designs will become available to the commercial market and a more viable business case will be established to bring new nuclear generating capacity on line.

The Nuclear Plant Optimization Program

The Nuclear Plant Optimization (NEPO) program was initially funded by Congress in FY 2000 to focus on performance of currently operating nuclear plants. This program supports research and development focused on improving the operations and reliability of currently operating nuclear power plants while maintaining a high level of safety. Improved efficiency is reflected in increases in power generating capacity and improvements in reliability are reflected in increased operating predictability. The NEPO program requires industry to fund at least half of the research conducted and has been designed to encourage the electric utility industry to conduct longer term or higher risk research than they would normally be likely to pursue.

the Federal government is essential. Without government support, new nuclear capacity would be added eventually, but at a much slower pace. A delay in deploying nuclear plants could lead to an excessive commitment to the near-term construction of fossil-burning power plants, resulting in an unnecessary increase of air pollutants and likely increases in electricity costs to the consumer.

The first goal of this plan is to clear a path for new construction of nuclear power plants by demonstrating the successful implementation of the new plant licensing process, focusing R&D activities on the design and certification of Generation III+[9] designs, improving technologies to accelerate the timeframe of plant construction, and enhancing the economic feasibility for investing in new nuclear power plants by cost-sharing their one-time engineering and licensing costs.

Government support is necessary to accelerate the licensing process and to make this process more predictable. It is necessary to share the initial costs associated with meeting the licensing requirements for new standardized designs due to the complexity of the effort, the need for DOE's inter-agency involvement in facilitating successful demonstration of new Federal regulatory and licensing processes, and the significant financial resources required. It is reasonable to expect that with plant standardization and economies of scale attained through design, licensing, and construction of subsequent plants, that costs would decline to levels where new plant construction will become a recoverable investment. Also, cost sharing the initial, one-time engineering costs will be critical to enabling utilities to invest in new construction of nuclear power plants.

The second goal of this plan is to optimize the performance, reliability, and security of existing nuclear power plants, while maintaining the current high standards of nuclear safety. Operation of existing nuclear power plants is critical to providing the United States with an economic and reliable electricity supply system. Nuclear power plants produce one-fifth of the Nation's electricity and up to three-quarters of the electricity in some states. To achieve the *National Energy Policy* goal of a stable, diverse, and reliable electricity supply system, the long-term operation of existing nuclear plants must be assured. As corporations, electric utilities have a fiscal responsibility to maintain shareholder value, despite an increasingly deregulated market. This responsibility inhibits them from investing in long-term R&D with "over the horizon" returns on investment. Consequently, government participation is essential to ensuring that a broad range of technologies is developed that promises to enhance the long-term performance of existing (and possibly future) nuclear power plants. DOE will partner with the nuclear power industry to conduct the necessary R&D to increase existing nuclear plant electricity generating capacity, enhance already high levels of security at nuclear plants, and assure the safe continued operation of the existing fleet of nuclear power plants throughout their lifetimes.

The proposed research for existing plants will support increasing their generation capacity, resolve material aging, and advance and optimize plant operations and physical security. The R&D activities proposed in this plan related to existing nuclear power plants are important because:

[9] Generation III+ nuclear power plants refer to those designs currently in development with the potential for deployment within the next decade. It refers primarily to the viable reactor designs referenced in the NTD Roadmap (e.g., AP1000, ABWR, ESBWR, SWR-1000) and newly introduced designs such as the AECL ACR-700.

- Increasing existing nuclear power plant generating capacity beyond current levels and extending their life for twenty years or more are highly cost-effective ways to add new baseload generation at a fraction of the cost of building new plants.

- Increasing nuclear generation avoids additional emissions of pollutants and greenhouse gases. This will make a significant contribution towards achieving U.S environmental goals.

- Inspection and early resolution of plant equipment and materials degradation issues can prevent extended nuclear plant shutdowns. Research on long-term operation and reliability of existing nuclear power plants is needed to assure availability of existing emission-free generation.

- No other Federal research program focuses on long-term operation and reliability of existing nuclear power plants. Industry R&D is short-term in nature with recovery of investment in the one- to two-year time frame.

- Increasing Federal funding to nuclear energy supply R&D is critical to achieving a balanced energy R&D portfolio that is consistent with the *National Energy Policy* emphasis on diverse energy sources.

- Investing in existing nuclear plant R&D that facilitates maintaining high levels of public, investor, and regulatory confidence in the nuclear industry is vital to obtaining new nuclear plant orders.

2 Research, Development, and Scope

Mission:

Expand the use of safe and economical nuclear energy in the United States to meet future electricity demand, foster economic growth, provide security and fuel diversity, and enhance environmental quality.

DOE and the nuclear industry have agreed to work together on the two ways to expand the use of nuclear energy: by building new nuclear power plants and by improving plant capacity, output, and the useful life of current plants. This chapter provides a description of the specific challenges to expanding nuclear energy in the United States as well as the corresponding R&D objectives for meeting these challenges. This chapter also outlines the scope of work for each objective area and the expected benefits of this work. Tables in Appendix A provide further detailed information on each objective including specific R&D focus areas, expected outcomes, and milestones. The metrics presented in these tables are intended to be aggressive yet credible targets to guide R&D decisions. Annual updates to this plan will refine these metrics based on the latest market information.

Goal #1:

Building New Nuclear Power Plants

The first goal of this plan is to **address and resolve the challenges to building new, economically competitive nuclear power plants in the United States.**

Challenges to Building New Nuclear Power Plants

To attract the substantial financial capital required to license, procure, and construct new nuclear plants, proposed plants must be economically competitive in the electricity marketplace. The major economic consideration that will affect the decision to build new generating capacity is the perceived risk to the utility posed by a large capital investment, electricity deregulation, and nuclear regulatory uncertainty. If analysts and investors perceive a commitment to construct a new nuclear plant as a risky enterprise, both the price of the company's stock and its credit rating could be adversely affected. In turn, this could hinder the utility's access to capital, possibly making the construction of a new nuclear power plant financially impractical or even impossible.

