3.3.5 Facility Requirements

A reconfigurable control room and control systems simulation laboratory is planned at INL's Center for Advanced Energy Studies building. This laboratory exists in a scaled version of the facility needed to support R&D of several activities of this R&D pathway. This laboratory will provide the capability to integrate advanced control technologies (e.g., automated procedures, advanced display technologies, and new forms of automation) into a control room and control system environment and will include the capability to conduct human-in-the-loop research. It will have large display and observation areas with quickly reconfigurable physical layouts. The laboratory will coexist with a computer-assisted, virtual environment, high-performance, visualization studio to support rapid prototype, human-in-the-loop, and immersive visualization environments. This laboratory will provide the ability to develop a technical basis for digital technology introduction in an integrated fashion and will address human interaction with emergent instrumentation and control technologies. The main functions and capabilities for this laboratory include (1) process modeling and demonstrations of new technologies, (2) evaluation of digital technology such as system prototyping for new kinds of automation to improve power production efficiencies, (3) usability testing and human-in-the-loop evaluation of operator performance that will be needed as part of future licensing, and (4) advanced visualization and data fusion with process data to support onsite and centralized offsite use and collaborations among experts.

3.3.6 Products and Implementation Schedule

The main products of the Advanced II&C Systems Technologies R&D pathway are as follows:

- Technologies for and demonstrations of highly integrated control and display technologies that address long-term objectives of nuclear power plant operation, including the following:
    - Fleetwide management of asset information to support integrated operations
    - Improved visualization and use of information to support decision-making and actions
    - Greater automation of functions and availability of operator support systems to improve efficiencies and reduce errors
- Online monitoring of active and passive components to reduce demands for unnecessary surveillance, testing, and inspection; minimize forced outages; and provide monitoring of physical performance of critical SSCs
- Nondestructive examination technologies for characterizing performance of physical systems in order to monitor and manage the effects of aging on SSCs.

The program activities occur in three phases (see Figure 3-6). Phase I (FY 2010 to FY 2015) R&D activities are intended to create technologies with new functional capabilities. The objectives of this phase are to create and demonstrate new capabilities to achieve the objectives and vision of long-term asset operation. Phase II (FY 2015 to FY 2020) R&D activities will create more mature technologies that are capable of some field deployments, pilot projects with asset owners, and consortia. During Phase III (FY 2020 to FY 2030), the technology maturity and success with initial deployments will lead to and motivate a shift in the technology base for II&C systems used during long-term operation. Fleetwide deployments and standardization of technology will be ongoing and more R&D activities will lead to greater regulatory engagement and acceptance.

Projects	Phase I: Building Confidence in Life Extension with Data and Tools	Phase II: Enable Industry Decision to Invest and License, for Life Extension	Phase III: Applications of Scientific Solutions to Address Issues in Life Extension Decision Making and Continuing Technology Development
Centralized Online Monitoring	• Algorithm development • Scale studies • Field studies • Industry participation	• Technology maturity • Fleet-wide tests • Industry leadership • Industry standards • License amendments	• Technology standardization • Industry-wide implementation • Regulatory acceptance
New I&C and HSI	• Advanced visualization technology development • System integration concept development • New automation	"First movers" • Individual plant deployment • Industry demonstration	"Modernized Industry" • Fleet-wide deployments • Industry deployment • Standardization
NDE Technologies	• SSC characterization needs defined • Characterization methods and technologies developing	• SSC characterization demonstrated • Characterization methods refinement • License applications using NDE methods	• SSC characterization needs being met • Characterization methods & technologies standard • Industry-wirde and international trending
	2010 – 2015	2015 – 2020	2020 – 2025 – 2030

11-GA50008-01-6

Figure 3-6. Advanced Instrumentation, Information, and Control Systems Technologies pathway implementation schedule.

3.4 Risk-Informed Safety Margin Characterization

3.4.1 Background and Introduction

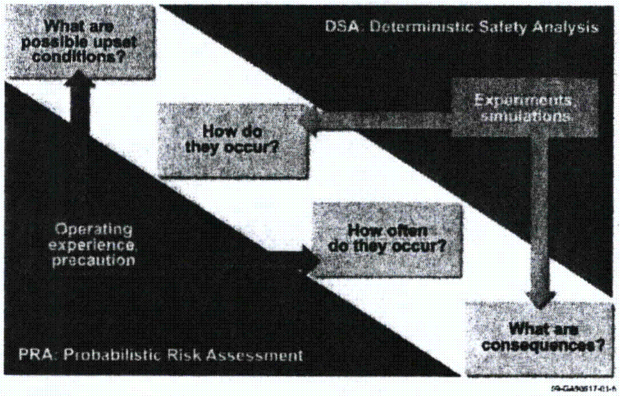

Figure 3-7. Nuclear plant safety analysis.

The Risk-Informed Safety Margin Characterization (RISMC) R&D pathway focuses on advancing the state-of-the-art in safety analysis and risk assessment to support decision making on nuclear power plant life extension beyond 60 years. A comprehensive approach involves four questions that need to be addressed and resolved from the risk and safety perspectives (Figure 3-7). With the plant life extension well beyond the originally licensed operating period, the safety questions take on additional significance due to plant aging (namely how plant aging affects the answer to the four questions). In particular, aging of SSCs has potential to increase frequency of initiating events of certain safety transients; create new sequences associated with previously-not-considered SSC failures; and increase severity of safety transients due to cascading failures of SSCs.

In parallel with a deterministic safety analysis approach, probabilistic risk analysis (PRA) methods have been developed and applied to analyze the safety of nuclear power plants. Notably, safety margins calculated by the deterministic safety analysis methods (e.g., accident simulation codes and structural capacity codes) are used to support the specification of "success criteria" in the plant's PRA. Pioneered by the "Reactor Safety Study" (WASH-1400 1975), the PRA technology has matured and currently provides the nuclear power industry and the regulator with powerful tools to analyze plant safety, identify system vulnerabilities, provide a framework for effective resource allocation, and focus research and plant operations on risk-significant safety threats.

3.4.2 Vision and Goals

Safety is central to design, licensing, operation, and economy of nuclear power plants. As the current LWR nuclear power plants age beyond 60 years, there are possibilities for increasing the frequency of equipment failures that initiate safety-significant events and for creating new failure modes. Accurate characterization of plant safety margins can play an important role in facilitating decision-making related to LWRs. In addition, as R&D in the LWRS Program and other collaborative efforts obtain new data and improve scientific understanding of physical processes that govern materials aging and degradation and develop technological advances in nuclear reactor fuels and plant II&C, there are needs and opportunities to manage plant safety, performance, and assets in an optimal way.

For several reasons, this R&D pathway is built around the idea of analyzing margin. First, as noted above, margin has long played a significant role in consideration of safety. Second, in order to support practical decision-making in so complex an arena, it is imperative to provide the decision-maker with a compact presentation of the safety case, the present vision being to do that in terms of key safety margins. This will be discussed further in Section 3.4.3.1. Finally, explicit analysis of margin drives the evaluation down to the engineering physics in a way that is more useful than just quantifying probabilities as done in a typical PRA.

The strategic objectives of the RISMC R&D pathway are to bring together risk-informed, performance-based methodologies with scientific understanding of critical phenomenological conditions and deterministic predictions of nuclear power plant performance, leading to an integrated characterization of public safety margins in an optimization of nuclear safety, plant performance, and long-term asset management. The RISMC R&D pathway aims to develop an integrated framework and advanced tools for safety assessment that enable more accurate characterization and visualization of the plant's safety margins.

These objectives are currently focused on plant decision-making, which includes NRC-related decision-making as a special case. NRC requirements protect the public, but do not necessarily protect the plant investment. In principle, therefore, the scope of the "risk-informed" margin evaluation includes a broader class of issues and SSCs than has been included in design-basis accident analysis or potentially even in PRA space. For example, events that do not pose a significant threat to public safety may pose a significant threat to plant economics by forcing a prolonged shutdown or perhaps a major component replacement. PRA does not typically analyze for those outcomes.

3.4.3 Highlights of Research and Development

The RISMC R&D pathway is driven by recognition that risk-informed plant safety margins present an avenue for enhancing operational flexibility and safety benefits obtained from the transition toward risk-informed and performance-based regulation. Tools used today in deterministic and probabilistic safety analysis are not adequate to cost-effectively manage the risk and operability significance of aging of SSCs. Therefore, there are conceptual and technical "capability gaps" (in frameworks, tools, and data) that need to be filled to enable integrated and defensible decision-making regarding the continued operation of nuclear power plants after their current license terms.

Once matured and established, RISMC developments will benefit the LWRS Program objectives by (1) creating a strong technical basis for an enhanced risk-informed regulatory structure that enables optimization of plant operation, inspection, maintenance, and replacement of plant SSCs, (2) enabling effective long-term management of plant resources (for which accurate characterization and prediction of safety margins are prerequisite), and (3) helping guide R&D planning toward maximum payoff from both resource utilization and risk perspectives.

RISMC technical work is organized into three major areas (illustrated in Figure 3-8 and discussed in following subsections).

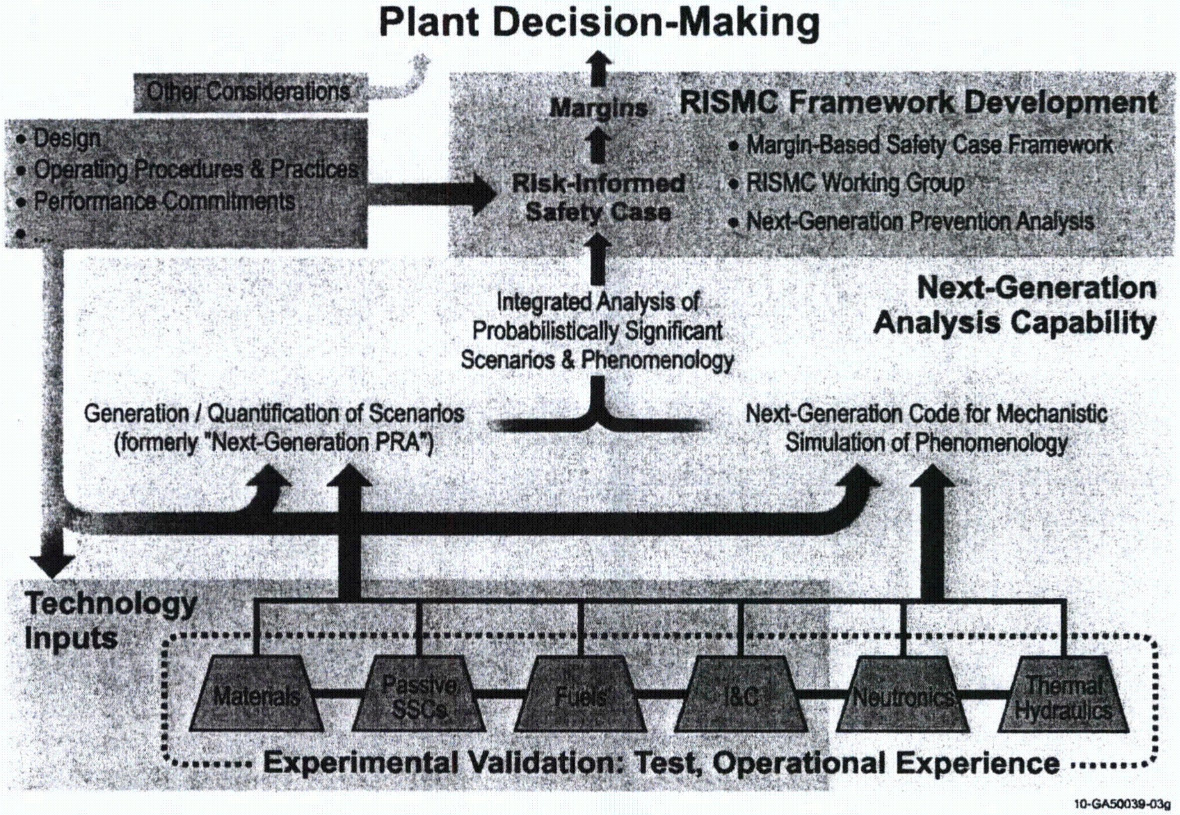

Figure 3-8. Work in Risk-Informed Safety Margin Characterization.

3.4.3.1 Risk-Informed Safety Margin Characterization Framework Development. The purpose of the framework portion of RISMC is to develop a risk-informed life extension safety case and summarize this case to the plant decision-maker in terms of a set of key margins. While definitions may vary in detail, "safety case" means essentially the following:

> *A structured argument, supported by a body of evidence that provides a compelling, comprehensible and valid case that a system is adequately safe for a given application in a given environment.*

For RISMC purposes, life extension safety case means the following:

> *The body of evidence and reasoning that either convincingly justifies a decision to proceed with life extension, or caveats such a decision, by showing where important SSC margins are either insufficient or trending towards insufficiency.*

Neither of the above definitions is explicitly restricted to a particular type of safety or performance requirement. In nuclear facility licensing, the safety case addresses NRC requirements. For a plant decision-maker, the decision would be based on consideration of risk metrics, including metrics addressing risk to plant availability or major capital items. As argued elsewhere, the needs of the plant decision-maker are more demanding than those of NRC in many respects. NRC may deem plant operation allowable; the plant decision-maker needs to make sure that it is economically viable.

Two types of issues are currently deemed significant within RISMC:

1. Issues associated with the capabilities of major components (such as the reactor vessel) under long-term operating conditions

2. Issues associated with possible changes in plant configuration or operation to improve economics.

Both of these types of issues can be analyzed in terms of margin.

Optimal development of a safety case calls for selection of a set of SSCs and associated levels of performance margin as the backbone of that safety case. Prevention analysis is the name that has been given to one specific way of doing this. Prevention analysis works by driving a risk model backward. Most applications of risk models proceed by estimating SSC performance margin (or in practice, directly estimating failure probability) *a priori*, and using that information to synthesize plant risk estimates for comparison with objectives. This supports a trial-and-error approach to optimization of the level of performance credit taken for each item. In contrast to that approach, prevention analysis starts with a desired top-level safety objective and determines what level of SSC performance margin (or in most extant applications, what failure probability allocation) would need to be credited in the risk model in order to optimally satisfy that safety objective (in this case, optimality means crediting a complement of equipment and associated performance margins that is *necessary* and sufficient to do the job). The solution to this is not unique; correspondingly, prevention analysis presents the decision-maker with alternative strategies for satisfying top-level objectives. These strategies can be ranked with respect to difficulty and expense of implementation. In short, prevention analysis identifies a complement of nuclear power plant capabilities that, taken together, serve to prevent accidents to the degree specified by the top-level safety objective.

It is clear that any coherent approach to safety case development is essentially equivalent to a prevention analysis thought process, and some applications of prevention analysis have been based on margin considerations. Therefore, it is technically straightforward in principle to use prevention analysis within RISMC. However, adapting prevention analysis tools to develop the life extension safety case will break some new ground conceptually, and there is no extant application that couples prevention analysis tools to phenomenology simulations. How best to apply prevention analysis within RISMC will be explored beginning early in FY 2011.

3.4.3.2 Next-Generation Analysis Capability (Enabling Methods and Tools).

Characterization of nuclear power plant safety margins is difficult because of large uncertainties that exist in modeling and predicting behaviors of aging SSCs in a broad range of nuclear power plant operating and abnormal conditions and nuclear power plant system dynamics in accident scenarios involving SSC failure modes not studied before. Moreover, existing analysis methods are ill-suited to analyze reliability of the plant's passive SSCs and plant phenomenology in a coupled way, making them suboptimal for analyzing change in margin due to aging. The RISMC R&D pathway is addressing these issues through development of a next-generation analysis capability, which is referred to within the project as RELAP7 or in its shortened form R7.

3.4.3.2.1 Mechanistic Simulation of Phenomenology (Right-Center Portion of Figure 3-8)—Although incremental advances were made continuously over the past two decades to improve modeling of plant components and transient/accident phenomena, the system (plant) analysis tools used in industry's engineering applications remain based on decades-old modeling framework and computational methodology, which have not taken advantage of modern developments in computer/computational science and engineering. Fundamental limitations in the current generation of system analysis codes are well known to the community of safety analysis professionals. Although the codes have served as an adequate basis to address traditional safety margin analysis, significant enhancements will be necessary to support the challenges of extended and enhanced plant operations. This was the initial impetus for embarking on R7. It now emerges that the new methods being applied in R7 lend themselves naturally to addressing the broader issues raised within a risk-informed, decision-making paradigm, as discussed in the following subsections.

3.4.3.2.2 Generation/Quantification of Scenarios (Left-Center Portion of Figure 3-8)—Although state-of-practice PRA makes some high-level use of certain thermal hydraulic analyses, the usual coupling between thermal hydraulic and scenario-based risk modeling is nowhere near to being close enough to support evaluation of RISMC. Efforts to transcend the 1970s PRA paradigm have been made periodically; these efforts incorporate dynamical considerations that are all but suppressed in existing PRAs and try to couple directly to mechanistic codes like RELAP. Within RISMC, R7 is being implemented in a way that straightforwardly allows for simulation of PRA component failure modes within time histories as part of the assessment of margin. This complements ongoing work by EPRI under its Long-Term Operation program, developing a next-generation tool to improve on current standard PRA capability.

3.4.3.3 Technology Inputs. Figure 3-8 (green area in lower left portion) shows technology areas to be integrated into R7. Materials, fuels, and instrumentation and control represent new developments in the corresponding LWRS R&D pathways. Currently, RISMC is not actively integrating new developments from those pathways, but will be in the future.

The "Passive SSCs" area is not a pathway in itself, but is called out for special emphasis in the figure to promote focus on the issue of aging of passive components. Apart from specialized application areas (such as seismic PRA), most current PRA methodology takes most passive SSCs for granted because it is believed that failure of these components does not contribute significantly to offsite risk. Within the LWRS Program, it is important to challenge that presumption and to examine whether margin issues could emerge for SSCs whose performance is presently taken for granted.

As a result of work done in the last year, the current plan is to develop models of passive SSC behavior that are part of R7 and couple directly to plant physics parameters (e.g., temperature cycling, pressure cycling, and neutronics) simulated within R7.

3.4.4 Industry Engagement and Cost Sharing

Industry is very significantly engaged in RISMC activities, and the level of the engagement is increasing. Up to now, industry engagement in RISMC (primarily through EPRI) has taken place at two levels: (1) input into program planning, and (2) active participation in RISMC Working Group activities.

One effect of this influence has been strengthening of the RISMC team consensus that RISMC developments should be driven by "use cases" (i.e., explicitly planned eventual applications that are used to formulate requirements on development of the next-generation capability) and "case studies" (i.e., actual applications that scope particular developments and once completed, support assessment of the current phase of development). Use cases have already played a significant role in the formulation of requirements on the next-generation analysis capability. Beginning in the latter part of FY 2010, EPRI and other industry representatives (the Nuclear Energy Institute representatives and independent consultants) are becoming increasingly involved in detailed technical planning of the case studies that now drive development activities and are expected to support actual execution. This has two effects: (1) it helps to ensure that the program moves in a direction that addresses practical industry concerns, and (2) it provides the RISMC team with access to engineering expertise that is needed in the development of enabling methods and tools discussed in Section 3.4.3.2, especially the formulation of component models and in the case studies performed with those tools.

Coordination of RISMC activities includes the following:

- **EPRI:** As stated above, EPRI will continue to play an important role in high-level technical steering and in detailed planning of RISMC case studies. RISMC work is coordinated with EPRI Long-Term Operation Program work.

- **Other Industry Partners:** Involvement of engineering and analysis support from industry is presently foreseen in the performance of case studies to drive next-generation analysis development and in the formulation of component models for implementation in next-generation analysis capability. The level of analysis effort to be provided and the source of financing for that effort are being negotiated. The individuals prospectively involved are either industry consulting firms or currently-independent consultants who have working relationships with current licensees. All are experts in applying traditional safety analysis tools and are conversant with risk-informed analysis.

3.4.5 Facility Requirements

In science-based, risk-informed safety analysis, new types of data are needed to enable quantification of uncertainty in advanced methods and tools, particularly in multiscale and multiphysics simulation. Infrastructure is needed to support a network of separate-effect tests on nuclear thermal-hydraulics (e.g., facility to measure critical heat flux) and LWR integral test facilities. Large-scale integral test facilities provide the most credible data needed by regulators for safety code qualification. Many integral facilities that represent the existing Gen II plant designs were decommissioned. The facilities that do remain are focused on the passive designs of Gen III+ plants. Even when they existed, facilities like Semiscale and Loss of Fluid Test Facility had a narrow focus on loss-of-coolant accidents for supporting design-basis emergency core cooling system analysis. Within a risk-informed approach, there is a need to validate system safety analysis codes in a much broader space of scenarios and conditions. In particular, sequences identified as risk significant may include those with tight coupling between processes in the reactor cooling system and in the containment system, with multiphysics (e.g., neutronics, thermal hydraulics, coolant chemistry, and structural mechanics) and eventually human factors. This scope presents the need for new data to support R7 code development and validation. This need can be met by modernizing and extending the experimental infrastructure for reactor safety research, which already includes a network of integral test facilities (e.g., APEX and PUMA) and separate effect test facilities located in universities and other institutions across the country and internationally.

3.4.6 Products and Implementation Schedule

The main products of the RISMC R&D pathway are as follows:

- Next-Generation Safety Analysis Code (R7) – A system code that does the following:
  - Performs mechanistic description and effective simulation of plant transient behavior under a broad range of upset conditions and sequences of risk importance under life extension operation
  - Incorporates models of reactor component performance and reliability into the simulations and properly models coupling between the scenario physics (e.g., thermal hydraulics and neutronics) and these aspects of component behavior
- RISMC framework – A comprehensive methodology that applies R7 to support life extension decision-making by bringing together advanced modeling, simulation and analysis tools, and relevant data to characterize nuclear power plant safety margins, including the effect of plant aging
- Enabling methods and tools for advanced PRA and advanced prevention analysis to support life extension decision making.

The implementation schedule (Figure 3-9) is structured to support the following high-level milestones:

- 2010
  - Formulation of RISMC methodology
  - Development, selection, implementation, and testing of architectural features and solution techniques for a next-generation safety analysis code.
- 2011
  - Within the technical scope defined by first-round case studies, development of the next-generation safety analysis code (R7) to simulate plant dynamics and compute safety margin
  - Development of a risk-informed, simulation-driven methodology to apply the R7 in safety system analysis and uncertainty quantification
  - Development of models of passive SSCs for application within the next-generation safety analysis code, in order to directly simulate the coupling between plant physics and SSC reliability and performance.
- 2012
  - Completion of the development of the next generation safety analysis code, the associated framework, and associated models of component behavior to the technical scope of the first-round case studies

- Extend the capability from small-scale demonstration of algorithmic features to plant-scale evaluations of issues of current interest, focusing on the first-round case studies being coordinated with industry
- With industry, define more broadly scoped case studies to drive the next stage (second round) of RISMC development.

- 2015
  - Based to the extent practical on available test and operating data, complete second-round RISMC development (e.g., phenomena modeling, component behavior modeling, and operator performance modeling)
  - Complete second-round case studies, including application of next-generation safety analysis code, next-generation prevention analysis, and integration of component behavior/T/H behavior into the assessment
  - Train a broader set of outside users in application of the RISMC framework and next-generation safety analysis code
  - As of 2015, R7 should support plant decision-making for most safety issues.
- 2020
  - Ensure development and validation to the degree that the RISMC framework and tools are the generally accepted approach for risk-informed, plant decision-making and risk-informed, regulatory decision-making

Figure 3-9 shows the intended schedule of development, whose details necessarily depend on the actual funding profile. Note that the color coding in Figure 3-9 is keyed to Figure 3-8.

Development is planned to take place in phases, rather than trying to deliver a "complete" but completely untested package at the end of the process. It has been agreed with industry to focus in Phase I on modeling a particular pressurized water reactor functional sequence in order to specify a scope of phenomena, components, and code capabilities needed to address that sequence, yielding a product at the end of the first round of development that will have only a partial scope of applicability, but will be testable and verifiable within that scope. Depending on the funding profile, it is currently expected that this first round of development will be complete at the end of 2012. As the first round nears completion, a more challenging set of case studies will be chosen to drive the second round, and a process analogous to that of the first-round development will occur.

It is expected that development of the framework will be substantially complete in the first round, including illustrations of margin characterization and methods for driving R7 to assess margin within the scope of first-round case studies. Refinement of the framework would continue thereafter at a level of effort significantly reduced compared to the effort associated with R7 development.

In the first round, R7-compatible models of passive SSC components also will be developed. As other pathways develop models and results to be input to margins assessments, these will be addressed beginning in the first round and continuing more intensively in the second round. Application of test and operating data to R7 calibration and model testing will begin in the first round with data used to validate existing safety analysis codes. As newer data become available to address issues not covered by those old data, comparison with those data will support R7 refinement. However, note that collection of those data per se is not a RISMC milestone.

The lower portion of Figure 3-9 shows that, beginning in the second round of Phase I development, inputs from other R&D pathways will become available and will be incorporated into R7. This does not mean that R7 is currently proceeding without consideration of fuels issues, materials issues, or II&C issues, but only means that new results from those pathways will begin to inform R7 development on that timeframe.

Assuming a funding profile commensurate with that in the current program plan, R7 development is expected to be substantially complete in 2015 at the end of the second round. This does not mean that R7 would be frozen as of 2015, any more than previous-generation safety analysis codes have been frozen, but its development would be more evolutionary in nature.

Beginning in 2012 and continuing thereafter, increasing effort will be devoted to training a broader user community of practice and supporting their applications.

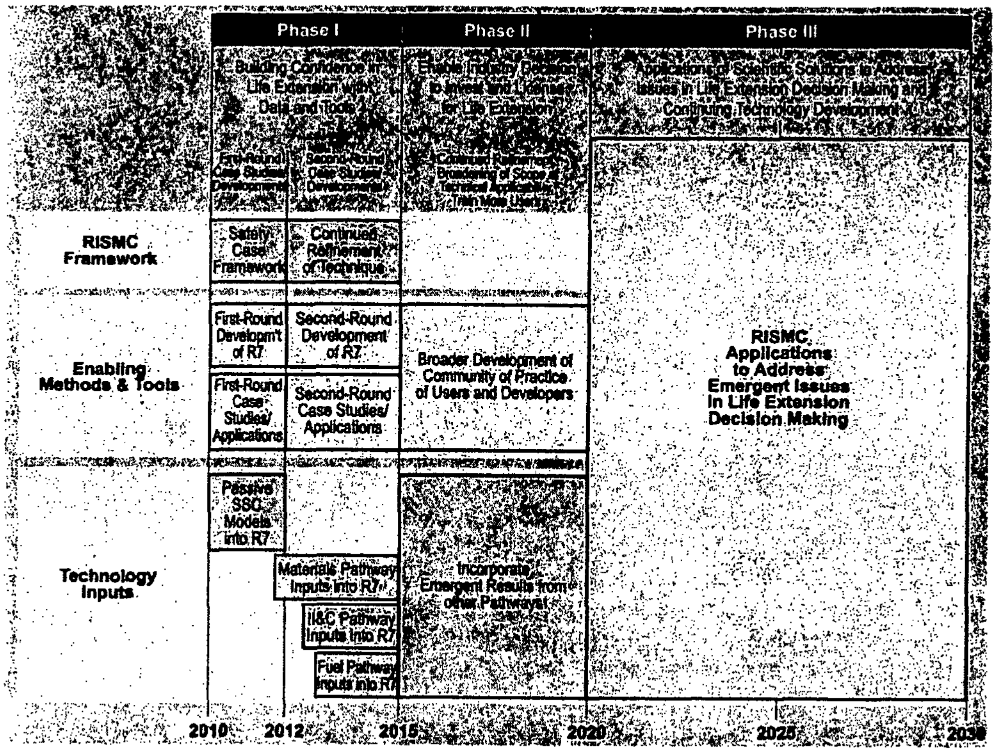

Figure 3-9. Risk-Informed Safety Margin Characterization pathway implementation schedule.

3.5 Economics and Efficiency Improvement

3.5.1 Background and Introduction

Improving the economics and efficiency of the current LWR fleet and maintaining excellent safety performance is a primary objective of the LWRS Program. Power uprates have been the most important methods that enable enhancement of the economic performance of the current operating fleet of LWRs. Cooling capability influences thermal efficiency and reliable operation. Increased reactor power and climate change concerns place more burdens on cooling requirements. Expanding the current fleet into nonelectric applications would further increase the value of LWR asset owners. This R&D pathway will focus on three activities: (1) alternative cooling technologies, (2) nonelectric applications (process heat), and (3) power uprates.

3.5.1.1 Alternative Cooling. Water consumed by thermoelectric power plants (such as those fueled by coal, natural gas, and nuclear) continues to receive increasing scrutiny as new power plants are proposed and existing power plants encounter water shortages. Climate change may exacerbate the situation through hotter weather and disrupted precipitation patterns that promote regional droughts. Before 1970, thermoelectric power plants addressed their need for cooling with either fresh or saline water withdrawals for once-through cooling. Since that time, closed-cycle systems (evaporative cooling towers or ponds) have become the dominant choice, with certain impacts on water usage. Figure 3-10 shows the Limerick nuclear power plant in Pennsylvania, which uses mine pool water for a substantial fraction of its cooling.

Figure 3-10. Limerick nuclear power plant.

3.5.1.2 Nonelectric Application (Process Heat). Nuclear power plants have very high capital investment and low operating costs. Therefore, to minimize the cost of electricity, these nuclear power plants are typically operated at full power to provide base load needs. With the potential extended power uprates for these nuclear power plants in the future and the eventual construction of new nuclear power plants in the United States, some of the nuclear power plants may need to be operated at reduced power levels when electricity demand is low at off-peak times, such as during the night. This is an operating strategy seen in France where power demand must affect reactor output because of the high percentage of nuclear power. Operating nuclear power plants at a reduced power level is not desirable for economic and safety reasons. On the other hand, only about one-fifth of the world's energy consumption is used for electricity generation. Most of the world's energy consumption is for heat and transportation. The existing LWR fleet in the United States has limited experience in nonelectric applications. However, the existing LWR fleet might have some potential to penetrate into the heat and transportation sectors, which are currently served by fossil fuels that are characterized by price volatility, finite supply, and, more importantly, environmental concerns. There are a wide variety of purely thermal applications of a reactor's output, which may be integrated with an electrical generating plant. These applications may be effective even at the conventional steam temperatures that exist in commercial nuclear power plants. These nonelectric applications of nuclear energy include providing heat and steam to industrial processes, seawater desalination, and district heating. The desalination of seawater using nuclear energy has been demonstrated, and nearly 200 reactor-years of operating experience have been accumulated worldwide. District heat involves the supply of heating and hot water through a distribution system, which is usually provided in a cogeneration mode in which waste heat from power production is used as the source of district heat. Several countries have district heating using heat from nuclear power plants.

3.5.1.3 Power Uprates. The nuclear industry has been making improvements in commercial nuclear power plants since the 1970s to increase their rated power output (power uprates). There are three types of power uprates defined by NRC: (1) measurement uncertainty recapture power uprates are less than 2% and are achieved by implementing enhanced techniques for calculating reactor power, (2) stretch power uprates are typically up to 7% and are within the design capacity of the plant, and (3) extended power uprates, which are greater than stretch power uprates and have been approved for increases as high as 20%. The primary methods of producing more power are improvements in the fuel design, operational restriction, reanalyzed reactor thermal-hydraulic parameters, more involved safety analysis, and upgrade of the balance of plant capacity by component replacement or modification (such as replacing a high-pressure turbine). Instrumentation upgrades that include replacing parts, changing set points, and modifying software also are required for operation at increased power levels. As of today, NRC has approved 129 power uprate submittals. The total extra power generated from power uprates is equivalent to building almost six 1,000-MWe new nuclear power plants. Uprating a nuclear power plant reduces the operating cost per unit energy generated and significantly enhances the asset value of the plant owner.

The industry has achieved such remarkable performance by using available fuel designs, materials, and engineering methods. To facilitate additional power uprates, especially extended power uprates, new materials, methods, and fuel designs are needed. It is LWRS Program's role to conduct R&D leading to the new materials, methods, and fuel designs to enable additional extended power uprates.

The changes in the physical nuclear power plant systems are theoretically able to sustain much higher power uprates. An additional cycle of extended power uprates greater than 20% is being considered. To increase a nuclear power plant's power to levels greater than 20% requires higher power density core designs and scientific understanding of plant performance issues. Power uprate causes higher radiation fluences, increased thermal-induced stress and fluid-induced vibrations, and corrosion. The plant owners must have the confidence that the power uprate will not cause accelerated damage to the nuclear power plant structure, system, and components. For instance, the integrity of steam dryers and steam generators must be ensured due to increased steam loads and the integrity of reactor pressure vessels and core internals due to increased radiation damage and corrosion. The plants also must demonstrate with confidence that mandated safety limits will not be violated during accident conditions to ensure the fuel integrity due to increased duty and containment integrity because of higher storage energy of the reactor coolant system. The LWRS Program focuses on developing enabling technologies, such as revolutionary fuel design, that offers superior safety and economic performance and modern design and safety analysis tools that can resolve extended power uprate inhibiting issues to significantly advance the potential for additional power uprates greater than 20%. Development of deep science-based knowledge also will be complemented by the DOE Energy Innovation Modeling and Simulation Hub, which is run by the CASL. The integration of results from CASL, plant changes, and operating conditions will be evaluated by the Economics and Efficiency Improvement R&D pathway to facilitate implementation of extended power uprates. An advanced study of these effects in an existing and aging plant is required. The ability to greatly uprate a nuclear power plant provides the national strategic benefits of increasing the total nuclear power supply at a lower cost per kW than building new nuclear plants. The previous success of power uprates makes this an attractive way to expand nuclear power supplies.

3.5.2 Vision and Goals

The commercial nuclear power industry will undertake additional power uprates beyond 20%. These uprates will require optimized cooling technology to minimize water usage to accommodate the uprated power output. The increased power available also can facilitate expansion of nonelectric applications within the framework of plant life extension to optimize the contribution of nuclear power to the national strategic benefits of low emissions energy production.

The programmatic goals for this R&D pathway are captured in the following statements:

1. Alternative Cooling Technology: Conceive, develop, and establish deployable technologies for optimizing use in the nuclear energy thermocycle, while minimizing reliance on water resources at the same time.

2. Nonelectric Application (Process Heat): Develop the energy conversion and heat transport technologies needed for applications of existing LWRs to low temperature process heat.

3. Power Uprates: Provide scientific and engineering solutions to facilitate extended power uprates for all operating LWRs in a cost-effective manner.

3.5.3 Highlights of Research and Development

3.5.3.1 Alternative Cooling. Alternatives to closed-cycle cooling (e.g., wet cooling tower) are generally dry cooling (e.g., waste heat rejected to the atmosphere) or hybrid cooling (e.g., using aspects of both wet and dry cooling), as well as replacing freshwater supplies with degraded water sources. Degraded water is polluted water that does not meet water-quality standards for various uses such as drinking, fishing, or recreation. Existing operating LWRs in the United States use either once-through cooling or wet cooling towers, with a few using degraded water.

It is essential to provide adequate and timely cooling for safe and economic operation of nuclear power plants. With more stringent regulation on the temperature of the discharged cooling water from a nuclear power plant, the potentially decreased availability of clean cooling water, increased cooling load with the power uprates, and potentially warmer weather in the summer season due to global climate change, alternative and potentially advanced cooling technology has to be developed in order to ensure the reactors can be safely and economically operated without being forced to shut down or reduce the power output due to cooling water issues. R&D activities will focus on the following: (1) technology development (such as advanced condenser design, reducing water losses in the wet cooling tower system, or improving dry cooling and hybrid cooling technology); (2) evaluating applicability of alternative water-conserving cooling technologies (such as dry cooling and hybrid cooling) to improve LWR plant efficiency, relieve the cooling water requirement, and expand use of alternative sources of water; and (3) improving analysis methodology, performing analysis to identify optimal designs, and developing water resource assessment and management decision support tools.

3.5.3.2 Nonelectric Application (Process Heat). Nuclear power plants produce 1,500 to 4,500 MW of steam. Very few markets exist for such large quantities of steam. Usually, it is not economical to modify a nuclear power plant to produce a few megawatts of heat to meet a local industry or district-heating need; therefore, district heating will not be considered. Seawater desalination using multi-stage distillation and existing LWRs also is a very remote possibility. Desalination using reverse osmosis, where most of the energy input is electricity, may be a viable, off-peak use of LWRs for economical fresh water production. Using nuclear energy indirectly for transportation by creating fuel ethanol has the potential to open new markets for existing LWRs. Cellulosic biomass-to-fuel ethanol plants require very large quantities of low-temperature steam that could be provided by LWRs if these plants were located close to the reactors.

Heat from nuclear power plants also can be used to provide process heat to a Fischer-Tropsch chemical process (or similar processes) to produce synthetic fuel. Coal gasification has the advantage of reduction of air emissions from coal combustion, an increased thermal efficiency of combustion, and use of a large resource base. Nuclear energy, being an industrially proven and nonpolluting technology, is a valid candidate for this purpose.

Technical and economic viability of different applications will be studied. One key issue to be addressed is interface design and plant modifications.

3.5.3.3 Power Uprates. R&D activities will be focused on enabling safe and cost-effective plant modifications and modernizations required to gain margins by enhancing the plant power limiting equipment capability. Consistent with the main themes currently identified in this R&D pathway, activities are planned in the following main areas to significantly uprate the current LWR power levels: (1) collaboration with Nuclear Materials Aging and Degradation R&D pathway on higher fluence effect, (2) innovative fuel design, fuel performance, and loading management, (3) high fidelity core physics and fuel depletion capability, (4) reactor thermal hydraulics, (5) safety assessment under high power, (6) balance of plant, including steam generators for pressurized water reactors, (7) operation with higher core outlet temperature, (8) instrumentation and control systems and software reliability and (9) integrated detailed physics from the DOE Energy Innovation Modeling and Simulation Hub.

3.5.4 Facility Requirements

No additional facilities are foreseen for alternative cooling technologies. Power uprates will leverage the facilities used in other R&D pathways.

3.5.5 Products and Implementation Schedule

The main products of this R&D pathway are as follows:

- Advanced cooling technologies that would reduce cooling water requirements and improve the plant's thermal efficiency
- Tools, methods, and technologies (collaborating with other pathways) to enable additional extended power uprates; these include innovative fuel designs (such as annular fuel design) to enable higher power density, improved reactor safety analysis tools, increased heat removal capabilities for containment, and economic analysis to guide power uprate decision-making
- Feasibility studies of the technical and economic viability of expanding the existing fleet into nonelectric applications.

The implementation schedule (Figure 3-11) is structured to support the following high-level milestones:

- 2015:
  - Preserve the once-through cooling technologies (advanced water conservation technologies for wet cooling tower)
  - Complete feasibility studies for process heat production and low-temperature distillation applications.
- 2020:
  - Ensure significant cost reduction of dry cooling technology and thermal efficiency improvement in the hot summer timeframe
  - Ensure next generation safety analysis tools available to support additional extended power uprates.
- 2025: Apply alternative and new cooling technologies.
- 2030: Enable 10-GWe extra capacity additions through additional extended power uprates.

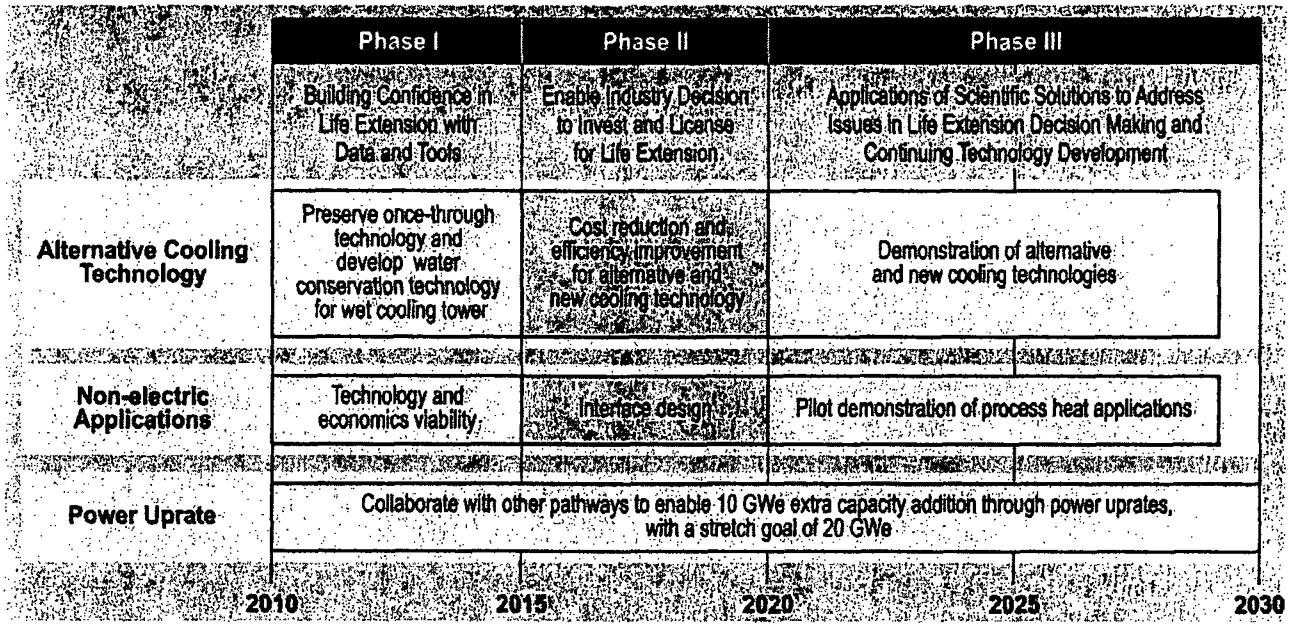

Figure 3-11. Economics and Efficiency Improvement pathway implementation schedule.