A second economic consideration is the issue of earnings dilution. When building any new generating capacity, the utility or power generator must invest large sums of money for several years as the new plant is being constructed. The company will not realize any return on that investment until the plant begins generating electricity. This opportunity cost is particularly high for large nuclear power plants, which historically have taken eight to ten years to build.

Finally, based on recent surveys, companies require a 10 to 12 percent after-tax, internal rate of return on investment for any construction of new nuclear generating capacity.[10] In the recent past, utilities and generators who had access to relatively inexpensive natural gas could expect high returns (with less risk and more certainty of return on investment) from new gas turbine generators. However, the cost of natural gas, like fuel oil, has recently increased substantially, making the overall cost of nuclear generation competitive with that of natural gas and fuel oil generation.

Achieving the stated goal in the 2010 timeframe will require major planning and coordination. DOE and industry need a comprehensive plan for building new nuclear power plants in the U.S that integrates the plans and resources of government and industry in support of the *National Energy Policy* and *Vision 2020*. This Strategic Plan, in combination with the NTD Roadmap, forms the foundation for converging on a joint planning basis. The following text describes challenges to the economic viability of nuclear power and the research activities that will resolve the challenges.

[10] *Business Case for New Nuclear Power Plants: Bringing Public and Private Resources Together for Nuclear Energy*, Scully Capital, July 2002.

Demonstrating Successful Implementation of the New Plant Licensing Processes

Among the contributors to the perception of undue economic risk for new plants is the uncertainty over the NRC's revamped licensing procedures. The early site permit (ESP) and combined construction and operating license (COL) are the two major elements of 10CFR52, "Early Site Permits, Standard Design Certifications, and Combined Licenses for Nuclear Power Plants," that have not yet been successfully demonstrated. The third major element, design certification, has been demonstrated, but not on a schedule that is conducive to new plant orders.

In addition, there is not enough investor confidence in the efficiency of the regulatory process for construction inspection. If this process is too cumbersome, or if the related acceptance criteria are insufficiently defined, then, even though a COL is obtained, power companies will still not be able to achieve the necessarily aggressive schedules for construction and commercial operation needed to obtain investor interest.

As new plant orders resume, all licensing processes will need to be optimized in such a way as to permit the timely processing of multiple applications. One key to this will be a major effort on the part of both industry and NRC to standardize application format, content, and review criteria/processes.

Developing Competitive, Standardized Generation III+ Reactor Designs

Industry needs, and society benefits from, competition among several different reactor design options. However, there is an inadequate amount of industry and DOE resources to finance a large number of near-term design options. DOE and the utility industry must support the minimum number of plant designs needed to assure market competition. The designs selected must be capable of meeting NRC and industry requirements. In addition, first-time engineering must be completed on those designs that industry is willing to consider for a plant order.

Improving Technologies to Accelerate the Timeframe of Plant Construction

High investor anxiety exists over an excessive "time to market" for nuclear construction projects that are vulnerable to costly interruption because of engineering challenges and licensing and regulatory delays. The long-term financial advantage of a nuclear plant must be sufficiently strong to outweigh the high capital costs and the time required before the investor realizes any return. Although efficient NRC licensing and construction inspection processes are key, high capital costs can also be reduced by standardizing designs and sharing one-time engineering and licensing costs; by developing modular, cost-effective construction technologies; and by developing associated planning and information management tools that reduce the labor intensity of these complex construction projects. In addition, digital planning tools can optimize construction sequencing and regulatory inspection, and eliminate the need for duplication of efforts.

Enhancing the Business Environment and Critical Nuclear Infrastructure

Deregulation has sharply changed the financial landscape for utilities—no longer are utilities guaranteed a fixed return. Accordingly, justifying the construction of a new capital-intensive plant to stockholders is extremely difficult especially in times of uncertainty in financing and new plant licensing. To secure capital, project risks and rewards have to meet the investment community's competitive standards.

Also, because of the lack of real growth in the nuclear industry, gradual erosion and current shortfalls in important infrastructure elements have ensued. These include deficiencies in qualified and experienced personnel in nuclear energy operations, engineering, radiation protection, and other professional disciplines; qualified suppliers of nuclear equipment and components; and contractor and architect/engineer organizations with the personnel, skills, and experience in nuclear design, engineering, and construction. Although market forces will eventually lead to an expansion of these skilled work force personnel, many of these resources may not be ready when needed, especially if multiple plant orders and construction projects ensue. Funding assistance provided to U.S. universities by current DOE R&D programs and by nuclear utilities is helping to address this need.

Objectives of Goal #1

Following is the first set of objectives for this strategic plan. The goal of these objectives is to clear a path for new construction:

- Objective 1-1 is to "successfully demonstrate the Early Site Permit (ESP) and combined Construction and Operating (COL) license regulatory processes, leading to the licensing of multiple sites for locating new nuclear power plants and the issuance of licenses to construct and operate new advanced nuclear power plants."
- Objective 1-2 is to "focus research and development activities on the design and certification of competitive, standardized Generation III+ reactor designs to obtain an industry decision to order a new nuclear plant by 2005."
- Objective 1-3 is to "focus technology development and process improvement activities on minimizing lead-times from plant orders through construction and operation, to allow construction completion of at least one new plant in the 2010 timeframe."
- Objective 1-4 is to "identify and implement appropriate Federal and industry actions to enhance the business environment and industry infrastructure to make deployment of new nuclear power plants feasible by 2010."

Scope of Work

The scope of work (SOW) related to these objectives is limited to R&D that addresses high-priority needs for new nuclear power plants that will be built within a ten-year planning horizon.