3.6 Pathway Crosscutting and Integration

The overall focus of the R&D activities will be on practically advancing the ability of the owner of nuclear assets to manage the effects of the aging of passive components and increase the efficiency and economics of operations. This will provide the necessary technology and ability to keep valuable nuclear power plant assets online and generating the required clean and safe energy. Transformational activities initially should be developed as limited-scope pilots that provide confidence in the program direction and developed technology. In selecting projects, it is vital that all consideration should be given to how each of the pathways can support achievement of safety and efficiency for existing LWRs by ensuring that each pathway is appropriately coordinated with the desired outcomes of the other pathways. Technical integration is an important and significant part of the LWRS Program. R&D within the program is integrated across scientific and technical disciplines in the five R&D pathways. The LWRS Program is integrated with outside sources of information and parallel R&D programs in industry, universities, and other laboratories, both domestic and international. Different methods of integration are used depending on the situation and goals.

3.6.1 Technical Integration

Interfaces between R&D pathways and the required integration across them are naturally defined by common objectives for materials and fuel performance and the system monitoring of their performance. Similarly, interface and integration of the pathways with the RISMC R&D pathway is defined by data

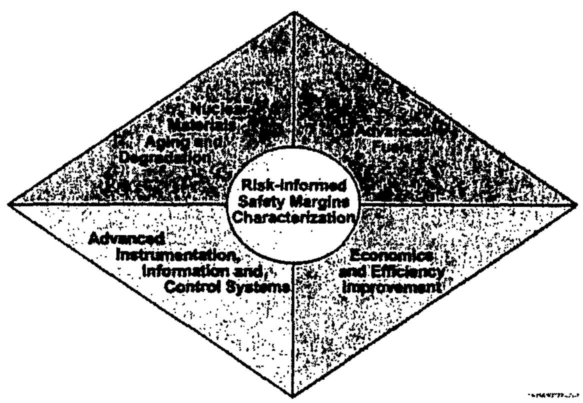

Figure 3-12. Integration of five research and development pathways.

and models, which affect performance, monitoring, and control (Figure 3-12).

Data and information from the Nuclear Materials Aging and Degradation, Advanced LWR Nuclear Fuel, and Economics and Efficiency Improvement R&D pathways will be fed into the RISMC models. Results of the RISMC analysis will guide development of advanced fuels; materials aging and degradation mitigation; advanced II&C systems; and economics and efficiency improvement. Examples of some crosscutting areas in the LWRS Program include coolant chemistry effects, crack growth mitigation effects, irradiation testing, irradiation source term changes, improved online monitoring of reactor chemistry, advanced instrumentation for the study of system degradation, fuel failure mechanisms, creation of SSC aging database, advanced measurement techniques, field testing and data collection/capture, nondestructive evaluation/assay tools, and advanced inspection techniques.

3.6.2 Advanced Modeling and Simulation Tools

The most common theme for the R&D pathways is use of computer modeling of physical processes or development of a larger system computer model. Extensive use of computer modeling by the R&D pathways is intended to distill the derived information so that it can be used for further research in other pathways and as the basis for decision-making. A cross-cutting implementation plan is being developed to address the interfaces for each of the pathways.

Computer modeling occurs in three forms with many overlapping aspects within the LWRS Program. Modeling a physical behavior (such as crack initiation in steel) is an example of direct computer modeling. The resulting model is used to store information for use in other pathways and to use in its own right for further research.

A second computer modeling activity is development of more detailed computer modeling tools capable of encoding more complex behaviors. One of the intended outcomes from Advanced LWR Nuclear Fuels Development research is new modeling tools that can describe behavior of such complexity that current computer models are incapable of producing. The increased accuracy will allow improved results to be incorporated into other pathways.

The final computer modeling improvement is creation of larger integrated databases that roll up results and allow decision-making. The large, system-wide, integrated models allow complex behavior to be understood in new ways and new conclusions to be drawn. These integrated databases can be used to further guide physical and modeling research, improving the entire program.

Because of their overlapping nature and numerous interfaces, these modeling activities tend to be naturally cross-cutting activities between R&D pathways. A separate cross-cutting implementation plan is being developed that will address the details of these interfaces and means of handling these overlaps for the LWRS Program and other DOE-NE programs.

3.6.2.1 Nuclear Energy Advanced Modeling and Simulation. A critical interaction of the LWRS Program is with the DOE Nuclear Energy Advanced Modeling and Simulation Program. The LWRS Program will take advantage of the detailed, multiscale, science-based modeling and simulation results developed by the DOE Nuclear Energy Advanced Modeling and Simulation Program that will be uniquely valuable to multiple R&D pathways. The modeling and simulation advances will be based on scientific methods, high dimensionality, and high resolution integrated systems. The simulations will use the most advanced computing programs available. These tools will be fully three-dimensional, high-resolution, modeling-integrated systems based on first-principle physics. To accomplish this, the modeling and simulation capabilities will have to be run on modern, highly parallel processing computer architectures. These advanced computational tools are needed to create a new set of modeling and simulation capabilities that will be used to better understand the safety performance of the aging reactor fleet. These capabilities will be information sources and tools for advancing the LWRS Program goals.

3.6.2.2 DOE Energy Innovation Modeling and Simulation Hub. The LWRS Program also will take advantage of the progress made by the DOE Energy Innovation Modeling and Simulation Hub managed by the Consortium for Advanced Simulation of Light Water Reactors (CASL). The Hub will support the LWRS Program by addressing long-term operational challenges faced by U.S. nuclear utilities. The alignment between the Hub and the LWRS Program's technical activities is by providing detailed calculations and large integrated models that address each of the technical needs of the LWRS Program R&D pathways.

A primary initial product of the Hub is a sophisticated integrated model of a LWR (a virtual reactor). The virtual reactor will be used to address issues for existing LWRs (e.g., life extensions and power uprates). The Hub challenge problems have been selected principally to demonstrate the capability of the virtual reactor to enable life extensions and power uprates. The enhanced computational capability of the virtual reactor will allow simulated proof of concepts for LWRS improvements and identify areas needing additional research.

With improvements in modeling and simulation capability centered on a science-based approach, the Hub will enable exploration of advanced fuel design features. These advanced features may range from modifications of the current compositions of the zirconium-based alloys now used for cladding to the development of entirely new cladding materials, new fuel materials with higher densities and improved thermal properties, and changes in fuel geometry and configuration. The virtual reactor capability will progress from analyses of operating reactors to design improvements. Improved modeling and simulation of the reactor internals and steam generators will support the needs of the Nuclear Materials Aging and Degradation and Economics and Efficiency Improvement R&D pathways. The virtual reactor performance will also provide modeling inputs for the Advanced Instrumentation, Information, and Control System Technologies R&D pathway.

3.6.3 Coordination with Other Research Efforts

In order to encourage communication and coordination with outside experts and parallel programs, the LWRS Program will be aware of issues and changes of technical needs that affect long-term, safe, and economical operation of existing operating LWRs, and share information and resources with other professionals and programs that can assist the LWRS Program to provide timelier, less expensive, and better solutions to the needs and issues.

Primarily, coordination will be with the EPRI Long-Term Operation Program. At the program level, formal interface documents will be used to coordinate planning and management of the work. This will provide a ready source of information from EPRI's Nuclear Power Council and through their contact with utilities. At the R&D project level, both programs encourage frequent communication and collaboration.

Consistent with the vision of the LWRS Program, working relationships have been established with international organizations in FY 2009 and will continue in FY 2010 and beyond. The goal is to facilitate communication and cooperative R&D with international R&D organizations.

R&D needs for existing LWRs are synergistic with those for the GEN III+ LWRs to be deployed and LWR small modular reactors being designed and licensed. Consequently, scientific solutions developed from Objective 1 are directly applicable to the technological challenges facing deployment and operation of GEN III+ LWRs and LWR small modular reactors as described in Objective 2.

3.6.4 Performance of Technical Integration and Coordination

The LWRS Program will lead and encourage technical integration and coordination of issues affecting the LWR Long-Term Operation Program using methods that best match the issue. For known gaps in data, understanding, or technology, the LWRS Program will plan and manage integrated R&D projects through the LWRS Program TIO and its multiple interfaces.

To accommodate currently unknown issues or gaps in technology that may arise as result of ongoing R&D or nuclear power plant operations, a broader approach is necessary. This approach should include active internal and external communication with professional organizations, industry groups, and interdisciplinary teams for project and program reviews. The steering committee is an essential part of this process. The LWRS Program encourages participation in professional technical societies and national standards committees.

4. PROGRAM MANAGEMENT

4.1 Organization Structure

The entire LWRS Program falls within DOE-NE. Program management and oversight, including programmatic direction, project execution controls, budgetary controls, and TIO performance oversight, are provided by the DOE Office of LWR Technologies in conjunction with the DOE Idaho Operations Office. The functional organization, reporting relationships, and roles and responsibilities for the TIO are explained in the following sections and are shown in Figure 4-1.

The DOE Office of LWR Deployment directs the program, establishes policy, and approves scope, budget, and schedule for the program through the LWRS Program Federal Program Director. The DOE LWRS Program Federal Program Director is assisted with program management and oversight by DOE Idaho Operations Office.

DOE Idaho Operations Office will provide technical and administrative support to the LWRS Program. This support includes activities such as assisting in development of administrative requirements in support of contracting actions, conducting merit reviews and evaluations of applications received in response to program solicitations, performing all contracting administration functions, and providing technical project management and monitoring of assigned projects.

The TIO basic organizational structure is used to accommodate the crosscutting nature of the proposed R&D pathways. This organization is responsible for developing and implementing integrated research projects consistent within the LWRS Program's vision and objectives. Additionally, the TIO is responsible for developing suitable industry and international collaborations appropriate to individual research projects and acknowledging industry stakeholder inputs to the program.

Within the TIO structure is the TIO director, deputy director, operations manager, each of the five R&D pathway leads, and an external steering committee. Nuclear industry interfaces and stakeholders' contributions are accommodated in program development and project implementation actions through the TIO management structure. Recognition of continuing industry collaborations, reflecting issues and concerns necessary to extend plant licenses, are incorporated through the same program development and implementation actions.

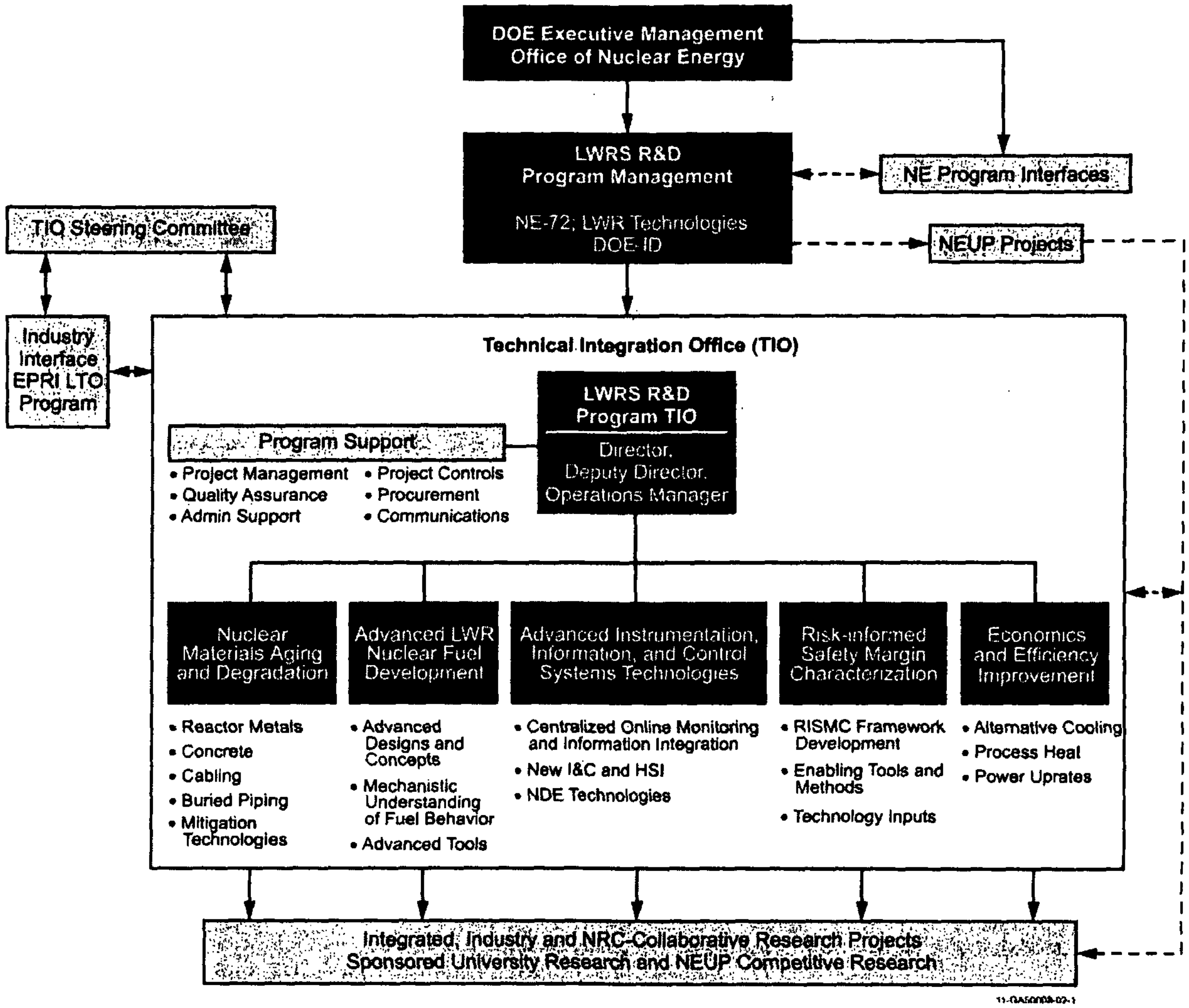

Figure 4-1. Light Water Reactor Sustainability Program organization.

4.2 Roles, Responsibilities, Accountabilities, and Authorities

4.2.1 Department of Energy Office of Nuclear Energy

DOE is responsible for the federal government's investments in nuclear power R&D and incentive programs, which all further the Nation's supply of clean, dependable nuclear-generated electricity. The LWRS Program conducts research that enables licensing and continued reliable, safe, long-term operation of current nuclear power plants beyond their initial license renewal period. The DOE Office of LWR Technologies directs the program, establishes policy, and approves scope, budget, and schedule for the program through the LWRS Program Federal Program Director. The LWRS Program Federal Program Director is assisted with program management and oversight by DOE Idaho Operations Office.

The essential programmatic DOE functions include, but are not limited to, the following:

- Establish program policy and issue program guidance assigned R&D mission. They are responsible for establishing scope, cost, and schedule of the R&D activities. They interface with other R&D pathway leads to ensure effectiveness of crosscutting activities.

4.2.2.3 Program Support Team. The program support staff is responsible for contractual operations of TIO and assists other parts of TIO to execute work. The team provides personnel with expertise in project management, quality assurance, procurement, project controls, and communications. They provide tools, structure, oversight, and rigor to maintain R&D schedules and interfaces with the LWRS Program. They also provide financial information to management (through the TIO director's office) and monitor technical progress and track milestones.

4.2.3 Project Monitoring and Evaluation

DOE and TIO use a variety of methods to provide oversight of their projects, including semiannual project reviews, periodic progress reports, and scheduled evaluations, invoice reviews, and participation in periodic project meetings and conference calls.

4.2.3.1 Project Reviews. DOE and TIO conduct semiannual and annual project progress review meetings with project participants, including all R&D pathway leaders. During these project review meetings, project activities, schedule progress, and cost are discussed in detail. Status of deliverables, funding, or schedule concerns and potential changes in scope also are discussed. Performance expectations for the remainder of the budget period and project are reviewed. On an annual basis, DOE staff reviews the work scope, budget requirements, schedule, deliverables, and milestones for the subsequent budget periods. This often requires face-to-face meetings with project participants to fully understand the future planned work.

4.2.3.2 Periodic Project Status Meetings and Conference Calls. DOE, TIO, and R&D pathway leaders participate in periodic project status meetings and conference calls. Typically, project conference calls are the method of choice because of the number and location of participants; they are held at least twice a month. In addition, DOE staff participates in TIO conference calls on specific tasks.

4.2.3.3 Monthly Progress Reporting. DOE personnel review and evaluate project monthly progress reports for the project task and activity progress, accomplishment of deliverables, and budget and cost status. This reporting provides project participants and DOE staff with a monthly snapshot of overall project cost and schedule performance against the project baseline.

4.3 Interfaces

The LWRS Program TIO is intended as a national organization and is expected to have multiple national laboratory, governmental, industrial, international, and university partnerships. As appropriate, the LWRS Program technology development and execution activities will use facilities and staff from national laboratories, universities, industrial alliance partners, consulting organizations, and research groups from cooperating foreign countries.

TIO is responsible for ensuring the necessary memorandum purchase orders, interagency work orders, or contracts are in place to document work requirements, concurrence with work schedules and deliverables, and transfer funds to the performing organizations for R&D activities.

4.3.1 Steering Committee

A TIO steering committee advises TIO on the content, priorities, and conduct of the steering committee. The committee is comprised of technical experts selected and agreed upon by the TIO director and the LWRS Program Federal Program Director. The committee, as a group, is knowledgeable of the various R&D needs of DOE, industry, and NRC; ongoing and planned research as related to nuclear power technology; and policies and practices in public and private sectors that are important for the collaborative R&D program. The TIO director, in consultation with the steering committee, may form ad hoc subcommittees to review specific technical issues.

4.3.2 Industry

Planning, execution, and implementation of the LWRS Program are done in coordination with U.S. industry and NRC to assure relevance and good management of the work. The LWRS Program addresses some of the most pressing R&D needs identified in the Strategic Plan for Light Water Reactor Research and Development, including R&D needed by currently operating LWRs to extend their safe economical lifetime to significantly contribute to the long-term energy security and environmental goals of the United States.

The LWRS Program works with industry on nuclear energy supply technology R&D needs of common interest. The interactions with industry are broad and include cooperation, coordination, and direct cost-sharing activities. The guiding concepts for working with industry are leveraging limited resources through cost-shared R&D with industry, direct work on issues related to the long-term operation of nuclear power plants, the need to develop state-of-the-art technology to ensure safe and efficient operation and the need to focus government-sponsored R&D on the higher-risk and longer-term projects incorporating scientific and qualitative solutions. These concepts are included in memorandums of understanding, nondisclosure agreements, and cooperative R&D agreements.

Cost-shared activities are planned and executed on a partnership basis and should include significant joint management and funding.

EPRI has established the Long-Term Operations Program to run in parallel with the DOE LWRS Program. The Long-Term Operations Program is based on the LWR R&D Strategic Plan and focuses on long-term operations of the current fleet. EPRI and industry's interests are applications of the scientific understanding and the tools to achieve safe, economical, long-term operation. Therefore, the government and private sector interests are similar and interdependent, leading to strong mutual support for technical collaboration and cost sharing. Formal interface agreements between EPRI and the TIO will be used to coordinate collaborations. Contracts with EPRI or other businesses may be used as appropriate for some work.

The LWRS Program has a steering committee with a diverse and experienced membership, including EPRI and utility members. The steering committee provides strategic guidance that helps ensure the program remains focused on useful industry results.

Each of the R&D pathways has interactions with the industry where detailed work packages are formed. DOE research is centered on general technology that advances and creates the knowledge base that will support individual applications for license renewals. The programmatic issue selection was created by the pathway definition that occurred with industry at the start of the LWRS Program. The technical pathway goals have been selected to drive the program toward solving problems that industry has been or will be unable to solve. The industry view does not look across the current commercial reactor fleet as generically or into the future as far as the DOE R&D. The ability of the LWRS Program to solve large, complex, and higher risk technical problems is a programmatic strength. The EPRI Long-Term Operation Program and LWRS Program cooperate to keep near-term research with EPRI and mid-term results aligned with LWRS objectives.

4.3.3 International

DOE is coordinating our LWRS Program activities with several international organizations with similar interests and R&D programs. We expect to continue to develop these contacts to provide timely awareness of emerging issues and their scientific solutions. A close working relationship with the Organization for Economic Cooperation and Development's Halden Reactor Project and with Electricite de France's Materials Aging Institute are particularly important to the LWRS Program. As funding is available, the LWRS Program intends to initiate formal R&D agreements with both institutions.

4.3.4 Universities

Universities will participate in the program in at least two ways: (1) through the Nuclear Energy University Program and (2) with direct contracts. In addition to contributing funds to the Nuclear Energy University Program, the LWRS Program will provide to the Nuclear Energy University Program descriptions of research from universities that would be helpful to the LWRS Program. In some cases, R&D contracts will be placed with key university researchers.