SOW for Objective 1-1: Demonstrate ESP and COL

- Standardized processes with technical bases will be developed and demonstration projects will be performed to ensure the stability, predictability, and efficiency of the ESP and COL processes. The ESP effort is already underway, but further efforts toward standardizing and streamlining the process are needed. The COL effort will include R&D to resolve all significant generic licensing issues associated with COL. Upon completion of this generic effort, applicants will have an approved COL format (e.g., template) to use for their COL submittal. Using this format, with all generic issues resolved in advance, should enable COL reviews to be completed in under two years.
- Standardized processes will be developed and demonstration projects will be performed to assure that the regulatory process for construction inspection and Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) verification can support an aggressive construction schedule.

SOW for Objective 1-2: Support Certification of Near-Term Deployment Reactor Designs

- At least two competitive, standardized Generation III+ designs will be developed for design certification.
- First-of-a-Kind Engineering (FOAKE) will be completed for those near-term Generation III+ designs that industry is willing to consider for a plant order.
- Recent progress in risk-informed regulation will be applied to better focus design certification reviews and requirements; e.g., apply risk-informed "special treatment requirements" to optimize component test programs and procurement specifications.

SOW for Objective 1-3: Shorten Lead Times for New Plants

- Technological advances will be developed that can reduce capital costs and construction times, including enhanced information management systems, virtual construction technologies, advanced instrumentation, controls, and on-line diagnostic monitoring.
- Emerging advanced modular and construction technologies will be developed to reduce "time-to-market" for new nuclear power plants.
- The adequacy of the fabrication/manufacturing infrastructure in supporting near-term deployment will be analyzed.

SOW for Objective 1-4: Support Enhanced Business Environment and Industry Infrastructure for New Reactors

- Vehicles for reducing the business risks of capital-intensive new baseload generation investment will be analyzed.
- The adequacy of the current nuclear training pipeline and the skilled construction trade sector in supporting near-term deployment will be analyzed.
- Policies/regulations and Federal R&D, tax, and business investment incentives will be analyzed. Specifically, alternative policy, business options, and associated economic impacts for improving air quality and reducing greenhouse gases will be evaluated, in order to identify an optimum balance between environmental improvements and maintaining a strong U.S. economy.
- Studies on the life-cycle costs and environmental benefits of nuclear energy will be performed. Specifically, the current and future role of all non-emitting generation options (i.e., nuclear, hydro, renewables) in avoiding emissions will be evaluated, along with their impact on Clean Air Act compliance and their ability to meet the goals of the President's Clear Skies Initiative.
- Alternative computer models available in industry and government (e.g., EIA's National Energy Modeling System [NEMS]) will be evaluated for strengths and weaknesses in their capability to do the above analysis, and recommendations to improve assumptions and models for joint use will be made.

Expected Benefits of the Scope of Work

The successful implementation of the Goal 1 objectives will achieve the intent of the Administration's *National Energy Policy* and the nuclear industry's Vision 2020—expanding nuclear energy in the United States as a major component of national energy policy—and will have new nuclear plants on-line by the 2010 timeframe. DOE and industry will work jointly to achieve three ESP approvals in 2005, one design certification in 2005, and design certification of a second design in 2007. Together, these will support one or more COL submittals in 2006 and subsequent new plant orders.

Accomplishing this goal will provide critical benefits to the United States. Expanding nuclear energy will provide safe, clean, and reliable electricity to support a growing U.S. economy. It will make a major contribution to U.S. energy independence, enhanced national security, and U.S. leadership in this vital energy technology of the future. And it will help Americans achieve a much cleaner environment.

Goal #2: Improving Current Plant Performance

The second goal of this plan is to **increase electrical generation capacity, achieve the longest possible safe and economic operating life, and improve the reliability and efficiency of the existing fleet of U.S. nuclear power plants.**

Challenges to Improving Current Plant Performance

For a viable, long-term nuclear industry, the current generation of reactors must operate safely and cost-effectively until ample replacement generation is in place. A significant safety event at any U.S. nuclear power plant could adversely affect the continued operation of other plants and the building of new generation. In addition, maximizing the output of the current generation of reactors helps displace air pollutants and greenhouse gases generated by fossil plants. In order to maximize existing plant output, several challenges must be resolved through the following research activities, which are essential to current plant performance. Much of this research also directly addresses and supports future reactor design and operation, and will help ensure public, investor, and regulatory confidence in the nuclear industry.

Developing/Applying Advanced Technologies for Increased Power Output

The *National Energy Policy* encourages expanding nuclear energy generation in the U.S. by uprating existing nuclear plants safely. To improve plant capacity, reliability, and availability, there is a need for technologies that can support substantial power uprates beyond those currently planned. This R&D must support new technologies and analytical methods that will allow safe, reliable power increases from existing plants without compromising safety margins. To enhance capacity factors of existing U.S. plants and extend their lives, this R&D must focus on 1) enhancing the physical plant to accommodate higher power levels and 2) improving equipment reliability technologies to maximize the benefit of advanced power uprates.

Without the application of new technological advances, long-term, fleet-wide, average capacity factors significantly higher than 90 percent may be very difficult to achieve. Power uprates and shorter outages place higher demands on plant systems, structures, components, and fuel. As such, a systems approach accompanied by reliability performance tests and analyses will be needed to ensure that advances in power generation can be made safely and reliably. Improved capability to perform inspections and repairs while on-line will be critical, along with technology advances that increase output and further reduce forced outage rates.

Developing Technologies for Long-Term Operation

To achieve and possibly exceed the full 60-year lifetimes planned for most of the existing nuclear power plants, R&D is required in the areas of materials and plant aging phenomena, advanced inspection and mitigation methods, and equipment obsolescence (especially Instrumentation and Control [I&C] systems). The results of this research will provide utilities and the NRC with the information needed to ensure continuous long-term operability of essential systems, structures, and components. It will provide utilities with effective methods for assessing, monitoring, and managing plant aging to achieve maximum useful life. A strong technical basis for long-term operation will also be provided by resolving open issues related to aging mechanisms and by applying new technologies to improve the cost-effectiveness and predictability of long-term operation.