4.3.5 Nuclear Regulatory Commission

DOE's mission to develop the scientific basis to support both planned lifetime extension up to 60 years and lifetime extension beyond 60 years and to facilitate high-performance economic operations over the extended operating period for the existing LWR operating fleet in the United States is the central focus of the LWRS Program. Therefore, more and better coordination with industry and NRC is needed to ensure that there is a uniform approach, shared objectives, and efficient integration of collaborative work for LWRS. This coordination requires that articulated criteria for the work appropriate to each group be defined in memoranda of understanding that are executed among these groups. NRC has a memorandum of understanding[b] in place with DOE, which specifically allows for collaboration on research in these areas. Although the goals of NRC and DOE research programs differ in many aspects, fundamental data and technical information obtained through joint research activities are recognized as potentially of interest and useful to each agency under appropriate circumstances. Accordingly, to conserve resources and to avoid duplication of effort, it is in the best interest of both parties to cooperate and share data and technical information and, in some cases, the costs related to such research, whenever such cooperation and cost sharing may be done in a mutually beneficial fashion.

[b] "Memorandum of Understanding Between U.S. Nuclear Regulatory Commission and U.S. Department of Energy on Cooperative Nuclear Safety Research," dated April 22, 2009, and signed by Brian W. Sheron, Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission and Rebecca Smith-Kevern, Acting Deputy Assistant Secretary for Nuclear Power Deployment, Office of Nuclear Energy, U.S. Department of Energy.

For RISMC purposes, life extension safety case means the following:

> *The body of evidence and reasoning that either convincingly justifies a decision to proceed with life extension, or caveats such a decision, by showing where important SSC margins are either insufficient or trending towards insufficiency.*

Neither of the above definitions is explicitly restricted to a particular type of safety or performance requirement. In nuclear facility licensing, the safety case addresses NRC requirements. For a plant decision-maker, the decision would be based on consideration of risk metrics, including metrics addressing risk to plant availability or major capital items. As argued elsewhere, the needs of the plant decision-maker are more demanding than those of NRC in many respects. NRC may deem plant operation allowable; the plant decision-maker needs to make sure that it is economically viable.

Two types of issues are currently deemed significant within RISMC:

1. Issues associated with the capabilities of major components (such as the reactor vessel) under long-term operating conditions

2. Issues associated with possible changes in plant configuration or operation to improve economics.

Both of these types of issues can be analyzed in terms of margin.

Optimal development of a safety case calls for selection of a set of SSCs and associated levels of performance margin as the backbone of that safety case. Prevention analysis is the name that has been given to one specific way of doing this. Prevention analysis works by driving a risk model backward. Most applications of risk models proceed by estimating SSC performance margin (or in practice, directly estimating failure probability) *a priori*, and using that information to synthesize plant risk estimates for comparison with objectives. This supports a trial-and-error approach to optimization of the level of performance credit taken for each item. In contrast to that approach, prevention analysis starts with a desired top-level safety objective and determines what level of SSC performance margin (or in most extant applications, what failure probability allocation) would need to be credited in the risk model in order to optimally satisfy that safety objective (in this case, optimality means crediting a complement of equipment and associated performance margins that is *necessary* and sufficient to do the job). The solution to this is not unique; correspondingly, prevention analysis presents the decision-maker with alternative strategies for satisfying top-level objectives. These strategies can be ranked with respect to difficulty and expense of implementation. In short, prevention analysis identifies a complement of nuclear power plant capabilities that, taken together, serve to prevent accidents to the degree specified by the top-level safety objective.

It is clear that any coherent approach to safety case development is essentially equivalent to a prevention analysis thought process, and some applications of prevention analysis have been based on margin considerations. Therefore, it is technically straightforward in principle to use prevention analysis within RISMC. However, adapting prevention analysis tools to develop the life extension safety case will break some new ground conceptually, and there is no extant application that couples prevention analysis tools to phenomenology simulations. How best to apply prevention analysis within RISMC will be explored beginning early in FY 2011.

3.4.3.2 Next-Generation Analysis Capability (Enabling Methods and Tools).

Characterization of nuclear power plant safety margins is difficult because of large uncertainties that exist in modeling and predicting behaviors of aging SSCs in a broad range of nuclear power plant operating and abnormal conditions and nuclear power plant system dynamics in accident scenarios involving SSC failure modes not studied before. Moreover, existing analysis methods are ill-suited to analyze reliability of the plant's passive SSCs and plant phenomenology in a coupled way, making them suboptimal for analyzing change in margin due to aging. The RISMC R&D pathway is addressing these issues through development of a next-generation analysis capability, which is referred to within the project as RELAP7 or in its shortened form R7.

3.4.3.2.1 Mechanistic Simulation of Phenomenology (Right-Center Portion of Figure 3-8)—Although incremental advances were made continuously over the past two decades to improve modeling of plant components and transient/accident phenomena, the system (plant) analysis tools used in industry's engineering applications remain based on decades-old modeling framework and computational methodology, which have not taken advantage of modern developments in computer/computational science and engineering. Fundamental limitations in the current generation of system analysis codes are well known to the community of safety analysis professionals. Although the codes have served as an adequate basis to address traditional safety margin analysis, significant enhancements will be necessary to support the challenges of extended and enhanced plant operations. This was the initial impetus for embarking on R7. It now emerges that the new methods being applied in R7 lend themselves naturally to addressing the broader issues raised within a risk-informed, decision-making paradigm, as discussed in the following subsections.

3.4.3.2.2 Generation/Quantification of Scenarios (Left-Center Portion of Figure 3-8)—Although state-of-practice PRA makes some high-level use of certain thermal hydraulic analyses, the usual coupling between thermal hydraulic and scenario-based risk modeling is nowhere near to being close enough to support evaluation of RISMC. Efforts to transcend the 1970s PRA paradigm have been made periodically; these efforts incorporate dynamical considerations that are all but suppressed in existing PRAs and try to couple directly to mechanistic codes like RELAP. Within RISMC, R7 is being implemented in a way that straightforwardly allows for simulation of PRA component failure modes within time histories as part of the assessment of margin. This complements ongoing work by EPRI under its Long-Term Operation program, developing a next-generation tool to improve on current standard PRA capability.

3.4.3.3 Technology Inputs. Figure 3-8 (green area in lower left portion) shows technology areas to be integrated into R7. Materials, fuels, and instrumentation and control represent new developments in the corresponding LWRS R&D pathways. Currently, RISMC is not actively integrating new developments from those pathways, but will be in the future.

The "Passive SSCs" area is not a pathway in itself, but is called out for special emphasis in the figure to promote focus on the issue of aging of passive components. Apart from specialized application areas (such as seismic PRA), most current PRA methodology takes most passive SSCs for granted because it is believed that failure of these components does not contribute significantly to offsite risk. Within the LWRS Program, it is important to challenge that presumption and to examine whether margin issues could emerge for SSCs whose performance is presently taken for granted.

As a result of work done in the last year, the current plan is to develop models of passive SSC behavior that are part of R7 and couple directly to plant physics parameters (e.g., temperature cycling, pressure cycling, and neutronics) simulated within R7.

3.4.4 Industry Engagement and Cost Sharing

Industry is very significantly engaged in RISMC activities, and the level of the engagement is increasing. Up to now, industry engagement in RISMC (primarily through EPRI) has taken place at two levels: (1) input into program planning, and (2) active participation in RISMC Working Group activities.

One effect of this influence has been strengthening of the RISMC team consensus that RISMC developments should be driven by "use cases" (i.e., explicitly planned eventual applications that are used to formulate requirements on development of the next-generation capability) and "case studies" (i.e., actual applications that scope particular developments and once completed, support assessment of the current phase of development). Use cases have already played a significant role in the formulation of requirements on the next-generation analysis capability. Beginning in the latter part of FY 2010, EPRI and other industry representatives (the Nuclear Energy Institute representatives and independent consultants) are becoming increasingly involved in detailed technical planning of the case studies that now drive development activities and are expected to support actual execution. This has two effects: (1) it helps to ensure that the program moves in a direction that addresses practical industry concerns, and (2) it provides the RISMC team with access to engineering expertise that is needed in the development of enabling methods and tools discussed in Section 3.4.3.2, especially the formulation of component models and in the case studies performed with those tools.

Coordination of RISMC activities includes the following:

- **EPRI:** As stated above, EPRI will continue to play an important role in high-level technical steering and in detailed planning of RISMC case studies. RISMC work is coordinated with EPRI Long-Term Operation Program work.

- **Other Industry Partners:** Involvement of engineering and analysis support from industry is presently foreseen in the performance of case studies to drive next-generation analysis development and in the formulation of component models for implementation in next-generation analysis capability. The level of analysis effort to be provided and the source of financing for that effort are being negotiated. The individuals prospectively involved are either industry consulting firms or currently-independent consultants who have working relationships with current licensees. All are experts in applying traditional safety analysis tools and are conversant with risk-informed analysis.

3.4.5 Facility Requirements

In science-based, risk-informed safety analysis, new types of data are needed to enable quantification of uncertainty in advanced methods and tools, particularly in multiscale and multiphysics simulation. Infrastructure is needed to support a network of separate-effect tests on nuclear thermal-hydraulics (e.g., facility to measure critical heat flux) and LWR integral test facilities. Large-scale integral test facilities provide the most credible data needed by regulators for safety code qualification. Many integral facilities that represent the existing Gen II plant designs were decommissioned. The facilities that do remain are focused on the passive designs of Gen III+ plants. Even when they existed, facilities like Semiscale and Loss of Fluid Test Facility had a narrow focus on loss-of-coolant accidents for supporting design-basis emergency core cooling system analysis. Within a risk-informed approach, there is a need to validate system safety analysis codes in a much broader space of scenarios and conditions. In particular, sequences identified as risk significant may include those with tight coupling between processes in the reactor cooling system and in the containment system, with multiphysics (e.g., neutronics, thermal hydraulics, coolant chemistry, and structural mechanics) and eventually human factors. This scope presents the need for new data to support R7 code development and validation. This need can be met by modernizing and extending the experimental infrastructure for reactor safety research, which already includes a network of integral test facilities (e.g., APEX and PUMA) and separate effect test facilities located in universities and other institutions across the country and internationally.

3.4.6 Products and Implementation Schedule

The main products of the RISMC R&D pathway are as follows:

- Next-Generation Safety Analysis Code (R7) – A system code that does the following:
  - Performs mechanistic description and effective simulation of plant transient behavior under a broad range of upset conditions and sequences of risk importance under life extension operation
  - Incorporates models of reactor component performance and reliability into the simulations and properly models coupling between the scenario physics (e.g., thermal hydraulics and neutronics) and these aspects of component behavior
- RISMC framework – A comprehensive methodology that applies R7 to support life extension decision-making by bringing together advanced modeling, simulation and analysis tools, and relevant data to characterize nuclear power plant safety margins, including the effect of plant aging
- Enabling methods and tools for advanced PRA and advanced prevention analysis to support life extension decision making.

The implementation schedule (Figure 3-9) is structured to support the following high-level milestones:

- 2010
  - Formulation of RISMC methodology
  - Development, selection, implementation, and testing of architectural features and solution techniques for a next-generation safety analysis code.
- 2011
  - Within the technical scope defined by first-round case studies, development of the next-generation safety analysis code (R7) to simulate plant dynamics and compute safety margin
  - Development of a risk-informed, simulation-driven methodology to apply the R7 in safety system analysis and uncertainty quantification
  - Development of models of passive SSCs for application within the next-generation safety analysis code, in order to directly simulate the coupling between plant physics and SSC reliability and performance.
- 2012
  - Completion of the development of the next generation safety analysis code, the associated framework, and associated models of component behavior to the technical scope of the first-round case studies

- Extend the capability from small-scale demonstration of algorithmic features to plant-scale evaluations of issues of current interest, focusing on the first-round case studies being coordinated with industry

- With industry, define more broadly scoped case studies to drive the next stage (second round) of RISMC development.

- 2015

  - Based to the extent practical on available test and operating data, complete second-round RISMC development (e.g., phenomena modeling, component behavior modeling, and operator performance modeling)

  - Complete second-round case studies, including application of next-generation safety analysis code, next-generation prevention analysis, and integration of component behavior/T/H behavior into the assessment

  - Train a broader set of outside users in application of the RISMC framework and next-generation safety analysis code

  - As of 2015, R7 should support plant decision-making for most safety issues.

- 2020

  - Ensure development and validation to the degree that the RISMC framework and tools are the generally accepted approach for risk-informed, plant decision-making and risk-informed, regulatory decision-making

Figure 3-9 shows the intended schedule of development, whose details necessarily depend on the actual funding profile. Note that the color coding in Figure 3-9 is keyed to Figure 3-8.

Development is planned to take place in phases, rather than trying to deliver a "complete" but completely untested package at the end of the process. It has been agreed with industry to focus in Phase I on modeling a particular pressurized water reactor functional sequence in order to specify a scope of phenomena, components, and code capabilities needed to address that sequence, yielding a product at the end of the first round of development that will have only a partial scope of applicability, but will be testable and verifiable within that scope. Depending on the funding profile, it is currently expected that this first round of development will be complete at the end of 2012. As the first round nears completion, a more challenging set of case studies will be chosen to drive the second round, and a process analogous to that of the first-round development will occur.

It is expected that development of the framework will be substantially complete in the first round, including illustrations of margin characterization and methods for driving R7 to assess margin within the scope of first-round case studies. Refinement of the framework would continue thereafter at a level of effort significantly reduced compared to the effort associated with R7 development.

In the first round, R7-compatible models of passive SSC components also will be developed. As other pathways develop models and results to be input to margins assessments, these will be addressed beginning in the first round and continuing more intensively in the second round. Application of test and operating data to R7 calibration and model testing will begin in the first round with data used to validate existing safety analysis codes. As newer data become available to address issues not covered by those old data, comparison with those data will support R7 refinement. However, note that collection of those data per se is not a RISMC milestone.

The lower portion of Figure 3-9 shows that, beginning in the second round of Phase I development, inputs from other R&D pathways will become available and will be incorporated into R7. This does not mean that R7 is currently proceeding without consideration of fuels issues, materials issues, or II&C issues, but only means that new results from those pathways will begin to inform R7 development on that timeframe.

Assuming a funding profile commensurate with that in the current program plan, R7 development is expected to be substantially complete in 2015 at the end of the second round. This does not mean that R7 would be frozen as of 2015, any more than previous-generation safety analysis codes have been frozen, but its development would be more evolutionary in nature.

Beginning in 2012 and continuing thereafter, increasing effort will be devoted to training a broader user community of practice and supporting their applications.

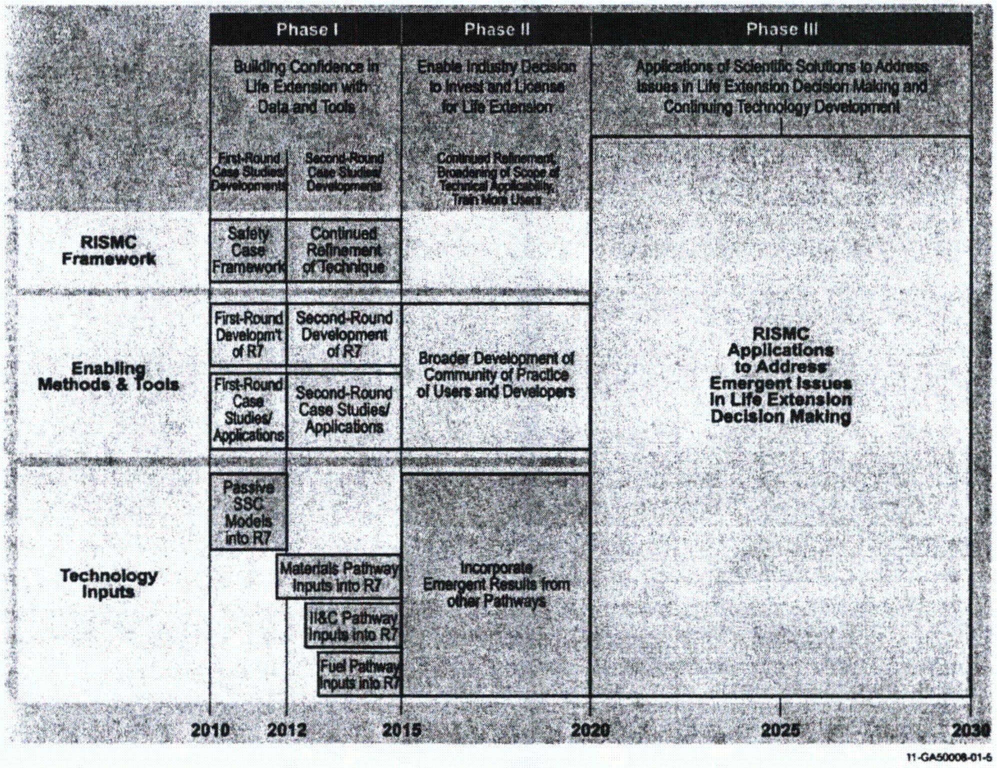

Figure 3-9. Risk-Informed Safety Margin Characterization pathway implementation schedule.

3.5 Economics and Efficiency Improvement

3.5.1 Background and Introduction

Improving the economics and efficiency of the current LWR fleet and maintaining excellent safety performance is a primary objective of the LWRS Program. Power uprates have been the most important methods that enable enhancement of the economic performance of the current operating fleet of LWRs. Cooling capability influences thermal efficiency and reliable operation. Increased reactor power and climate change concerns place more burdens on cooling requirements. Expanding the current fleet into nonelectric applications would further increase the value of LWR asset owners. This R&D pathway will focus on three activities: (1) alternative cooling technologies, (2) nonelectric applications (process heat), and (3) power uprates.

3.5.1.1 Alternative Cooling. Water consumed by thermoelectric power plants (such as those fueled by coal, natural gas, and nuclear) continues to receive increasing scrutiny as new power plants are proposed and existing power plants encounter water shortages. Climate change may exacerbate the situation through hotter weather and disrupted precipitation patterns that promote regional droughts. Before 1970, thermoelectric power plants addressed their need for cooling with either fresh or saline water withdrawals for once-through cooling. Since that time, closed-cycle systems (evaporative cooling towers or ponds) have become the dominant choice, with certain impacts on water usage. Figure 3-10 shows the Limerick nuclear power plant in Pennsylvania, which uses mine pool water for a substantial fraction of its cooling.

Figure 3-10. Limerick nuclear power plant.

3.5.1.2 *Nonelectric Application (Process Heat).* Nuclear power plants have very high capital investment and low operating costs. Therefore, to minimize the cost of electricity, these nuclear power plants are typically operated at full power to provide base load needs. With the potential extended power uprates for these nuclear power plants in the future and the eventual construction of new nuclear power plants in the United States, some of the nuclear power plants may need to be operated at reduced power levels when electricity demand is low at off-peak times, such as during the night. This is an operating strategy seen in France where power demand must affect reactor output because of the high percentage of nuclear power. Operating nuclear power plants at a reduced power level is not desirable for economic and safety reasons. On the other hand, only about one-fifth of the world's energy consumption is used for electricity generation. Most of the world's energy consumption is for heat and transportation. The existing LWR fleet in the United States has limited experience in nonelectric applications. However, the existing LWR fleet might have some potential to penetrate into the heat and transportation sectors, which are currently served by fossil fuels that are characterized by price volatility, finite supply, and, more importantly, environmental concerns. There are a wide variety of purely thermal applications of a reactor's output, which may be integrated with an electrical generating plant. These applications may be effective even at the conventional steam temperatures that exist in commercial nuclear power plants. These nonelectric applications of nuclear energy include providing heat and steam to industrial processes, seawater desalination, and district heating. The desalination of seawater using nuclear energy has been demonstrated, and nearly 200 reactor-years of operating experience have been accumulated worldwide. District heat involves the supply of heating and hot water through a distribution system, which is usually provided in a cogeneration mode in which waste heat from power production is used as the source of district heat. Several countries have district heating using heat from nuclear power plants.

3.5.1.3 Power Uprates. The nuclear industry has been making improvements in commercial nuclear power plants since the 1970s to increase their rated power output (power uprates). There are three types of power uprates defined by NRC: (1) measurement uncertainty recapture power uprates are less than 2% and are achieved by implementing enhanced techniques for calculating reactor power, (2) stretch power uprates are typically up to 7% and are within the design capacity of the plant, and (3) extended power uprates, which are greater than stretch power uprates and have been approved for increases as high as 20%. The primary methods of producing more power are improvements in the fuel design, operational restriction, reanalyzed reactor thermal-hydraulic parameters, more involved safety analysis, and upgrade of the balance of plant capacity by component replacement or modification (such as replacing a high-pressure turbine). Instrumentation upgrades that include replacing parts, changing set points, and modifying software also are required for operation at increased power levels. As of today, NRC has approved 129 power uprate submittals. The total extra power generated from power uprates is equivalent to building almost six 1,000-MWe new nuclear power plants. Uprating a nuclear power plant reduces the operating cost per unit energy generated and significantly enhances the asset value of the plant owner.

The industry has achieved such remarkable performance by using available fuel designs, materials, and engineering methods. To facilitate additional power uprates, especially extended power uprates, new materials, methods, and fuel designs are needed. It is LWRS Program's role to conduct R&D leading to the new materials, methods, and fuel designs to enable additional extended power uprates.

The changes in the physical nuclear power plant systems are theoretically able to sustain much higher power uprates. An additional cycle of extended power uprates greater than 20% is being considered. To increase a nuclear power plant's power to levels greater than 20% requires higher power density core designs and scientific understanding of plant performance issues. Power uprate causes higher radiation fluences, increased thermal-induced stress and fluid-induced vibrations, and corrosion. The plant owners must have the confidence that the power uprate will not cause accelerated damage to the nuclear power plant structure, system, and components. For instance, the integrity of steam dryers and steam generators must be ensured due to increased steam loads and the integrity of reactor pressure vessels and core internals due to increased radiation damage and corrosion. The plants also must demonstrate with confidence that mandated safety limits will not be violated during accident conditions to ensure the fuel integrity due to increased duty and containment integrity because of higher storage energy of the reactor coolant system. The LWRS Program focuses on developing enabling technologies, such as revolutionary fuel design, that offers superior safety and economic performance and modern design and safety analysis tools that can resolve extended power uprate inhibiting issues to significantly advance the potential for additional power uprates greater than 20%. Development of deep science-based knowledge also will be complemented by the DOE Energy Innovation Modeling and Simulation Hub, which is run by the CASL. The integration of results from CASL, plant changes, and operating conditions will be evaluated by the Economics and Efficiency Improvement R&D pathway to facilitate implementation of extended power uprates. An advanced study of these effects in an existing and aging plant is required. The ability to greatly uprate a nuclear power plant provides the national strategic benefits of increasing the total nuclear power supply at a lower cost per kW than building new nuclear plants. The previous success of power uprates makes this an attractive way to expand nuclear power supplies.

3.5.2 Vision and Goals

The commercial nuclear power industry will undertake additional power uprates beyond 20%. These uprates will require optimized cooling technology to minimize water usage to accommodate the uprated power output. The increased power available also can facilitate expansion of nonelectric applications within the framework of plant life extension to optimize the contribution of nuclear power to the national strategic benefits of low emissions energy production.

The programmatic goals for this R&D pathway are captured in the following statements:

1. Alternative Cooling Technology: Conceive, develop, and establish deployable technologies for optimizing use in the nuclear energy thermocycle, while minimizing reliance on water resources at the same time.

2. Nonelectric Application (Process Heat): Develop the energy conversion and heat transport technologies needed for applications of existing LWRs to low temperature process heat.

3. Power Uprates: Provide scientific and engineering solutions to facilitate extended power uprates for all operating LWRs in a cost-effective manner.

3.5.3 Highlights of Research and Development

3.5.3.1 Alternative Cooling. Alternatives to closed-cycle cooling (e.g., wet cooling tower) are generally dry cooling (e.g., waste heat rejected to the atmosphere) or hybrid cooling (e.g., using aspects of both wet and dry cooling), as well as replacing freshwater supplies with degraded water sources. Degraded water is polluted water that does not meet water-quality standards for various uses such as drinking, fishing, or recreation. Existing operating LWRs in the United States use either once-through cooling or wet cooling towers, with a few using degraded water.

It is essential to provide adequate and timely cooling for safe and economic operation of nuclear power plants. With more stringent regulation on the temperature of the discharged cooling water from a nuclear power plant, the potentially decreased availability of clean cooling water, increased cooling load with the power uprates, and potentially warmer weather in the summer season due to global climate change, alternative and potentially advanced cooling technology has to be developed in order to ensure the reactors can be safely and economically operated without being forced to shut down or reduce the power output due to cooling water issues. R&D activities will focus on the following: (1) technology development (such as advanced condenser design, reducing water losses in the wet cooling tower system, or improving dry cooling and hybrid cooling technology); (2) evaluating applicability of alternative water-conserving cooling technologies (such as dry cooling and hybrid cooling) to improve LWR plant efficiency, relieve the cooling water requirement, and expand use of alternative sources of water; and (3) improving analysis methodology, performing analysis to identify optimal designs, and developing water resource assessment and management decision support tools.

3.5.3.2 Nonelectric Application (Process Heat). Nuclear power plants produce 1,500 to 4,500 MW of steam. Very few markets exist for such large quantities of steam. Usually, it is not economical to modify a nuclear power plant to produce a few megawatts of heat to meet a local industry or district-heating need; therefore, district heating will not be considered. Seawater desalination using multi-stage distillation and existing LWRs also is a very remote possibility. Desalination using reverse osmosis, where most of the energy input is electricity, may be a viable, off-peak use of LWRs for economical fresh water production. Using nuclear energy indirectly for transportation by creating fuel ethanol has the potential to open new markets for existing LWRs. Cellulosic biomass-to-fuel ethanol plants require very large quantities of low-temperature steam that could be provided by LWRs if these plants were located close to the reactors.

Heat from nuclear power plants also can be used to provide process heat to a Fischer-Tropsch chemical process (or similar processes) to produce synthetic fuel. Coal gasification has the advantage of reduction of air emissions from coal combustion, an increased thermal efficiency of combustion, and use of a large resource base. Nuclear energy, being an industrially proven and nonpolluting technology, is a valid candidate for this purpose.

Technical and economic viability of different applications will be studied. One key issue to be addressed is interface design and plant modifications.

3.5.3.3 Power Uprates. R&D activities will be focused on enabling safe and cost-effective plant modifications and modernizations required to gain margins by enhancing the plant power limiting equipment capability. Consistent with the main themes currently identified in this R&D pathway, activities are planned in the following main areas to significantly uprate the current LWR power levels: (1) collaboration with Nuclear Materials Aging and Degradation R&D pathway on higher fluence effect, (2) innovative fuel design, fuel performance, and loading management, (3) high fidelity core physics and fuel depletion capability, (4) reactor thermal hydraulics, (5) safety assessment under high power, (6) balance of plant, including steam generators for pressurized water reactors, (7) operation with higher core outlet temperature, (8) instrumentation and control systems and software reliability and (9) integrated detailed physics from the DOE Energy Innovation Modeling and Simulation Hub.

3.5.4 Facility Requirements

No additional facilities are foreseen for alternative cooling technologies. Power uprates will leverage the facilities used in other R&D pathways.

3.5.5 Products and Implementation Schedule

The main products of this R&D pathway are as follows:

- Advanced cooling technologies that would reduce cooling water requirements and improve the plant's thermal efficiency
- Tools, methods, and technologies (collaborating with other pathways) to enable additional extended power uprates; these include innovative fuel designs (such as annular fuel design) to enable higher power density, improved reactor safety analysis tools, increased heat removal capabilities for containment, and economic analysis to guide power uprate decision-making
- Feasibility studies of the technical and economic viability of expanding the existing fleet into nonelectric applications.

The implementation schedule (Figure 3-11) is structured to support the following high-level milestones:

- 2015:
  - Preserve the once-through cooling technologies (advanced water conservation technologies for wet cooling tower)
  - Complete feasibility studies for process heat production and low-temperature distillation applications.
- 2020:
  - Ensure significant cost reduction of dry cooling technology and thermal efficiency improvement in the hot summer timeframe
  - Ensure next generation safety analysis tools available to support additional extended power uprates.
- 2025: Apply alternative and new cooling technologies.
- 2030: Enable 10-GWe extra capacity additions through additional extended power uprates.

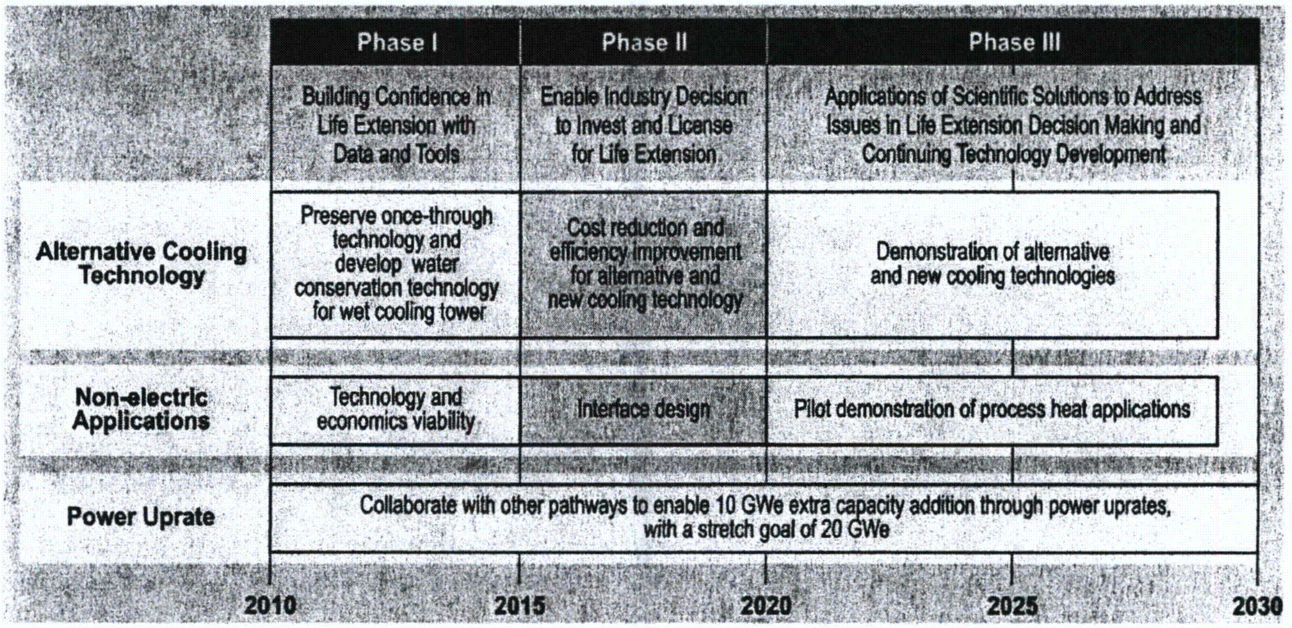

Figure 3-11. Economics and Efficiency Improvement pathway implementation schedule.

3.6 Pathway Crosscutting and Integration

The overall focus of the R&D activities will be on practically advancing the ability of the owner of nuclear assets to manage the effects of the aging of passive components and increase the efficiency and economics of operations. This will provide the necessary technology and ability to keep valuable nuclear power plant assets online and generating the required clean and safe energy. Transformational activities initially should be developed as limited-scope pilots that provide confidence in the program direction and developed technology. In selecting projects, it is vital that all consideration should be given to how each of the pathways can support achievement of safety and efficiency for existing LWRs by ensuring that each pathway is appropriately coordinated with the desired outcomes of the other pathways. Technical integration is an important and significant part of the LWRS Program. R&D within the program is integrated across scientific and technical disciplines in the five R&D pathways. The LWRS Program is integrated with outside sources of information and parallel R&D programs in industry, universities, and other laboratories, both domestic and international. Different methods of integration are used depending on the situation and goals.

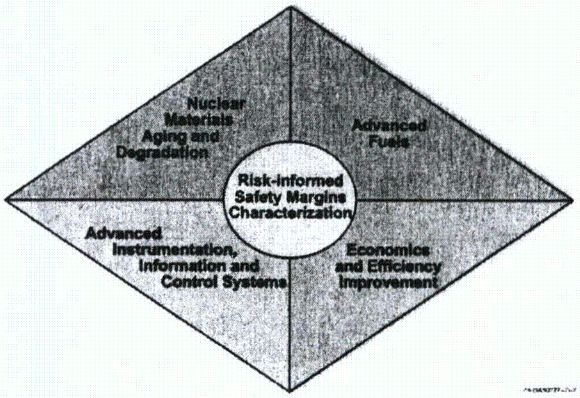

Figure 3-12. Integration of five research and development pathways.

3.6.1 Technical Integration

Interfaces between R&D pathways and the required integration across them are naturally defined by common objectives for materials and fuel performance and the system monitoring of their performance. Similarly, interface and integration of the pathways with the RISMC R&D pathway is defined by data and models, which affect performance, monitoring, and control (Figure 3-12).

Data and information from the Nuclear Materials Aging and Degradation, Advanced LWR Nuclear Fuel, and Economics and Efficiency Improvement R&D pathways will be fed into the RISMC models. Results of the RISMC analysis will guide development of advanced fuels; materials aging and degradation mitigation; advanced II&C systems; and economics and efficiency improvement. Examples of some crosscutting areas in the LWRS Program include coolant chemistry effects, crack growth mitigation effects, irradiation testing, irradiation source term changes, improved online monitoring of reactor chemistry, advanced instrumentation for the study of system degradation, fuel failure mechanisms, creation of SSC aging database, advanced measurement techniques, field testing and data collection/capture, nondestructive evaluation/assay tools, and advanced inspection techniques.

3.6.2 Advanced Modeling and Simulation Tools

The most common theme for the R&D pathways is use of computer modeling of physical processes or development of a larger system computer model. Extensive use of computer modeling by the R&D pathways is intended to distill the derived information so that it can be used for further research in other pathways and as the basis for decision-making. A cross-cutting implementation plan is being developed to address the interfaces for each of the pathways.

Computer modeling occurs in three forms with many overlapping aspects within the LWRS Program. Modeling a physical behavior (such as crack initiation in steel) is an example of direct computer modeling. The resulting model is used to store information for use in other pathways and to use in its own right for further research.

A second computer modeling activity is development of more detailed computer modeling tools capable of encoding more complex behaviors. One of the intended outcomes from Advanced LWR Nuclear Fuels Development research is new modeling tools that can describe behavior of such complexity that current computer models are incapable of producing. The increased accuracy will allow improved results to be incorporated into other pathways.

The final computer modeling improvement is creation of larger integrated databases that roll up results and allow decision-making. The large, system-wide, integrated models allow complex behavior to be understood in new ways and new conclusions to be drawn. These integrated databases can be used to further guide physical and modeling research, improving the entire program.

Because of their overlapping nature and numerous interfaces, these modeling activities tend to be naturally cross-cutting activities between R&D pathways. A separate cross-cutting implementation plan is being developed that will address the details of these interfaces and means of handling these overlaps for the LWRS Program and other DOE-NE programs.

3.6.2.1 Nuclear Energy Advanced Modeling and Simulation. A critical interaction of the LWRS Program is with the DOE Nuclear Energy Advanced Modeling and Simulation Program. The LWRS Program will take advantage of the detailed, multiscale, science-based modeling and simulation results developed by the DOE Nuclear Energy Advanced Modeling and Simulation Program that will be uniquely valuable to multiple R&D pathways. The modeling and simulation advances will be based on scientific methods, high dimensionality, and high resolution integrated systems. The simulations will use the most advanced computing programs available. These tools will be fully three-dimensional, high-resolution, modeling-integrated systems based on first-principle physics. To accomplish this, the modeling and simulation capabilities will have to be run on modern, highly parallel processing computer architectures. These advanced computational tools are needed to create a new set of modeling and simulation capabilities that will be used to better understand the safety performance of the aging reactor fleet. These capabilities will be information sources and tools for advancing the LWRS Program goals.

3.6.2.2 DOE Energy Innovation Modeling and Simulation Hub. The LWRS Program also will take advantage of the progress made by the DOE Energy Innovation Modeling and Simulation Hub managed by the Consortium for Advanced Simulation of Light Water Reactors (CASL). The Hub will support the LWRS Program by addressing long-term operational challenges faced by U.S. nuclear utilities. The alignment between the Hub and the LWRS Program's technical activities is by providing detailed calculations and large integrated models that address each of the technical needs of the LWRS Program R&D pathways.

A primary initial product of the Hub is a sophisticated integrated model of a LWR (a virtual reactor). The virtual reactor will be used to address issues for existing LWRs (e.g., life extensions and power uprates). The Hub challenge problems have been selected principally to demonstrate the capability of the virtual reactor to enable life extensions and power uprates. The enhanced computational capability of the virtual reactor will allow simulated proof of concepts for LWRS improvements and identify areas needing additional research.

With improvements in modeling and simulation capability centered on a science-based approach, the Hub will enable exploration of advanced fuel design features. These advanced features may range from modifications of the current compositions of the zirconium-based alloys now used for cladding to the development of entirely new cladding materials, new fuel materials with higher densities and improved thermal properties, and changes in fuel geometry and configuration. The virtual reactor capability will progress from analyses of operating reactors to design improvements. Improved modeling and simulation of the reactor internals and steam generators will support the needs of the Nuclear Materials Aging and Degradation and Economics and Efficiency Improvement R&D pathways. The virtual reactor performance will also provide modeling inputs for the Advanced Instrumentation, Information, and Control System Technologies R&D pathway.

3.6.3 Coordination with Other Research Efforts

In order to encourage communication and coordination with outside experts and parallel programs, the LWRS Program will be aware of issues and changes of technical needs that affect long-term, safe, and economical operation of existing operating LWRs, and share information and resources with other professionals and programs that can assist the LWRS Program to provide timelier, less expensive, and better solutions to the needs and issues.

Primarily, coordination will be with the EPRI Long-Term Operation Program. At the program level, formal interface documents will be used to coordinate planning and management of the work. This will provide a ready source of information from EPRI's Nuclear Power Council and through their contact with utilities. At the R&D project level, both programs encourage frequent communication and collaboration.

Consistent with the vision of the LWRS Program, working relationships have been established with international organizations in FY 2009 and will continue in FY 2010 and beyond. The goal is to facilitate communication and cooperative R&D with international R&D organizations.

R&D needs for existing LWRs are synergistic with those for the GEN III+ LWRs to be deployed and LWR small modular reactors being designed and licensed. Consequently, scientific solutions developed from Objective 1 are directly applicable to the technological challenges facing deployment and operation of GEN III+ LWRs and LWR small modular reactors as described in Objective 2.

3.6.4 Performance of Technical Integration and Coordination

The LWRS Program will lead and encourage technical integration and coordination of issues affecting the LWR Long-Term Operation Program using methods that best match the issue. For known gaps in data, understanding, or technology, the LWRS Program will plan and manage integrated R&D projects through the LWRS Program TIO and its multiple interfaces.

To accommodate currently unknown issues or gaps in technology that may arise as result of ongoing R&D or nuclear power plant operations, a broader approach is necessary. This approach should include active internal and external communication with professional organizations, industry groups, and interdisciplinary teams for project and program reviews. The steering committee is an essential part of this process. The LWRS Program encourages participation in professional technical societies and national standards committees.

4. PROGRAM MANAGEMENT

4.1 Organization Structure

The entire LWRS Program falls within DOE-NE. Program management and oversight, including programmatic direction, project execution controls, budgetary controls, and TIO performance oversight, are provided by the DOE Office of LWR Technologies in conjunction with the DOE Idaho Operations Office. The functional organization, reporting relationships, and roles and responsibilities for the TIO are explained in the following sections and are shown in Figure 4-1.

The DOE Office of LWR Deployment directs the program, establishes policy, and approves scope, budget, and schedule for the program through the LWRS Program Federal Program Director. The DOE LWRS Program Federal Program Director is assisted with program management and oversight by DOE Idaho Operations Office.

DOE Idaho Operations Office will provide technical and administrative support to the LWRS Program. This support includes activities such as assisting in development of administrative requirements in support of contracting actions, conducting merit reviews and evaluations of applications received in response to program solicitations, performing all contracting administration functions, and providing technical project management and monitoring of assigned projects.

The TIO basic organizational structure is used to accommodate the crosscutting nature of the proposed R&D pathways. This organization is responsible for developing and implementing integrated research projects consistent within the LWRS Program's vision and objectives. Additionally, the TIO is responsible for developing suitable industry and international collaborations appropriate to individual research projects and acknowledging industry stakeholder inputs to the program.

Within the TIO structure is the TIO director, deputy director, operations manager, each of the five R&D pathway leads, and an external steering committee. Nuclear industry interfaces and stakeholders' contributions are accommodated in program development and project implementation actions through the TIO management structure. Recognition of continuing industry collaborations, reflecting issues and concerns necessary to extend plant licenses, are incorporated through the same program development and implementation actions.