Developing Technologies to Cost-Effectively Advance Nuclear Plant Security

U.S. commercial nuclear power plants have had security measures in place, in accordance with NRC regulations, making them among the most robust and well-protected civilian facilities in the country. After September 11, 2001, the NRC immediately advised nuclear facilities to go to the highest level of security and issued a series of advisories and orders to further strengthen security at nuclear power plants. In response to the NRC orders, and to continue to provide the public with confidence in its ability to protect against a more robust and diverse threat, the industry has already spent over $400 million in security-related improvements, and expenditure projections of over $1 billion are anticipated by the end of 2004. Most of this investment has involved site modifications to barriers and armament, and increased manpower to address the threat, as it was immediately perceived after September 11.

Research is needed to identify the most promising security technologies and strategies, in order to optimize security systems and the resources required to maintain them. R&D activities in this area will include demonstrations of the security technology and the regulatory process necessary to ensure adoption of this new paradigm for nuclear plant security. In addition, R&D activities will include the development of a systematic, risk-informed vulnerability assessment method to identify and prioritize threats and mitigation opportunities.

Implementing Technologies for High Burn-up Fuel

The primary challenge utilities face regarding nuclear fuel is to maintain extremely high standards of fuel reliability at the higher burnups being used today. Root cause analyses of fuel defect experience needs to be improved to identify underlying fuel design, operations, and chemistry contributors and prevention and mitigation strategies. Increased testing, analyses, and hot cell examinations are needed. This work will benefit both current and future plants.

Many pressurized water reactors are refueling close to one-half of their cores at each outage when they are on a 24-month cycle. Higher fuel burn-ups would allow utilities to reload a smaller fraction—perhaps as low as one-quarter of the core. Development of advanced fuels capable of burn-ups well beyond the current NRC limit would enable longer in-reactor fuel cycles and, therefore, minimize outage time. However, higher burn-ups tend to increase the burden on fuel rod materials and to decrease fuel thermal margins, negatively impacting fuel reliability, operational safety, and spent fuel management.

R&D and careful testing is required to assure fuel reliability at the higher burnups. In addition, R&D is needed to resolve current licensing issues impacting high burn-up fuel and ensure a clear path exists for licensing increases to beyond the current burn-up limits. This R&D will also take into account the necessity to maintain the ability to manage the spent fuel (interim wet and dry storage, transportation, and eventually disposal) associated with higher burn-ups and evaluate the impact on spent fuel repository. This R&D focus area must also be conducted using a systems approach that, at a minimum, considers life cycle economics, lessons learned from previous fuel performance issues, and a careful assessment of the impacts resulting from these changes.

Objectives of Goal #2

Following is the second set of objectives for this strategic plan. The goal of these objectives is to identify, develop, and apply new nuclear energy technologies to extend the operating life of existing nuclear power plants.

- Objective 2-1 is to "develop and demonstrate advanced power generating technologies necessary for the existing fleet of U.S. nuclear power plants to substantially increase electrical generation capacity by 2015."
- Objective 2-2 is to "develop advanced technologies and asset management strategies that ensure very long-term, safe, secure, and reliable operation."
- Objective 2-3 is to "develop and demonstrate cost-effective, state-of-the-art, security technologies to advance and optimize security at existing commercial power plants that will result in security systems and programs that are more adaptable to changing threat environments."
- Objective 2-4 is to "establish the technical basis for use of highly reliable nuclear reactor fuel with a peak burn-up rate of 80 GWd/mtU or higher, to optimize fuel cycle economics."

Scope of Work for Each Objective

The scope of work (SOW) for these objectives is focused on R&D that addresses high-priority needs for currently operating nuclear plants within a ten-year planning horizon.

SOW for Objective 2-1: Support Increased Capacity and Capacity Factors

- Reactor and Balance-of-Plant (BOP) systems will be analyzed to determine the maximum power uprates that can be achieved cost-effectively.
- Improved instrumentation and control (I&C) technologies (e.g., advanced sensors and calibration technologies and 'smarter' control systems) will be developed to support and allow uprates.
- Techniques for assessing and trending equipment reliability will be developed along with the means for resolving adverse trends through development of improved materials and new technologies for replacement equipment.
- Bases for regulatory acceptance of advanced technology applications will be developed, particularly in areas of dynamic change and rapid evolution, such as digital equipment.

SOW for Objective 2-2: Support Long-Term Operation

- Nuclear and environmental effects of higher reactor power levels on reactor vessel, reactor internal component materials, primary coolant chemistry, and associated component corrosion rates will be analyzed and tested.
- Technologies to conduct real-time performance monitoring of major nuclear plant components (e.g., reactor coolant pump seals) will be developed and demonstrated.
- Technologies, criteria, and methods to implement improved on-line monitoring to support operations and maintenance of plant equipment and components will be developed.
- Technologies to support strategic upgrading of plant I&C will be developed (e.g., transitioning from analog to digital environments).
- Advanced inspection techniques for critical plant structures, systems, and components will be developed.
- Environment-related phenomena and environmental variables affecting the rate of material degradation will be modeled and monitoring techniques developed.

SOW for Objective 2-3: Develop Cost-Effective Advanced Security Technology

- Emerging technologies and technologies that have been applied successfully in other industrial and government applications will be identified and, if beneficial, adapted for nuclear plant use.
- Vulnerability assessment guidelines, security intrusion detection, and perpetrator delay and denial systems will be developed and assessed that will allow an optimized on-site security force to better defend the site from a range of security threats.
- Technologies will be developed that will provide the plant with enhanced response, mitigation, and recovery capability.