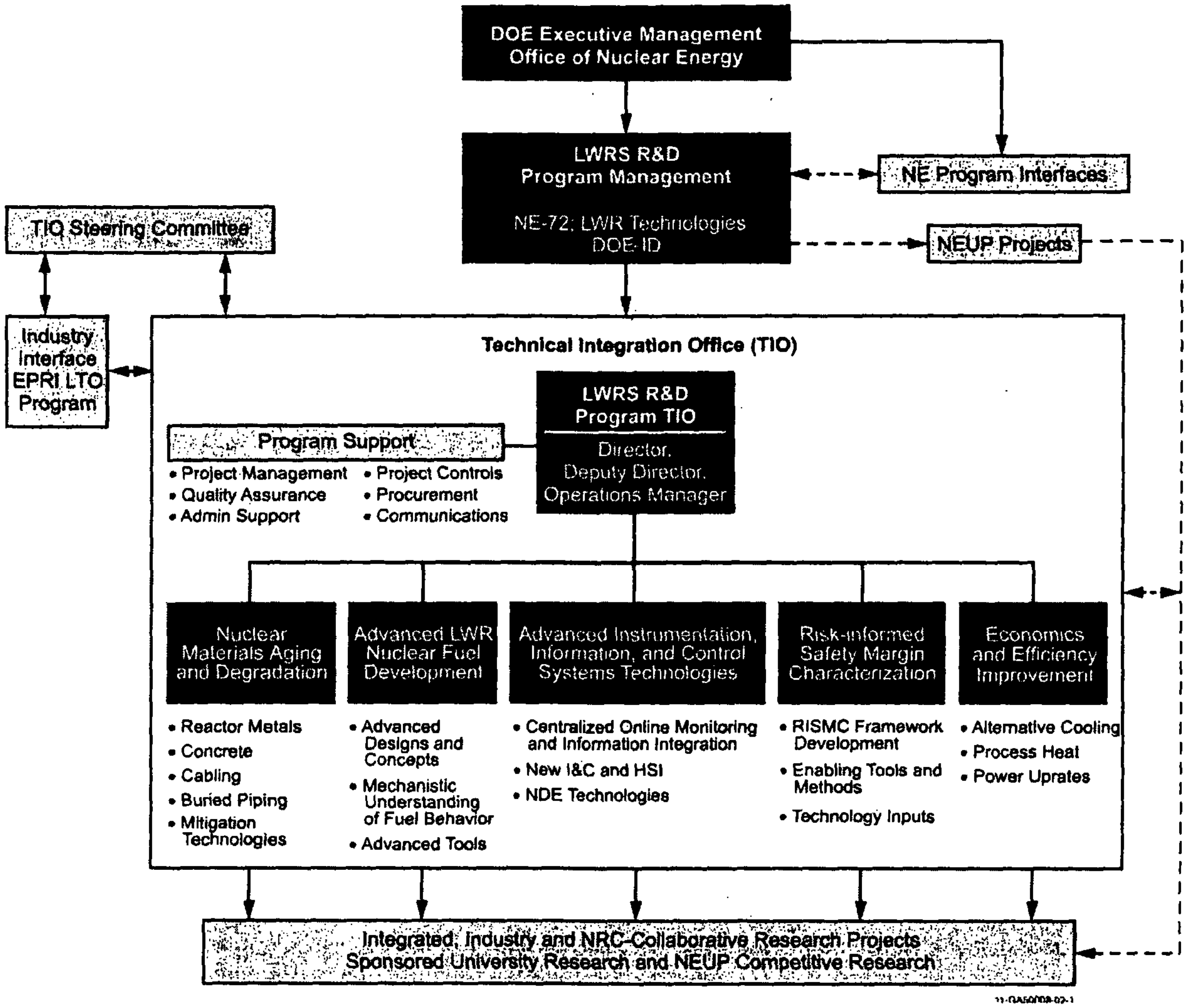

Figure 4-1. Light Water Reactor Sustainability Program organization.

4.2 Roles, Responsibilities, Accountabilities, and Authorities

4.2.1 Department of Energy Office of Nuclear Energy

DOE is responsible for the federal government's investments in nuclear power R&D and incentive programs, which all further the Nation's supply of clean, dependable nuclear-generated electricity. The LWRS Program conducts research that enables licensing and continued reliable, safe, long-term operation of current nuclear power plants beyond their initial license renewal period. The DOE Office of LWR Technologies directs the program, establishes policy, and approves scope, budget, and schedule for the program through the LWRS Program Federal Program Director. The LWRS Program Federal Program Director is assisted with program management and oversight by DOE Idaho Operations Office.

The essential programmatic DOE functions include, but are not limited to, the following:

- Establish program policy and issue program guidance assigned R&D mission. They are responsible for establishing scope, cost, and schedule of the R&D activities. They interface with other R&D pathway leads to ensure effectiveness of crosscutting activities.

4.2.2.3 Program Support Team. The program support staff is responsible for contractual operations of TIO and assists other parts of TIO to execute work. The team provides personnel with expertise in project management, quality assurance, procurement, project controls, and communications. They provide tools, structure, oversight, and rigor to maintain R&D schedules and interfaces with the LWRS Program. They also provide financial information to management (through the TIO director's office) and monitor technical progress and track milestones.

4.2.3 Project Monitoring and Evaluation

DOE and TIO use a variety of methods to provide oversight of their projects, including semiannual project reviews, periodic progress reports, and scheduled evaluations, invoice reviews, and participation in periodic project meetings and conference calls.

4.2.3.1 Project Reviews. DOE and TIO conduct semiannual and annual project progress review meetings with project participants, including all R&D pathway leaders. During these project review meetings, project activities, schedule progress, and cost are discussed in detail. Status of deliverables, funding, or schedule concerns and potential changes in scope also are discussed. Performance expectations for the remainder of the budget period and project are reviewed. On an annual basis, DOE staff reviews the work scope, budget requirements, schedule, deliverables, and milestones for the subsequent budget periods. This often requires face-to-face meetings with project participants to fully understand the future planned work.

4.2.3.2 Periodic Project Status Meetings and Conference Calls. DOE, TIO, and R&D pathway leaders participate in periodic project status meetings and conference calls. Typically, project conference calls are the method of choice because of the number and location of participants; they are held at least twice a month. In addition, DOE staff participates in TIO conference calls on specific tasks.

4.2.3.3 Monthly Progress Reporting. DOE personnel review and evaluate project monthly progress reports for the project task and activity progress, accomplishment of deliverables, and budget and cost status. This reporting provides project participants and DOE staff with a monthly snapshot of overall project cost and schedule performance against the project baseline.

4.3 Interfaces

The LWRS Program TIO is intended as a national organization and is expected to have multiple national laboratory, governmental, industrial, international, and university partnerships. As appropriate, the LWRS Program technology development and execution activities will use facilities and staff from national laboratories, universities, industrial alliance partners, consulting organizations, and research groups from cooperating foreign countries.

TIO is responsible for ensuring the necessary memorandum purchase orders, interagency work orders, or contracts are in place to document work requirements, concurrence with work schedules and deliverables, and transfer funds to the performing organizations for R&D activities.

4.3.1 Steering Committee

A TIO steering committee advises TIO on the content, priorities, and conduct of the steering committee. The committee is comprised of technical experts selected and agreed upon by the TIO director and the LWRS Program Federal Program Director. The committee, as a group, is knowledgeable of the various R&D needs of DOE, industry, and NRC; ongoing and planned research as related to nuclear power technology; and policies and practices in public and private sectors that are important for the collaborative R&D program. The TIO director, in consultation with the steering committee, may form ad hoc subcommittees to review specific technical issues.

4.3.2 Industry

Planning, execution, and implementation of the LWRS Program are done in coordination with U.S. industry and NRC to assure relevance and good management of the work. The LWRS Program addresses some of the most pressing R&D needs identified in the Strategic Plan for Light Water Reactor Research and Development, including R&D needed by currently operating LWRs to extend their safe economical lifetime to significantly contribute to the long-term energy security and environmental goals of the United States.

The LWRS Program works with industry on nuclear energy supply technology R&D needs of common interest. The interactions with industry are broad and include cooperation, coordination, and direct cost-sharing activities. The guiding concepts for working with industry are leveraging limited resources through cost-shared R&D with industry, direct work on issues related to the long-term operation of nuclear power plants, the need to develop state-of-the-art technology to ensure safe and efficient operation and the need to focus government-sponsored R&D on the higher-risk and longer-term projects incorporating scientific and qualitative solutions. These concepts are included in memorandums of understanding, nondisclosure agreements, and cooperative R&D agreements.

Cost-shared activities are planned and executed on a partnership basis and should include significant joint management and funding.

EPRI has established the Long-Term Operations Program to run in parallel with the DOE LWRS Program. The Long-Term Operations Program is based on the LWR R&D Strategic Plan and focuses on long-term operations of the current fleet. EPRI and industry's interests are applications of the scientific understanding and the tools to achieve safe, economical, long-term operation. Therefore, the government and private sector interests are similar and interdependent, leading to strong mutual support for technical collaboration and cost sharing. Formal interface agreements between EPRI and the TIO will be used to coordinate collaborations. Contracts with EPRI or other businesses may be used as appropriate for some work.

The LWRS Program has a steering committee with a diverse and experienced membership, including EPRI and utility members. The steering committee provides strategic guidance that helps ensure the program remains focused on useful industry results.

Each of the R&D pathways has interactions with the industry where detailed work packages are formed. DOE research is centered on general technology that advances and creates the knowledge base that will support individual applications for license renewals. The programmatic issue selection was created by the pathway definition that occurred with industry at the start of the LWRS Program. The technical pathway goals have been selected to drive the program toward solving problems that industry has been or will be unable to solve. The industry view does not look across the current commercial reactor fleet as generically or into the future as far as the DOE R&D. The ability of the LWRS Program to solve large, complex, and higher risk technical problems is a programmatic strength. The EPRI Long-Term Operation Program and LWRS Program cooperate to keep near-term research with EPRI and mid-term results aligned with LWRS objectives.

4.3.3 International

DOE is coordinating our LWRS Program activities with several international organizations with similar interests and R&D programs. We expect to continue to develop these contacts to provide timely awareness of emerging issues and their scientific solutions. A close working relationship with the Organization for Economic Cooperation and Development's Halden Reactor Project and with Electricite de France's Materials Aging Institute are particularly important to the LWRS Program. As funding is available, the LWRS Program intends to initiate formal R&D agreements with both institutions.

4.3.4 Universities

Universities will participate in the program in at least two ways: (1) through the Nuclear Energy University Program and (2) with direct contracts. In addition to contributing funds to the Nuclear Energy University Program, the LWRS Program will provide to the Nuclear Energy University Program descriptions of research from universities that would be helpful to the LWRS Program. In some cases, R&D contracts will be placed with key university researchers.

4.3.5 Nuclear Regulatory Commission

DOE's mission to develop the scientific basis to support both planned lifetime extension up to 60 years and lifetime extension beyond 60 years and to facilitate high-performance economic operations over the extended operating period for the existing LWR operating fleet in the United States is the central focus of the LWRS Program. Therefore, more and better coordination with industry and NRC is needed to ensure that there is a uniform approach, shared objectives, and efficient integration of collaborative work for LWRS. This coordination requires that articulated criteria for the work appropriate to each group be defined in memoranda of understanding that are executed among these groups. NRC has a memorandum of understanding[b] in place with DOE, which specifically allows for collaboration on research in these areas. Although the goals of NRC and DOE research programs differ in many aspects, fundamental data and technical information obtained through joint research activities are recognized as potentially of interest and useful to each agency under appropriate circumstances. Accordingly, to conserve resources and to avoid duplication of effort, it is in the best interest of both parties to cooperate and share data and technical information and, in some cases, the costs related to such research, whenever such cooperation and cost sharing may be done in a mutually beneficial fashion.

[b] "Memorandum of Understanding Between U.S. Nuclear Regulatory Commission and U.S. Department of Energy on Cooperative Nuclear Safety Research," dated April 22, 2009, and signed by Brian W. Sheron, Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission and Rebecca Smith-Kevern, Acting Deputy Assistant Secretary for Nuclear Power Deployment, Office of Nuclear Energy, U.S. Department of Energy.

Building a *New* NY...*with you*

2012 State of the State Address

Governor Andrew M. Cuomo

Building a *New* New York...*with you*

ANNUAL MESSAGE
STATE OF NEW YORK
January 4, 2012

To the Members of the Legislature of the State of New York:

One year ago — almost to the day — I delivered my first State of the State address as your Governor.

I said last year that New York was at a crossroads.

New Yorkers were hurting. The economy was causing hardship and anxiety. People needed help. But our State government was mired in scandal, ineffective, and rife with partisanship.

One year ago, we were divided as a state: Upstate and Downstate, millionaires and the middle class, gay and straight, Democrats and Republicans.

Our state had a deficit. And not just a fiscal deficit, but even worse, a trust deficit, a performance deficit, and an integrity deficit.

New Yorkers deserved better — and New Yorkers knew it.

For me, the Capitol building itself was a symbol of the deterioration, decline, and dysfunction of State government. It had been under renovation for eleven years, and it was scheduled to take an additional four. By the time they were done with the repairs, we would have had to start all over again!

The situation was grim. Our people had problems, and our government did not have the capacity or the credibility to help.

New Yorkers had a choice to make. We could remain dysfunctional and divided, or we could come together, reestablish our government, and rebuild our great state. We made the right choice.

We chose to begin to change the culture of Albany.

To put the people first.

To rebuild the trust.

To restore our deteriorating Capitol.

And in just one year, working together, we made great progress. The 234th Legislative Session was one of the most productive for our state government in modern political history.

We began the year by closing a $10 billion deficit with no gimmicks, and we did it on time. The budget included historic reforms to redesign and consolidate state government, eliminate automatic spending increases that cost New Yorkers billions of dollars, and cap spending increases for education and Medicaid.

After 20 years of failure, we enacted the state's first-ever property tax cap. New York's property taxes are among the highest in the nation, but for more than 15 years, both houses of the Legislature and three governors failed to bring these skyrocketing costs under control. The tax cap that we enacted limits increases in property taxes to 2 percent, or the rate of inflation — whichever is less. Schools and local governments can go beyond the cap, but only if 60 percent, respectively, of the voters or local legislative body approve.

We eliminated over 3,800 prison beds and 370 juvenile facility beds — because we finally accepted that prisons are not an economic development program. In addition to the closure of Tryon Boys Residential Center in January 2011, we shut four residential juvenile facilities and downsized another four. We have worked to put a greater emphasis on prevention and on community-based alternatives to incarceration.

We eliminated the MTA payroll tax for almost 290,000 small businesses, 81 percent of small businesses in the MTA region. In addition, we cut the payroll tax by as much as two-thirds for more than 6,000 businesses with payrolls between $1.25 and $1.75 million. We also eliminated the MTA payroll tax for over 410,000 self-employed taxpayers who make less than $50,000 a year. The total savings from the MTA tax cuts will be $250 million. The state will compensate the MTA for revenue lost as a result of the tax cut.

We passed the toughest rent regulation laws in 30 years. The new laws will protect more than one million New Yorkers from skyrocketing rent by, among other things, raising the deregulation rent threshold for the first time since 1993 and raising the income threshold for the first time since 1997. It will also help prevent landlords from manipulating the system to move apartments out of rent regulation.

We executed a new economic development policy with our New York Open for Business campaign and by establishing Regional Economic Development Councils across the state.

We passed an affordable energy policy with Recharge NY, on-bill energy efficiency financing, and, after a decade of trying, an Article X electric generation siting law. These programs will lower energy costs, promote energy efficiency, and reduce pollution.

We passed ethics reforms to restore trust in government. The Public Integrity Reform Act of 2011 contains some of the most comprehensive ethics improvements enacted in state government. Among other things, it requires state officials to disclose outside clients and customers, requires a detailed disclosure of officials' income and assets, creates a database of all individuals and firms that represent clients before state agencies, requires all lobbyists and clients of lobbyists to disclose all business relationships with public officials, and broadens the definition of lobbying. And it strips public officials convicted of a felony in relation to their office from receiving their taxpayer-funded pension.

We attacked chronic, high unemployment among disadvantaged inner-city youth with an innovative jobs program that will provide immediate tax credits to businesses that hire our youth and will also provide training to make sure these youths are ready for employment.

We provided desperately needed flood relief to storm-ravaged homeowners, farmers, and small business owners.

We restored New York's reputation as *the* progressive capital of the nation. We passed landmark achievements in social justice and economic justice.

For decades, millions of New Yorkers had been treated as second-class citizens by their own government. We ended that injustice. We stopped the discrimination. We made history. We led the nation. We passed marriage equality for ALL New Yorkers and we did it together. With this historic victory, New York is the largest state in the nation to grant same-sex couples the freedom to marry.

But we didn't stop there. We also fought for tax fairness. For decades, millions of New Yorkers were burdened with an unfair tax code. Whether a person made $20,000 or $20 million, they paid the same rate. It was just wrong —

because a flat tax is not a fair tax. Last month, we changed that, adding new brackets for the middle class and for high-earners. Our principle is simple: the more you make, the higher rate you pay. And we stimulated our economy by cutting taxes for New Yorkers earning $40,000 to $300,000. Today, the middle class is paying the lowest rate in 58 years.

Without a doubt, 2011 was a successful year for our state. It was also a challenging year. And the most heroic acts of last year did not happen in Albany — they happened in communities across the state.

Last summer, Hurricane Irene and Tropical Storm Lee devastated communities all over the state — communities that could least afford it. We are still reeling from the damage today. But in our darkest hours, New York shined the brightest, and the storm clouds had a silver lining: the way New Yorkers responded.

People all across the state came together in a beautiful display of community. And our first responders were selfless. They were professional. And they were courageous. They are what public service is all about.

We have accomplished much, there is no doubt. We have been through much, there is no doubt. But there is also no doubt that we have only just begun. We have established the capacity and credibility to govern. We have reversed decades of decline. Now is the time to get to work — building a *New* New York.

In New York, we may have big problems, but we confront them with big solutions. Today, I am laying out a three-part plan:

1. The next phase in our economic blueprint for growth

2. A reimagined government that can make our plans a reality

3. And a New York vision for a progressive future

THE ECONOMIC BLUEPRINT

Our challenge for 2012 is this: How does government spur job creation in a down economy while limiting spending and maintaining fiscal discipline? The answer: Creative public-private partnerships that leverage state resources to generate billions of dollars in economic growth.

We Will Build the Largest Convention Center in the Nation

Let's begin by building on our economic strength.

New York is an international destination. Tourism is at record numbers. Tourists spent $50 billion in New York State in 2010. We know that if we build it, they will come — because New York is the place to be. But we must stay ahead of the competition.

Convention centers are important generators of economic activity. New York needs a larger, state-of-the-art venue to be competitive for the largest tradeshows and conventions.

The Jacob Javits Convention Center on Manhattan's West Side is obsolete and not large enough to be a top tier competitor in today's marketplace. The Javits Center is, in fact, 12th in the nation in size — behind the convention centers in Anaheim and Atlanta.

This is not a new problem. We have talked about it for years. But today is different, because today I propose we do something about it. I propose that we build the largest convention center in the nation. 3.8 million square feet — larger than McCormick Place in Chicago, which is currently the largest in the United States. This will bring to New York the largest events, driving demand for hotel rooms and restaurant meals and creating tax revenues and jobs, jobs, jobs.

We are pursuing a joint venture with the Genting Organization, a gaming development company, to complete this vision at the Aqueduct Racetrack venue. It is a $4 billion private investment that will generate tens of thousands of jobs and economic activity that will ripple throughout the state. In addition to the new convention space, up to 3,000 hotel rooms will be developed. We will make New York the #1 convention site in the nation.

We Will Master Plan the Javits Convention Center Site

We can then master plan the 18-acre Jacob Javits Convention Center site as a mixed-use facility to revitalize New York City's West Side. We will follow the highly successful Battery Park City model, which has resulted in housing, hotels, museums, and over 10 million square feet of Class A office space. As part of the redevelopment, we will explore options for serving the needs of smaller and medium sized trade shows at the Javits site or elsewhere on the West Side of Manhattan.

We estimate over $2 billion in private sector development in creating a new 21st century neighborhood for the West Side. To put it in perspective, the Javits Center site is larger than the World Trade Center and the United Nations. This will complement the development at Hudson Yards and Moynihan Station.

$1 Billion Economic Development Package for Buffalo

While we build on our strength in New York City, we must also invest in the struggling areas of our state. New York is a stronger state when every region of our state is strong.

Buffalo has the third highest poverty rate of any city in the nation, behind only Detroit and Cleveland, with 28% of residents living in poverty and chronically high unemployment.

But it doesn't have to be that way.

We know from experience that large investments in growth industries can pay substantial dividends. Twenty-five years ago, the state began investing in the Albany area's high-tech industry. Today, the Albany area is a world-class center for nanotechnology innovation and the home of major semiconductor manufacturers. We saw great results from a substantial, sustained state investment.

We can do it again. We did it in Albany, and we can do it in Buffalo.

Buffalo has the workforce, the talent, the resources, and the will to succeed. We believe in Buffalo. And we'll put our money where our mouth is.

So, today, I say to national and global industries: Come to Buffalo. The State of New York is ready to invest $1 billion in a multi-year package of economic development incentives. That's a "B" — for $1 billion and for Buffalo.

Let's empower the Buffalo Regional Council to develop a viable plan to create thousands of jobs and to spur at least $5 billion in new investment and economic activity.

I have asked Bruce Katz of the Brookings Institution, a national expert on regional economic development strategies, to work with Buffalo to meet this challenge.

Second Round of Regional Economic Development Awards

Last year, we implemented our new economic policy:

- A macro strategy with New York Open for Business, a coordinated communications and marketing effort demonstrating to business leaders throughout the world the benefits of doing business in New York State; and

- A micro strategy with the Regional Economic Development Councils.

The Regional Councils exceeded all expectations across the state and redefined the way New York invests. Lieutenant Governor Bob Duffy has done a remarkable job in this effort. The councils transformed the state's economic development approach from a top-down model to a bottom-up, community-based one. The Councils act as a coordinated point of contact for state-supported economic development funding and business assistance programs in each region. This year, $785 million was awarded through the Councils.

We will keep the momentum going this year. We will be launching a $200 million second competitive round of regional economic development awards.

This year, New York Open for Business will go global and include a new effort coordinated by the Empire State Development Corporation and the Port Authority to boost New York's international competitiveness and market New York to the world as a place to invest and do business. New

York Open for Business will also promote tourism by highlighting our regional treasures like the Adirondacks, Catskills, our wine country, and our Long Island beaches. We have the greatest attractions in the country; let's market them properly and generate more tourism throughout the state.

Comprehensive Approach to Casino Gaming

We have long flirted and dallied with another potential economic engine — casino gaming — and when it comes to gaming, we have been in a state of denial.

It's time we confronted reality.

It's not a question of whether we should have gaming in New York — the fact is we already do. Native Americans have five casinos in New York and we have nine racinos at our racetracks. We don't fully realize it, regulate it, or capitalize on it, but we have gaming. In fact, New York State now has 29,000 electronic gaming machines — more than Atlantic City, and more than any state in the Northeast or Midwest.

Our state is also surrounded by gaming. States and Canadian provinces just across our borders have legalized casino gaming. They get the tourism, the revenue, and the good jobs that belong here.

It's estimated that over $1 billion of economic activity from gaming can be generated in our state. Therefore, let's amend the Constitution so that we can do gaming right. And let's take the first step this year.

The NY Works Fund and Task Force

We have a great opportunity to rebuild New York. We need private sector jobs, and we also need to rebuild our infrastructure to keep New York competitive and safe.

Currently:

- 32 percent of the state's bridges are rated deficient;

- 40 percent of the state's roads are rated fair or poor and getting worse; and

- 83 percent of our state parks and DEC's major dams are in disrepair.

We have much work to do. We cannot wait. And we need a new approach to get it done.

Today, I am announcing the New York Works Fund and Task Force to master plan, coordinate, leverage, and accelerate capital investment and put thousands of New Yorkers to work in every corner of the state. We will leverage state investment by a multiple of 20-to-1.

We will improve or replace more than 100 bridges. And we will finally build a new the Tappan Zee Bridge — because 15 years of planning is too long. We will repair 2,000 miles worth of roads – that's like driving from Buffalo to New York City five times! We will build new roads, bridges, and other critical transportation projects across the state.

We will finance upgrades to 90 municipal water systems. We will improve 48 state parks and historic sites visited by over 37 million people each year.

And in the wake of Hurricane Irene and Tropical Storm Lee, we will repair 114 flood control projects and dams.

Strengthen Our Energy Infrastructure with an "Energy Highway" System to Power New York's Economic Growth

Another key to powering our economic growth is expanding our energy infrastructure. Just as President Eisenhower's interstate highway project propelled the nation forward in the 1950s, today the energy grid provides critical infrastructure and an opportunity for economic growth.

We have an excess of generation capacity and tremendous wind power potential in Upstate and Western New York and north of the border in Quebec. We have tremendous energy needs Downstate. Just as we built the New York State Thruway to unite distant parts of the state, we will develop an "Energy Highway" system that will bring excess fossil-fuel energy from Western New York downstate, and also tap into Upstate's potential for renewable energy, like wind power. Just like we built the Northway, we will develop an energy expressway down from Quebec. This will preserve Western New York's current allocation of low cost hydropower and at the same time help address the energy needs of Downstate.

To make this happen, we will issue requests for proposals to implement a master plan to power our needs for the next half-century. We believe private companies will finance and build $2 billion in infrastructure to complete the system and build the capacity to supply New Yorkers.

We will also work on repowering old and dirty plants so they stop polluting our urban neighborhoods and start increasing energy supply. The permanent Article X energy siting law we passed last year will be a critical tool to help with meeting our energy needs *and* protecting our environment in this effort. Not only will it fast-track much needed energy generation projects, but it will also be a model for including some of the strongest environmental protection regulations in the nation.

MTA Investment

Investments by the Metropolitan Transportation Authority help protect the reliability of the transportation network that supports the metropolitan New York regional economy and 8.5 million riders a day. MTA capital investment is also a major driver of economic activity and infrastructure development. The MTA's "Built in NY" program has an impact on economic development throughout New York State, from Oriskany to Jamestown, Yonkers to Plattsburgh. Vendors and suppliers around the state support MTA work and provide thousands of local jobs. We will continue to work with the Legislature to support the MTA capital program, not only for the system's 8.5 million daily riders, but also for manufacturing in the state.

Invest in Solar While Protecting Ratepayers

New York is a national leader in renewable energy production and use. Not counting our large-scale hydropower resources, close to 2,000 megawatts of renewable energy capacity have been built in New York — a number nearly three times greater than the combined total of Massachusetts, New Jersey, and Connecticut. Moreover, we have one of the most cost-effective renewable resource development programs in the country.

New York is fortunate to have abundant water, wind, biomass, and solar resources. Over the decades, we have aggressively developed our hydroelectric resources and are making great progress in tapping our land-based wind resources. Now it is time to focus more attention on exploiting our solar potential.

But we need to do this in ways that protect the ratepayer — and certain approaches that have been proposed do not meet both goals of expanding production of solar energy *and* protecting the ratepayer. Solar power is still more expensive per megawatt hour to develop than other renewables.

Therefore, we will greatly expand the state's solar programs, but as we do so we will keep an eye firmly on costs. We will increase competitive procurement of large, commercial-sized solar projects. And we will expand rebate programs for residential and commercial small-to-medium systems.

In its first year, the NY-Sun Initiative will be capable of doubling the customer-sited photovoltaic capacity that was installed in 2011. By 2013, we estimate that NY-Sun will quadruple the 2011 capacity. We will continue to establish New York's technology leadership in this important emerging market while balancing investments in other renewable resources and protecting the taxpayer. This approach will create jobs, expand solar power, and protect ratepayers — a win, win, win.

Expedite On-Bill Financing for Consumer Energy Efficiency Upgrades

New York was the first state in the nation to offer a statewide program that allows consumers to retrofit their homes with energy efficient upgrades and pay for the cost on their monthly energy bill. The work pays for itself over time because the energy savings reduce consumers' energy bills by more than the cost of repaying the loan. On-bill financing was scheduled to commence in June 2012, but we have reached an agreement with utilities to begin offering it in January 2012. This early start will help produce immediate jobs, and it has the potential to provide benefits to 40,000 homes across the state.

Master Plan for Energy Efficiency in State Facilities

In order to promote energy efficiency — and, at the same time, save money, create jobs, and reduce pollution – we are developing a master plan for accelerating energy-saving improvements in state facilities. The plan will call for substantial investment in cost-effective energy efficiency measures in state buildings over the next four years.

Millions of dollars can be saved if we implement economical energy efficiency measures. All of this will be accomplished at no cost to the state because the upfront investment will be repaid from the energy savings.

Beyond the financial benefit, this program will also create thousands of highly skilled jobs across the state, including energy auditors, planners, engineers, electricians, and construction workers, and it will reduce lifecycle greenhouse gas emissions by 8.1 million metric tons — roughly equivalent to removing 1.4 million passenger vehicles from the road for one year.

Hydraulic Fracturing in the Southern Tier

In 2011, the Department of Environmental Conservation ("DEC") conducted a comprehensive review of the impact of proposed gas drilling using high-volume hydraulic fracturing. DEC presented for comment significantly improved measures to protect the state's drinking water, air, land, and other natural resources, and completed a study of potential socioeconomic impacts. DEC released the revised draft Supplemental Generic Environmental Impact Statement and comprehensive regulations governing all aspects of high volume hydraulic fracturing. DEC also held four public hearings around the state, attended by a total of 6,000 people. The Department received more than 15,000 comments.

DEC is reviewing all the comments and expects the final environmental impact study and the advisory panel's recommendations to be released in 2012, before any decisions are made on how to proceed.

Farm-NY: Strengthening Our Agriculture Sector

Agriculture contributes billions of dollars to New York's economy and has even more untapped capacity. We must do more to support and grow this critical industry. There is a serious need for new and upgraded farm infrastructure, and farmers will need access to low-interest loans, especially if interest rates rise in the next few years, to make these improvements.

We will free up vital capital by expanding the New York State Linked Deposit Program (LDP). Administered by the Empire State Development Corporation, the Linked Deposit Program provides farmers with capital at affordable interest rates. Currently, farmers can qualify for loans at a 3 percent interest rate reduction, if the project is located in a designated area of the state. We propose modifying the program to allow farmers anywhere in the state to qualify.

The U.S. Department of Agriculture has identified "food deserts" in 32 of New York's 62 counties, affecting more than 600,000 New Yorkers. Data show that almost 1.5 million New Yorkers live in areas with limited supermarket access. To help meet these New Yorkers' needs, we plan to expand FreshConnect farmers' markets, which have been highly successful. For example, our flagship market in Harlem attracted approximately 2,000 people each week.

Finally, we will promote food distribution by creating large-scale distribution hubs strategically located across the state.

Expanding food access for underserved communities can improve nutrition and lower costs related to obesity and diet-related disease while fostering community and economic development. Tackling the food access problem with New York agricultural products is a "win-win," benefitting underserved communities and New York farmers alike.

REIMAGINING GOVERNMENT

Without a doubt, this is an ambitious agenda. And we need a government that can make it happen. This is not a question of tinkering around the edges. We have to fundamentally reimagine how government operates.

We need a government that performs better and costs less.

A government that works for the people must make a long-term commitment to fiscal discipline. Our state is better able to compete when we keep taxes down. That means holding the line this year and agreeing to close our remaining $2 billion budget deficit with no new taxes and no new fees.

It also means enacting mandate relief. By next year, pension costs for schools and state and local governments will have increased 100 percent since 2009. We need to reform the pension system and create a Tier VI.

The joint Legislative and Executive Mandate Relief Council we created last year will begin its work this month. I will request that the Council hold public hearings. We need a robust public discussion on the pros and cons of the mandates. The Commission will issue a package of recommendations by the end of the session. We need a yea or nay vote this year.

Using Technology to Improve Performance and Reduce Cost: Virtual Capitol Online

To give our citizens more direct access to state government and to improve their customer experience, we are creating a "Virtual Capitol Online," a one stop shop for citizens.

The Virtual Capitol Online will feature a seamless approach, allowing citizens young and old to easily access information about an array of state agencies. It will also build on existing efforts to simplify online procedures for citizens searching for a range of services, such as finding support for a business, accessing health and human services information, and interacting with tax, labor, and motor vehicle agencies.

Education Commission to Promote Performance and Accountability

As we reimagine government, we must focus on our core values.

The future of our state depends on our public schools. A strong, effective school system is the hallmark of a healthy democracy.

We must make our schools accountable for the results they achieve and the dollars they spend.

I learned my most important lesson in my first year as Governor in the area of public education. I learned that everyone in public education has his or her own lobbyist.

Superintendents have lobbyists.

Principals have lobbyists.

Teachers have lobbyists.

School boards have lobbyists.

Maintenance personnel have lobbyists.

Bus drivers have lobbyists.

The only group without a lobbyist?

The students.

Well, I learned my lesson. This year, I will take a second job — consider me the lobbyist for the students. I will wage a campaign to put students first, and to remind us that the purpose of public education is to help children grow, not to grow the public education bureaucracy.

Today, we are driven by the business of public education more than the achievement in public education. Maybe that's why we spend more money than any other state but are 38th in graduation rates.

We have to change the paradigm. We need major reform in two areas:

- Teacher accountability and student achievement. We need a meaningful teacher evaluation system. The legislation enacted in 2010 to qualify for Race to the Top didn't work.

- Management efficiency. We must make our schools accountable for the results they achieve and the dollars they spend.

We cannot fail in our mission to reform public education, because we simply cannot fail our children.

I will appoint a bipartisan education commission to work with the Legislature to recommend reforms in these key areas.

Redesigning Our Emergency Management System

Another core mission of government is public safety. In this year's floods, we learned the hard way that we must anticipate and be well-prepared for all emergencies. We need a statewide network of emergency responders who are prepared for anything, anytime.

Our current system has serious limitations. During storms Irene and Lee, I witnessed firsthand breakdowns in communications and transportation and inadequate deployment of personnel. We must have the best state emergency management operation in the country.

Thankfully, we have the right person to lead this effort, Jerry Hauer. Jerry is an emergency management expert who served as Acting Assistant Secretary for the Office of Public Health Emergency Preparedness at the U.S. Department of Health & Human Services. He was also the former head of emergency management for the City of New York and the State of Indiana. He will help establish a new statewide network of municipal and regional emergency responders to help ensure the most efficient deployment of all our combined resources in emergency situations. Jerry will convene the first network conference in the coming months.

NEW YORK AS PROGRESSIVE CAPITAL

New York has a long and proud history as the progressive capital of the nation. It's a legacy that we reestablished last year with passage of landmark legislation such as the Marriage Equality Act. We must build on our success this year.

Foreclosure Prevention Assistance: Creation of a Foreclosure Relief Unit

The financial crisis has taken a terrible toll on our state's homeowners, forcing many out of their homes and putting many others at risk of foreclosure. Banks are unable or unwilling to renegotiate loans, and many of their foreclosure practices were questionable. Last year, I announced the new Department of Financial Services to provide meaningful oversight of our banks. The Department of Financial Services was a New York State innovation, combining financial regulation with consumer protection.

This year, I'm proud to announce that DFS is fully functioning and will soon include a Foreclosure Relief Unit to provide counseling and mediation services to help New Yorkers stay in their homes. We need to resolve this crisis so we can move on.

Creating a Tenant Protection Unit

Last year, we enacted the strongest rent regulations in 30 years. However, we have learned that tough laws on the books are not enough. Now, we must make sure those laws and regulations are being enforced.

While most landlords follow the law, there are still some bad actors and they must be held accountable. We will create the Tenant Protection Unit, which will be a part of an aggressive protection and landlord fraud prevention initiative housed in New York State Homes and Community Renewal. The Tenant Protection Unit will proactively enforce landlord obligations and impose strict penalties for failure to comply with New York's rent laws. Specifically, the Unit will investigate owners who may be involved in fraudulent schemes to deregulate apartments and thereby eliminate Rent Stabilization Law protections; commence overcharge proceedings against owners who are gouging tenants; and prosecute owners who fail to maintain basic building services such as heat and hot water. The Unit is just one part of my administration's plan to ensure that we are protecting the rights of the over one million tenants in rent stabilized apartments. The initiative includes developing state of the art technology to improve compliance monitoring and fraud detection. We will also improve outreach, service and notice to tenants.

These efforts will help to preserve the supply of safe and affordable housing in New York. Too many tenants have been abused for too long and it stops now.

Continued Commitment to Minority- and Women-Owned Businesses

Last year, I created a Minority- and Women-Owned Business Task Force dedicated to expanding economic opportunities for minority- and women-owned business enterprises ("MWBE"). The MWBE Task Force has aggressively sought ways to expand opportunities for MWBEs, and we will build on the Task Force's work this year.

In this economy, obtaining credit is difficult for almost everyone, especially small and minority-and-women-owned businesses. MWBEs historically have not been able to compete with more established companies on large construction projects because they lack credit and capital. The state will address this problem by extending credit that will give MWBE contractors the backing they need to compete. This program will support at least $200 million in contracting for MWBE firms over a period of years.

We must also make sure that all eligible MWBEs are certified. Therefore, we will expand the pool of certified MWBEs and expedite and modernize the certification process. We will implement a new web-based MWBE Certification and Tracking System to enable applicants to submit documents online, track the progress of their application, and be notified electronically of any missing information.

The state will also hold quarterly open houses to provide technical and procurement support for small businesses, helping both to increase the pool of certified MWBEs and to provide the tools necessary to obtain state contracts.

Because of these efforts, among many others, we will hit our target of doubling MWBE participation in state contracting to 20 percent.

Caring for Our Most Vulnerable Citizens

We must transform the way we deliver services to our over two million residents with disabilities. We spend more than any other state on services and support provided both by our government and a vast array of nonprofit and private agencies. Yet according to a recent report, New York ranks in the bottom quartile among states in serving adults with disabilities. This situation is fiscally irresponsible and morally unacceptable.

Many of the problems our disabled residents encounter are not the result of limited resources, but rooted instead in failures in the organization and management of services. We must develop a system that recognizes the potential of and the barriers faced by each individual we serve. We must focus on quality and prevention, and simplify and streamline access to services.

As the Supreme Court ruled in *Olmstead v. L.C.*, people with disabilities have a right to receive care in the most integrated setting appropriate to their needs. Therefore, we will develop an Olmstead Implementation Plan that will guide the transition of individuals from institutional to community-based care, provide access to affordable and accessible housing, and promote employment of persons with disabilities. We must erase stigmas and ensure that the rights of people with disabilities are fully recognized and fully protected.

In addition, we must do all we can to ensure the safety of those in our care. That is why, last year, I appointed Clarence Sundram, a leading expert on the provision of care to persons with developmental disabilities, as my Special Advisor on Vulnerable Persons. Mr. Sundram has engaged in a comprehensive review of relevant state programs and we will implement reforms to better protect against abuse and neglect.

Implement the New York Health Exchange

Almost 16 percent of New Yorkers under the age of 65 — 2.7 million people — are uninsured. Most are working people and their dependents.

We have a unique opportunity to address this challenge by developing a New York State Health Insurance Exchange that will be financed entirely by the federal government. When the Exchange is implemented, more than one million New Yorkers will gain health coverage and individuals who currently buy their coverage directly will see their cost drop by 66 percent. Small businesses will see the cost of providing coverage to their employees drop by 22 percent. In addition to the benefits to the uninsured and small businesses, the Exchange will benefit New York's taxpayers. The $1.7 billion that taxpayers currently contribute to offset the cost of providing care to the uninsured will be significantly reduced. The increased federal Medicaid match that recognizes New York's higher Medicaid eligibility levels will bring an additional $18 billion in funds to the state over 10 years.

We must enact the legislation necessary to establish the Health Insurance Exchange now.

Additional SUNY Challenge Grants

Our SUNY system is a precious New York asset. It has been the great equalizer for the middle class. It has allowed countless New Yorkers from working families to gain a quality college education. Last year, we enacted NYSUNY2020, offering challenge grants to SUNY research centers for plans to connect academic excellence and economic development. This year, we will offer SUNY's 60 other campuses the ability to compete for three $20 million challenge grants, with $10 million coming from the Executive and $10 from SUNY.

I am proud to partner with SUNY Chancellor Nancy Zimpher to make our colleges and universities centers of excellence, innovation, and job creation.

No Child Should Go to Bed Hungry in New York

For all of our progress, there are still basic wrongs to right. There is never an excuse for letting any child in New York go to bed hungry. Statewide, 1 in 6 children live in homes without enough food on the table. Yet 30 percent of New Yorkers eligible for food stamps — over 1.4 million people — do not receive them, leaving over $1 billion in federal funds unclaimed every year. We must increase participation in the food stamp program, remove barriers to participation, and eliminate the stigma associated with this program. And we must stop fingerprinting for food. No child should go hungry in the great State of New York and we will do all that we can to prevent it.

Create an All-Crimes DNA Database

To protect all New Yorkers, I propose that we expand our DNA databank. This databank helps establish guilt and innocence; it has provided leads in over 2,700 convictions and — just as important — led to 27 exonerations of the wrongfully accused.

Currently, DNA is collected only from those convicted of less than half the crimes on the books in New York State. Among the exclusions are numerous crimes that are often precursors to violent offenses. As a result, we are missing an important opportunity to prevent needless suffering of crime victims. We are also failing to use the most powerful tool we have to exonerate the innocent.

I will propose a bill requiring the collection of a DNA sample from any person convicted of a felony or Penal Law misdemeanor. DNA can be the key to exonerating the innocent, convicting the guilty, and protecting all New Yorkers in a fair and cost-effective way. Let's put New York on the cutting edge of criminal justice and become the first state in the nation to collect DNA on all crimes. Let's lead the way again.

Establish a Tax Reform and Fairness Commission

Our recent reforms to the state's tax code will boost job creation and restore fairness to the tax system. While these reforms were huge steps forward, there is more work to be done to create a complete fair tax plan. That is why I am creating a Tax Reform and Fairness Commission to propose additional, long-term changes to our corporate, sales, and personal income tax systems. We will find ways to close tax loopholes, promote efficiency in administration, enhance collection and enforcement, and simplify the tax code to improve New York's business climate, especially for small businesses.

Implement Campaign Finance Reform

It's time we make sure that all New Yorkers have an equal voice in our political process. Therefore, it is imperative that we implement real campaign finance reform and provide citizens with a voice in the very foundation of democracy — the ballot box.