SOW for Objective 2-4: Support Implementation of High Burn-up Fuel

- Fuel reliability performance margins under high-duty conditions will be evaluated, existing performance anomalies will be resolved, and regulatory criteria will be developed for high burn-up levels and advanced cladding material.
- Improved analytical tools for advanced fuel designs to assess aspects of fuel operating margins under steady-state and transient operation will be developed.
- The technical basis for using higher burn-up fuel, the optimal enrichment percentage, and other fuel utilization parameters to balance fuel cycle economics will be evaluated.
- Outage cycle parameters (i.e., maintenance, ISI), plant life, and regulatory analysis/licensing/testing requirements to refine the 80 GWD/MTU target[11] will be evaluated.
- On-site storage and spent fuel transportation issues for higher burn-up fuel will be resolved.

[11] SECY-00-0153, *Weekly Information Report to the Commissioners – Week Ending July 7, 2000*, Enclosure B, 7/13/00.

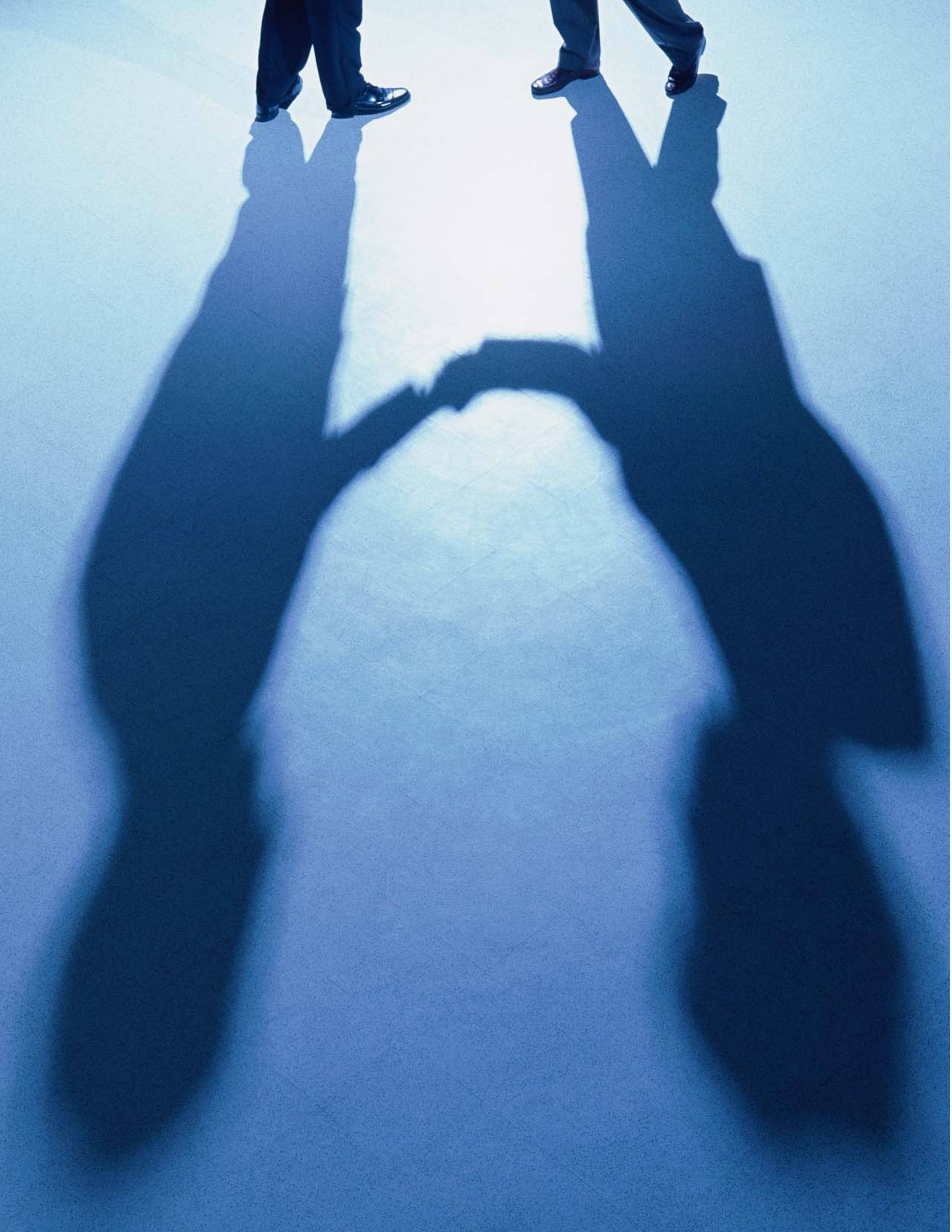
Expected Benefits of the Scope of Work

The primary benefit that will be derived from this R&D work scope will be continued, long-term availability of the existing nuclear plants to produce power safely, economically, and reliably. This, in turn, will help to ensure public, investor, and regulatory confidence in the nuclear industry and will enhance the potential for new nuclear plant orders.

In addition, the successful implementation of the Goal 2 objectives will support the goals of the *National Energy Policy* and the nuclear industry's *Vision 2020*—expanding nuclear energy in the United States as a major component of national energy policy—and specifically to uprate and relicense existing plants. Expected milestones include:

- Achieving an additional 5,000 MWe generation capacity from current plants by 2015, in addition to the 10,000 MWe identified in *Vision 2020*.
- Achieving 50 percent of current plants obtaining NRC-approved license renewals by 2010 and 80 percent by 2015.

Current plants must generate power for the foreseeable future. Without them, 100 gigawatts of replacement power would be necessary, which would most likely have to come from construction of fossil power plants resulting in substantial increases in air pollutants and greenhouse gases. These plants must run safely, securely, and cost-effectively while the next generation of plants is being constructed and for a significant period thereafter.



3 The Path Forward

Increasing Productivity with Joint Planning and Joint Funding

R&D of common interest should be conducted as collaborative and cost-shared activities whenever possible. In doing so, greater assurance is provided that common visions, goals, and objectives will be achieved and that duplication and gaps in technology development will be eliminated. In addition, greater leveraging of resources can be achieved along with a stronger rationale for increasing the R&D investment by respective R&D funding sources.

In the past, collaborative research between DOE and industry has been implemented under two broad categories:

1. **Collaborative and cost-shared activities.** For work in this category, DOE and industry typically execute the work jointly on a partnership basis. These activities involve, to a certain degree, joint management and/or joint funding.
2. **Coordinated but independent activities.** In general, work in this category pertains to related activities that are typically funded solely by DOE or industry either because of the specific independent nature of the effort or because the work may not be appropriate for government funding. These efforts are managed by either DOE or industry, using standard, approved processes for R&D management. Coordination is limited generally to joint planning (to ensure no overlaps and gaps in respective programs), joint communications, and, where appropriate, joint program review as work is undertaken.

The majority of the R&D activities proposed in this plan are expected to fall under the first category, "collaborative and cost-shared activities." Although there will be a number of R&D activities related to this plan's goals and objectives that will be conducted under the "coordinated but independent activities" category, this work will be closely monitored by both DOE and industry to minimize duplication of effort.

The DOE/Industry Management Team

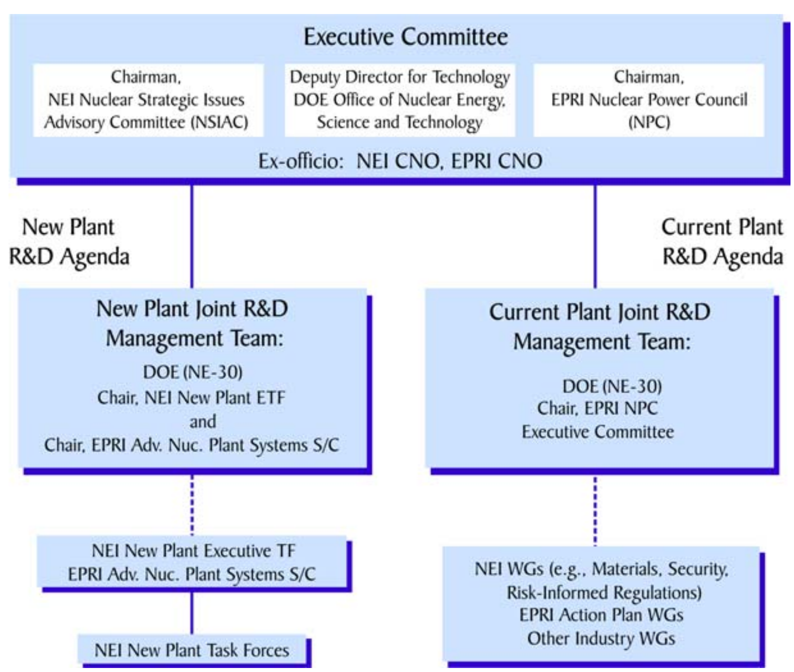
To implement this joint DOE-industry strategic plan, a new management team has been assembled comprised of DOE, Office of Nuclear Energy, Science and Technology (NE) and industry staff. An executive committee will be formed consisting of the NE Deputy Director for Technology plus two additional members representing nuclear utility management: the Chairman of the NEI Nuclear Strategic Issues Advisory Committee (NSIAC) and the Chairman of the EPRI Nuclear Power Council (NPC). These three executives currently provide overall leadership for the nuclear industry on technical and regulatory issues including technical direction and resource prioritization. The utility representatives chair industry-wide committees comprised of chief nuclear officers from all U.S. nuclear power plant licensees, plus other key industry executives. Their participation will strengthen the utility voice, optimizing R&D planning and setting annual funding priorities. The Executive Committee will meet at least annually and will:

- review the status and progress of ongoing cooperative research programs;
- review potential new candidate cooperative research programs;
- agree on priority, terms, and conditions of new cooperative research initiatives; and,
- provide direction on continued work, termination, or other matters, as necessary.

There will be a number of DOE/industry cooperative agreements that will be initiated within the scope of this strategic plan that will focus on specific demonstration tasks, such as early site permit or design certification projects. In these cases, the progress made with these cooperative agreements will come under the oversight of the Executive Committee.

Directing the R&D activities proposed in this plan will be a group of participating managers primarily from the DOE, Office of Nuclear Power Systems (NE-30), NEI, EPRI, and utility executives in their respective advisory structures. This group will comprise two Joint Strategic Plan Management Teams, one for new plants and one for current plants. These managers will be supported by the various task forces, committees and subcommittees, as well as industry vendors and contractors currently addressing the type of issues and R&D activities referenced in this plan.
The proposed management organization is depicted in Figure 7.

Figure 7: Joint DOE-Nuclear Utility Industry R&D Strategic Planning Organization



Program Direction and Oversight

DOE and industry will seek advice on program direction from key executive-level advisory resources. They include:

- the DOE Nuclear Energy Advisory Committee (NERAC),
- the EPRI NPC, and
- the NEI NSIAC.

DOE and EPRI have established close working relations with NEI and its senior-level advisory committee, the NSIAC.

On specific new plant issues, DOE will coordinate its efforts with NEI's Executive Task Force on New Plants and EPRI's parallel Advanced Nuclear Plant Systems Steering Committee. Working level interactions will also continue with NEI's Part 52 Licensing Issues Task Force, Early Site Permitting Task Force, Combined License Task Force, and New Plant Regulatory Framework Task Force. On specific current plant issues, DOE will continue to coordinate its efforts with the NPC Executive Committee for existing nuclear power plant-related R&D.

Appendices

Appendix A: Objective Highlights

Objective 1-1 Highlights:
Demonstrating Successful Implementation of the New Plant Licensing Process

Focus Areas	Expected Outcomes	Milestones
1. Stable, predictable, and efficient ESP process	1.1 Achieve the capability to prepare and submit an ESP application in less than one year.	1.1.1 Submit to NRC three ESP applications in 2003. Update the generic ESP Application Guide based on first applicants' experience by 2005.
		1.1.2 Submit at least one more ESP application by 2007, preferably demonstrating different siting scenarios.
	1.2 Demonstrate that NRC technical review and approval of ESP applications can be achieved in less than 2 years.*	1.2.1 Document resolution of all generic policy and ESP process implementation issues by the end of 2004.
		1.2.2 NRC issue Safety Evaluation Reports (SERs) and Environmental Impact Statements (EISs) within 630 days of docketing the first ESP application.
2. Stable, predictable, and efficient COL process	2.1 Achieve the capability to prepare and submit a COL application in less than one year.	2.1.1 Develop a detailed COL application guidance document by the end of 2004.
		2.1.2 Reach agreement with NRC on how operational programs will be treated in COL applications by the end of 2004.
		2.1.3 Document resolution by the end of 2005 of generic policy and COL process implementation issues that can be resolved prior to submittal of the first COL application.
		2.1.4 Achieve at least one new plant COL submittal in 2006.
		2.1.5 Achieve at least one more COL submittal by 2008, preferably for a second reactor technology.
	2.2 Demonstrate that NRC technical review and approvals of COL applications can be achieved in less than 2 years.*	2.2.1 Resolve a nominal review timeline for COL applications to optimize NRC technical reviews under each likely COL scenario, including NRC agreement, by the end of 2004.
3. Efficient NRC inspection and verification programs for construction and transition to power operations	3.1 Achieve establishment of predictable and efficient NRC processes to verify that construction meets the COL licensing requirements.	3.1.1 Complete, by 2005, the regulatory guidance necessary for the NRC construction inspection and ITAAC verification processes to support a construction schedule of 36 months from first concrete to fuel load.

* Noted time does not include the mandatory hearings time period that is estimated to take an additional nine months. Also, it should be understood that these goals are clearly achievable for "Nth plant" applications but are expected to be more challenging for first application.

Objective 1-2 Highlights:
Developing Competitive, Standardized Generation III+ Reactor Designs

Focus Areas	Expected Outcomes	Milestones
1. Design certification (DC) for near-term designs currently under NRC review	1.1 Obtain NRC approval of DC applications in less than three years (less for partially reviewed designs).	1.1.1 Achieve Final Design Approval (FDA) of one design in 2004, DC in 2005.
2. DC of additional near-term advanced designs	2.1 Assuming market interest in additional near-term advanced designs, obtain NRC technical review and approval of second DC application in less than three years.	2.1.1 Obtain an industry commitment and initiate a cost-shared effort to achieve DC for one or more designs in 2004. 2.1.2 Assuming adequate market interest, achieve FDA for one additional design by 2007.
3. First-of-a-kind engineering (FOAKE) completion for advanced designs, including procurement specifications	3.1 Complete FOAKE for near-term designs one year after DC.	3.1.1 Achieve completion of sufficient FOAKE to prepare a cost estimate adequate for a new plant order decision for a specific design in 2005. Complete all FOAKE for that design by 2006. 3.1.2 Assuming adequate market interest, achieve completion of FOAKE for a second design in 2008.
	3.2 Apply risk-informed "special treatment" requirements to procurement specifications.	3.2.1 Achieve a plant cost estimate sufficiently competitive to obtain an industry decision for a new plant order by 2006. 3.2.2 Achieve a construction schedule estimate of 36 months from first concrete to fuel load.

Objective 1-3 Highlights:
Improving Technologies to Accelerate the Timeframe of Plant Construction

Focus Areas	Expected Outcomes	Milestones
1. Technologies that can reduce capital cost and construction times for new plants	1.1 Apply new technologies to nuclear plant construction/management that: • enable computer-aided detailed design review of entire construction sequence prior to construction start (e.g., four-dimensional modeling) • facilitate advances in manufacturing and construction technology (e.g., modular and virtual reality construction techniques) • utilize advanced electronic information management technologies (e.g., integrated data architectures)	1.1.1 Complete an assessment of advanced technologies and methodologies and their ability to support aggressive new plant construction schedule of 36 months from first concrete to fuel load by 2004. 1.1.2 Achieve a plant cost estimate sufficiently competitive to obtain an industry decision for a new plant order by 2006.

Objective 1-4 Highlights:
Enhancing the Business Environment and Critical Infrastructure for New Plants

Focus Areas	Expected Outcomes	Milestones
1. Projected shortfalls in nuclear infrastructure needed to support a major expansion of nuclear energy	1.1 Assess the adequacy of the fabrication/manufacturing infrastructure to support near-term deployment, including major components such as reactor vessels and steam generators, as well as smaller components such as pumps and valves.	1.1.1 Identify sources for all major nuclear plant systems and components by 2005.
	1.2 Assess the adequacy of the current nuclear training pipeline and the skilled construction trade sector to support near-term deployment.	1.2.1 Complete the study by 2005 and implement study recommendations to attain adequate industrial and personnel resources to support the expansion of nuclear energy in the 2010 timeframe.
2. Life cycle costs and environmental benefits of nuclear energy in relation to alternatives	2.1 Complete studies on the life cycle costs and environmental benefits of nuclear energy (e.g., improved air quality).	2.1.1 Promote the results of these studies by 2004 to achieve convergence among energy experts on the costs and benefits of nuclear energy by 2006.

Objective 2-1 Highlights:
Developing/Applying Advanced Technologies for Increased Power Output

Focus Areas	Expected Outcomes	Milestones
1. Technologies supporting substantial power uprates beyond those currently planned, such as physical plant enhancements to accommodate higher power levels: • balance of plant upgrades (e.g., feedwater, turbine, generator, condenser) • advanced fuel designs • analysis tools to support uprate decisions	1.1 Using a systems approach develop and demonstrate substantive new innovative technologies for increased power output that go beyond currently planned uprates.	1.1.1 Achieve a minimum of 5,000 megawatts of additional electrical generation capacity by 2015 (in addition to the 10,000 MWe identified in *Vision 2020*).
2. Improved equipment reliability technologies to maximize the benefit of advanced power uprates including: • on-line inspection, monitoring, diagnostic, prognostic, and maintenance technologies • new I&C technology applications and related enhancements in plant information management • equipment reliability • analysis tools and their ability to support capacity factor strategy decisions (safety, reliability)	2.1 Achieve improvements in World Association of Nuclear Operators (WANO) performance indicators (PIs): • unit capability* • unplanned capability loss • unplanned automatic scrams.	2.1.1 Increase average unit capability factor from 91 percent today to 94 percent by 2015. 2.1.2 Minimize unplanned nuclear plant closures due to technical issues through 2015 with a goal of zero.

*Includes capacity factor, outage duration, and other factors.

Objective 2-2 Highlights:
Developing Technologies for Long-Term Operation

Focus Areas	Expected Outcomes	Milestones
1. R&D in the following areas: • materials aging phenomena and degradation • asset management and equipment reliability • equipment and I&C modernization issue resolution • low level waste (LLW) minimization and nuclide removal	1.1 Reduce plant annual O&M costs and average annual capital expenditures and achieve overall stability and predictability of plant financial performance. In addition, minimize cost, time, and radiation exposure trends associated with major plant modifications, replace-ments, and in-service inspection.	1.1.1 Minimize unplanned nuclear plant closures due to technical issues through 2015 with a goal of zero.

Objective 2-3 Highlights:
Developing Technologies to Cost-Effectively Advance Nuclear Plant Security

Focus Areas	Expected Outcomes	Milestones
1. Security-related technologies that incorporate opportunities to: • deter intrusion from both internal and external threats • detect intrusion (early) • delay adversaries • neutralize adversaries • limit/mitigate consequences and enhance systems recovery	1.1 Address current regulatory requirements and industry standards for security by exploiting the advantages of technology to reduce manpower intensity/cost and to add adaptability to existing security systems.	1.1.1 Develop and obtain industry consensus for the Security Technologies Roadmap implementation strategy by 2004. 1.1.2 Obtain NRC concurrence to the Security Technologies Roadmap implementation strategy by 2004.
2. New technologies to reassess and optimize plant security and the resources needed to ensure it	2.1 Reduce the costs and manpower intensity of nuclear plant security, while advancing the level of security to meet potential emerging threats.	2.1.1 Develop and demonstrate a vulnerability assessment (VA) methodology for U.S. nuclear plants to determine optimum future security posture by 2005. 2.1.2 Develop and demonstrate the technology needed to improve the adaptability of existing security systems by 2007. 2.1.3 Complete a reassessment of security vulnerabilities following a demonstration of advanced security technologies by 2008.

Objective 2-4 Highlights:
Implementing Technologies for High Burnup Fuel

Focus Areas	Expected Outcomes	Milestones
1. Current fuel performance issues in support of plant reliability, capacity factor, and power uprate goals	1.1 Existing plant nuclear fuel performance improvements.	1.1.1 Maintain number of defective fuel assemblies per GW(e) to less than 0.1 per year.
2. Advanced fuel designs, irradiation testing, and regulatory/licensing criteria appropriate for high burn-up fuel (e.g., in-reactor accident analysis issue and on-site storage of used fuel at this higher burnup)	2.1 Resolve current licensing issues impacting high burn-up fuel (LOCA, RIA) and ensure a clear path exists for licensing of increases to beyond the current burn-up limits of 62 GWd/mtU.	2.1.1 Achieve a NRC license for on-site storage of this fuel and qualified transportation canisters by 2010. 2.1.2 Develop advanced fuels capable of burnups at 80 GWd/mtU or higher by 2010. 2.1.3 Establish regulatory analysis/licensing/testing requirements to refine the target and obtain NRC approval for an 80+ GWd/mtU core reload by 2015.
3. Optimal enrichment percentage and other fuel utilization parameters	3.1 Achieve a balance between fuel cycle economics and outage cycle parameters and complete an acceptable business case for high burn-up fuel, including the feasibility of utilizing enrichments >5 percent.	3.1.1 Achieve economically competitive fuel designs with a peak burnup rate of 80 GWd/mtU or higher by 2015 with >5 percent enrichment.

Appendix B: List of Abbreviations

ALWR	Advanced Light Water Reactor
BOP	Balance of Plant
CFR	Code of Federal Regulations
COL	Combined Construction and Operating License
DC	Design Certification
DOE	Department of Energy
EIA	Energy Information Agency
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
ESP	Early Site Permit
FDA	Final Design Approval
FOAKE	First-of-a-Kind Engineering
HTGR	High Temperature Gas Reactor
I&C	Instrumentation and Control
INPO	Institute of Nuclear Power Operations
ITAAC	Inspections, Tests, Analyses, and Acceptance Criteria
R&D	Research and Development
NDE	Nondestructive Examination
NE	Office of Nuclear Energy, Science and Technology
NE-30	Office of Nuclear Power Systems
NEI	Nuclear Energy Institute
NEMS	National Energy Modeling System
NEP	*National Energy Policy*
NEPO	Nuclear Energy Plant Optimization
NERAC	Nuclear Energy Research Advisory Committee
NERI	Nuclear Energy Research Initiative
NP 2010	Nuclear Power 2010 Program
NPC	EPRI Nuclear Power Council
NRC	Nuclear Regulatory Commission
NSIAC	NEI Nuclear Strategic Issues Advisory Committee
NTD	Near Term Deployment
MOA	Memorandum of Agreement
MW	Megawatts
LLW	Low Level Waste
LOCA	Loss of Coolant Accident
RIA	Reactivity Insertion Accident
SER	Safety Evaluation Reports
O&M	Operating and Maintenance
PI	Performance Indicators
VA	Vulnerability Assessment
WANO	World Association of Nuclear Operators