New York currently ranks 48th in voter turnout in the nation. Moreover, according to the Campaign Finance Institute, a smaller percentage of the population gives to candidates for election to state office in New York than in any other state.

We must reconnect the people to the political process and their government.

First, we must achieve fundamental campaign finance reform by implementing a system of public funding of elections. New York City's public financing system provides a good model for statewide reform. The system has helped to increase the number of overall contributors — and especially the number of small donors — in city elections. To make sure we are protecting taxpayers, we will enact strict limits on total public funding per election, and we will phase the system in gradually.

Second, we must lower contribution limits. For most offices, New York State's contribution "limits" are substantially higher than those of any other state that imposes limits. Further, existing contribution limits for corporations are riddled with loopholes. In short, the state's campaign finance laws fail to prevent the dominance of wealthy contributors and special interests.

Third, we must enact pay-to-play rules to further restore the public trust. Companies and individuals who do business with the state should have no undue influence over elected officials. Accordingly, we must enact low contribution limits for public contractors and lobbyists.

Fourth, we must improve the enforcement of our state's campaign finance laws by creating a new enforcement unit in the State Board of Elections with the independence and authority to investigate alleged violations.

These and other reforms to our campaign finance laws are necessary to empower New Yorkers by giving them an equal voice in our elections. We must enact campaign finance reform this year.

Independent Redistricting

Unlike many other states, New York's elected representatives decide what their districts should look like. That puts the interests of incumbents ahead of the public interest. As part of my reform agenda, it is imperative that an independent redistricting process produce new district maps for New York State after each census and I would veto any lines not developed through such a process. Independent redistricting will help restore public trust in government.

The redistricting process would work transparently with public hearings held in every corner of New York. Comments and feedback would be submitted by individual voters, organizations, and stakeholders. The proposed district maps will be subject to extensive public comment and revised as necessary before being finalized.

Protect Reproductive Rights

I will continue to vigorously protect a woman's right to choose and will fight for passage of the Reproductive Health Act. This Act protects the fundamental right of reproductive freedom and a woman's right to make private health care decisions. A woman facing an unplanned or problem pregnancy should have the opportunity to make the best decision for herself and her family. The Reproductive Health Act will ensure that the rights of individuals to make difficult and personal health care decisions are preserved

Create an Office for New Americans

We must also live up to the promise of the Lady in our Harbor and ensure that New York remains a land of opportunity for all. We will create an Office for New Americans to assist the many legal permanent residents eager to contribute to our economy and become part of the family of New York.

For those with high skills training and experience, the Office for New Americans will provide assistance in obtaining the licenses and credentials they need to get good jobs. For those with limited formal education, the Office will provide access to adult education and job training.

The Office will promote programs that encourage new Americans to participate in New York State civic and economic life, and will help legal permanent residents navigate the path to citizenship. It will also help them by encouraging entrepreneurship. Finally, it will take steps to protect new Americans as they transition to full participation in New York's communities.

When new New Yorkers prosper, we all prosper. When they succeed, we all succeed. We are not afraid of immigrants in New York – because we are immigrants, and children of immigrants, and we know how much they contribute to the state.

Train Leaders for a *New* New York

As I've said, we must address the state's human capital crisis. The *New* New York Leaders Initiative will create opportunities for the state's next generation to dedicate their careers to public service.

The Initiative will consist of two components aimed at renewing the connection between young people and the state and ensuring that our government is diverse, talented, and prepared to lead the way for decades to come.

The first component, the Student Intern Program, will bring students into state government to allow them to experience the work of governing and the complex policy challenges facing New York State. Each student will be assigned to a particular area within an Executive Branch agency or department. The program will provide hands-on experiences for interns to interact with government leaders and policymakers.

The second component, the Empire State Fellows Program, is a full-time leadership training program that will prepare the next generation of talented professionals who are members of underrepresented groups for careers as New York State policymakers. The program will provide exceptional mid-career professionals with firsthand experience working at the highest levels of New York State government. The Empire State Fellows Program is an opportunity to expand the way we develop policymakers in New York State and help ensure that New York retains its position as a leader in policy innovation.

Conclusion

By all accounts, last year was a tremendous success. There are many reasons why, including one simple one: We changed our attitude. We had a constructive impatience for government dysfunction and a disregard for the political extremists on the left and the right, we believed in the people, and we had a mutual respect, both institutional and personal.

By the end of the year, we were not first Democrats and Republicans, we were first New Yorkers and we acted that way. We put the politics aside and put the people first. And it worked. And we worked. We delivered for the people — and we made this state a better state and I was honored to be a part of it with you.

Cynics will say we can't do it again, that we can't do any better. Well, cynics don't know us, and they don't know New York.

Today, I am telling you this: we are going to reach even higher.

Last year, we learned to walk — this year, we run.

They elected us to lead, and we will join hands and lead.

We have only begun to explore the capacity of our partnership and the limits of our imagination.

Together, we can make New York the strongest it has ever been. We can build the biggest convention center in the country. We can build a new energy system across our entire state. We can stop talking about yesterday in Buffalo and start talking about tomorrow. We can rebuild this government for a new generation. We can rebuild 100 bridges and 2,000 miles of road. We can create thousands of jobs. We can rebuild our State Capitol better, brighter, and smarter than ever before.

And we can welcome a new generation of New Yorkers to visit the best Capitol in the country, where we stand on a proud history to reach toward a brighter future.

We dream big and we act smart — because we know who we are, we are New York.

We built the Empire State Building — all 102 stories — in just 400 days — in the middle of the depression — because we are New York.

We opened the Erie Canal, an engineering marvel that opened the nation to commerce — because we are New York.

We are the birthplace of the women's suffrage movement, the environmental movement, the workers' rights movement. We are the nation's progressive voice — because we are New York.

We are the gateway for immigrants worldwide and we are proud of it.

Other states build walls to keep people out and we open our arms and invite people in because we are the state of immigrants.

We don't fear diversity, we celebrate diversity—because we are New York

We are the state of infinite possibility — because we are New York.

There is nothing that we can't do when we are together. Because we are New York.

Let's make dreams come true.

Let's get to work!

CONGRESS OF THE UNITED STATES
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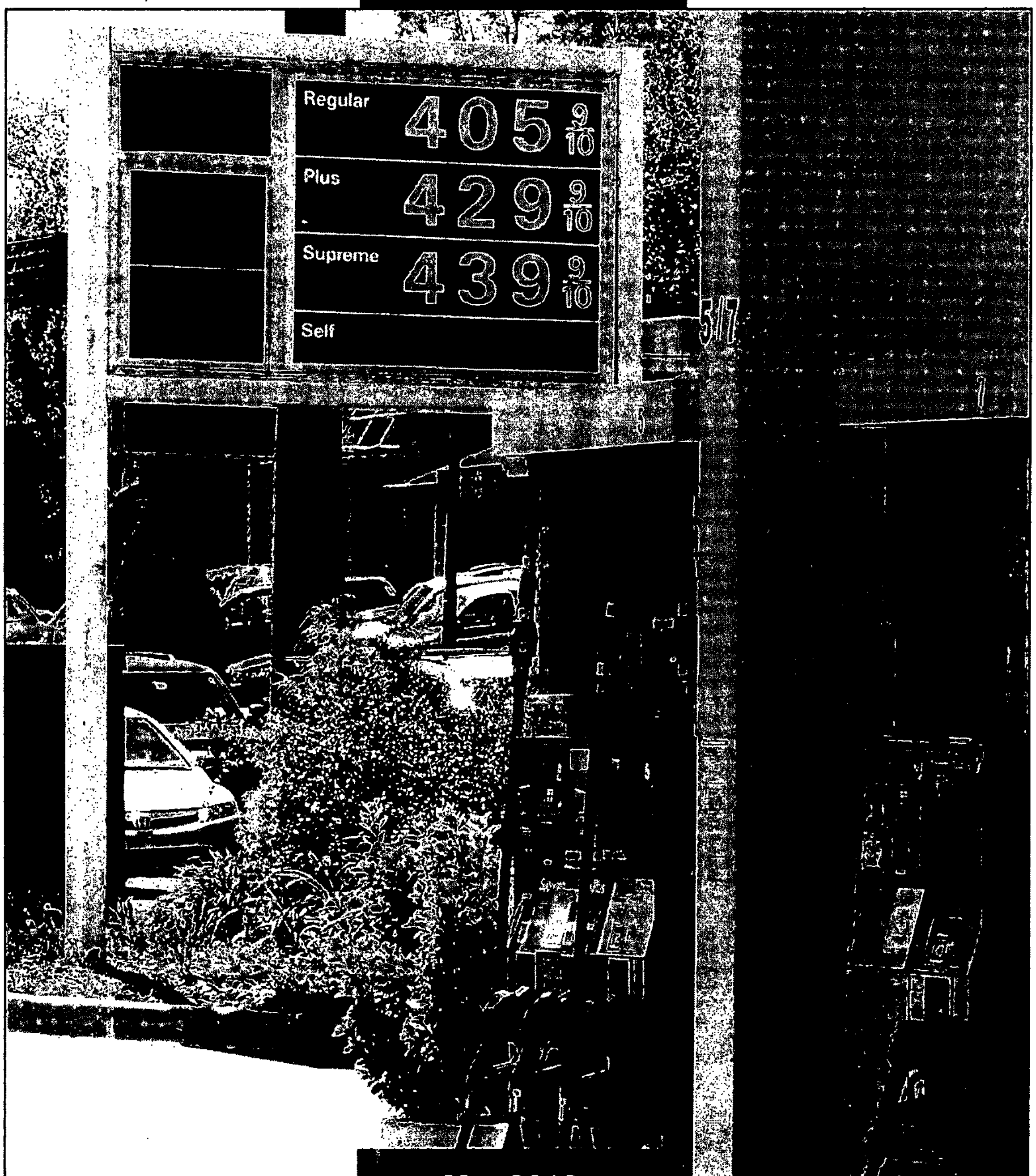
Energy Security in the United States



May 2012

Note

Numbers in the text and tables may not add up to totals because of rounding.

Contents

Summary

Energy use is pervasive throughout the U.S. economy. Households and businesses use energy from oil, natural gas, coal, nuclear power, and renewable sources (such as wind and the sun) to generate electricity, provide transportation, and heat and cool buildings. In 2010, energy consumption represented 8.4 percent of U.S. gross domestic product.

Disruptions in the supply of commodities used to produce energy tend to raise energy prices, imposing an increased burden on U.S. households and businesses. Disruptions can also reduce the nation's economic output and thus people's income. This paper examines energy security in the United States—that is, the ability of U.S. households and businesses to accommodate disruptions of supply in energy markets—and actions that the government could take to reduce the effects of such disruptions.

The vulnerability of the U.S. economy to disruptions in the supply of a particular energy source depends on the importance of that energy source to the economy. More than 80 percent of the energy consumed in the United States comes from oil, natural gas, or coal. For each source, several factors determine how vulnerable the nation is to a disruption in its supply:

- The extent to which disruptions occurring anywhere in the world affect energy costs in the United States,
- The likelihood of disruptions and the ability of energy suppliers to respond to disruptions if they occur, and
- The ability of energy consumers (including electricity producers, oil refiners, households, and businesses) to shift to other, less expensive sources of energy.

Consumers and the economy are more vulnerable to disruptions in oil markets than they are to disruptions in other energy markets, as shown by a comparison of the two largest energy-consuming sectors of the U.S. economy—transportation and electricity. In particular, transportation is almost exclusively dependent on oil supplied in a global market in which disruptions can cause large price changes. Moreover, consumers have few easy and inexpensive options for switching to other fuels or reducing consumption of transportation fuels. In contrast, electricity can be produced from several sources of energy, all of which are less prone to disruptions, and consumers have more options for reducing demand for electricity.

The Potential for Global Disruptions to Affect U.S. Energy Prices

Disruptions in the supply of any commodity tend to raise that commodity's price; however, disruptions in the supply of oil have a much larger effect on prices than interruptions in the supply of other energy commodities. The extensive network of pipelines, shipping, and other options for transporting oil around the world means that a single world price for oil prevails, after accounting for the quality of that oil and the cost of transporting it to the marketplace. Except for countries where the price of oil is regulated or subsidized in certain ways, disruptions related to oil production that occur anywhere in the world raise the price of oil for every consumer of oil, regardless of the amount of oil imported or exported by that consumer's country. In contrast, the high cost of moving natural gas, coal, nuclear power, and renewable energy limits their markets to geographically bounded regions, such as North America. Consequently, foreign disruptions have had little or no effect on the prices of those fuels in the United States.

Although the global nature of the market for oil makes U.S. consumers vulnerable to price fluctuations caused by events elsewhere in the world, it also benefits those consumers by lowering the price of oil relative to what it

would be in a regional oil market; that benefit would be greater, however, if the global market was less prone to disruptions or if oil producers and consumers were better able to adjust to such disruptions.

The Likelihood of Disruptions and the Ability of Suppliers to Adjust to Them

A substantial amount of oil is produced in countries that are vulnerable to disruptions resulting from geopolitical, military, or civil developments, and few countries other than Saudi Arabia have much spare production capacity in the near term to offset such disruptions. In contrast, the U.S. markets for natural gas, coal, nuclear power, and renewable energy either are less prone to long-term disruptions or have significant spare production and storage capacity. For example, U.S. producers and consumers of natural gas maintain a significant reserve in storage (30 percent of annual consumption in 2010). Similarly, stocks of coal in 2010 represented 9 weeks of U.S. consumption and, over the past decade, producers of coal in the United States maintained an average spare production capacity of 17 percent. Much of the limited potential for disruptions in the supply of those fuels involves their transport across the United States (via pipeline, railcar, river barge, or truck), for which redundancy and spare transport capacity exist.

The Ability of Energy Consumers to Adjust to Disruptions

The U.S. electricity system is quite flexible and operates with significant spare capacity in most circumstances. That spare capacity means that when western coal is not available to electricity providers in the East, for example, they can shift generation to facilities that rely on coal from Illinois or Appalachia or increase generation from natural gas or renewable sources. In addition, some facilities are maintained in reserve and operated only during periods of peak electricity demand or during a disruption at another facility. Thus, when the price of one commodity used to generate electricity rises, another commodity can be substituted, keeping electricity prices relatively stable.

In contrast, the United States has no alternatives that can be readily substituted in large quantities for oil in providing fuel for transportation. Moreover, consumers have less flexibility in the near term in how they use transportation, and changes in transportation use tend to be more expensive over the long term than changes in electricity use. For example, households and businesses can reduce electricity consumption by adjusting their thermostat settings or switching to energy-efficient light bulbs in the near term, or they can switch to natural gas heating or energy-efficient appliances over the long term. However, most decisions that would reduce transportation costs, such as what vehicle to drive or where to live, cannot easily be altered in the near term. Changes can be made over the long term, but such adjustments tend to be more expensive than those that can be made to reduce electricity use.

Policy Options to Improve Energy Security in Transportation

Addressing concerns about U.S. energy security requires considering policies related to the nation's supply of and demand for oil, because transportation relies so heavily on that commodity. Because of the global nature of the oil market, no policy could eliminate the costs borne by consumers as a result of disruptions but some policies could reduce those costs. This report examines the ability of some commonly proposed policies to decrease those costs, but it does not evaluate the costs or benefits of implementing those policies or how well they would address other objectives.

Policies designed to address temporary disruptions could seek to increase the supply of oil (by releasing oil from the Strategic Petroleum Reserve, for instance); facilitate development of markets to provide insurance that would protect consumers against sharp increases in prices; or provide consumers with options for reducing their consumption of oil (by expanding public transportation service, for example, or promoting the use of telecommuting). A release of oil from the Strategic Petroleum Reserve or more widespread use of insurance could reduce the impact of some disruptions, although the beneficial effects of such policies could be neutralized if releases were not implemented in coordination with other oil-producing countries or the insurance did not transfer risk to those better able to bear it. Policies that enabled consumers to use their vehicles less during periods of high gasoline prices would be more likely to lower costs for households and businesses.

Policies designed to decrease the impact of increases in oil prices that persist for several years or more can also be divided into those that would increase the supply of oil or oil substitutes (such as increasing domestic oil production) and those that would encourage consumers to reduce their reliance on oil (such as increasing the gasoline tax or developing vehicles that are more fuel efficient or that use other types of fuel). Both types of policies would tend to lower the world price of oil, either by making more oil available to the world market or by reducing demand for it. However, the effect of either type of policy on the world price would probably be small. Many analysts (including the U.S. Energy Information Administration) expect that large oil-producing countries would reduce their actual or planned production of oil in the face of increased production of oil in the United States, thereby diminishing or eliminating the effect of such U.S. actions on the world price of oil. Recently, for instance, Saudi Arabia announced that it would reduce its planned expansion of oil production in light of increased production in Brazil and Iraq.

Policies that promoted greater production of oil in the United States would probably not protect U.S. consumers from sudden worldwide increases in oil prices stemming from supply disruptions elsewhere in the world, even if increased production lowered the world price of oil on an ongoing basis. In fact, such lower prices would encourage greater use of oil, thus making consumers more vulnerable to increases in oil prices. Even if the United States increased production and became a net exporter of oil, U.S. consumers would still be exposed to gasoline prices that rose and fell in response to disruptions around the world.

When a disruption occurs, those countries with spare production capacity—of which Saudi Arabia is the largest—can determine whether to partially or fully offset the disruption. In fact, Saudi Arabia has chosen to offset, to a large extent, the impact of disruptions by increasing production when oil prices rise because of a disruption. If the United States was able to develop similar spare production capacity held in reserve until disruptions occurred, that capacity could be used to limit increases in oil prices during times of disruption—but pursuing that option would probably be costly or impractical. Production capacity in the United States is owned by private firms and operated on the basis of the geologic characteristics of the oil reserves and the returns required by shareholders. Without sufficient compensation, private firms would be unlikely to hold newly developed capacity in reserve and use it only to offset disruptions in other countries. Therefore, such spare capacity would probably need to be owned by the U.S. government.

In contrast, policies that reduced the use of oil and its products would create an incentive for consumers to use less oil or make decisions that reduced their exposure to higher oil prices in the future, such as purchasing more fuel-efficient vehicles or living closer to work. Such policies would impose costs on vehicle users (in the case of fuel taxes or fuel-efficiency requirements) or taxpayers (in the case of subsidies for alternative fuels or for new vehicle technologies). But the resulting decisions would make consumers less vulnerable to increases in oil prices.

Energy Security in the United States

Energy Security and Its Economic Significance

Energy plays a vital role in Americans' lives and in the U.S. economy as a whole, particularly in the provision of electricity, transportation, heating and cooling, and industrial processing—the four main energy-consuming sectors of the economy. Energy consumption in those four sectors equaled 8.4 percent of gross domestic product (GDP) in 2010 (see Table 1).

This report examines the various commodities used to generate energy in the United States, focusing on the two largest energy-consuming sectors of the U.S. economy—electricity and transportation—and the differences in how they expose U.S. households and businesses to disruptions, either domestic or international, in the supply of energy. In particular, electricity is generated from multiple sources (coal, natural gas, nuclear power, and renewable fuels) that are primarily supplied in regional markets made up of one or more countries; in contrast, the transportation sector in the United States is powered almost exclusively by oil, which is supplied in a global market (see Figure 1).

What Is Energy Security?

One widely used definition of energy security—and the one used in this report—is the ability of U.S. households and businesses to accommodate disruptions of supply in energy markets.[1] Following a disruption or threat of disruption, energy prices can rise, imposing costs on U.S. consumers. Households and businesses are "energy secure" with respect to a particular source of energy if a disruption in the supply of that source would create only limited additional costs.

At times, policymakers have defined energy security in other ways. Some policymakers, for example, define energy security as having the flexibility to choose not to import oil from countries associated with terrorism or from countries that might seek to use their exports of oil to influence international affairs. That definition is often accompanied by a desire to rely on energy products from domestic sources or from countries that are unlikely to change the terms of their exports to the United States on the basis of its foreign policy decisions. Although there might be some benefits from increased domestic production, those benefits probably would not stem from an improvement in energy security as defined in this report. That is the case because competition within the marketplace ensures that all countries receive the same price for their energy products, after accounting for quality and transportation costs. Thus, even if the United States produced all of the oil it consumes (as Canada does), the nation would still be vulnerable to disruptions that cause oil prices to increase. Moreover, reducing imports of oil or other energy products from a particular country would probably not affect the income received by that country as long as other countries were willing to purchase those products. In global or regional markets, the price of energy depends on total consumption by all consumers within the same global or regional market.

Economic Effects of Disruptions in the Supply of Energy

Disruptions in the supply of energy impose both direct costs and indirect costs on households and businesses faced with higher energy prices. When supply disruptions cause energy prices to rise, U.S. households and businesses incur *direct costs* by paying more for goods and services (such as electricity, gasoline, and heat) produced

1. That definition conforms with those used by, for example, World Economic Forum, "The New Energy Security Paradigm," *Energy Vision Update* (Spring 2006); Michael Toman, "The Economics of Energy Security: Theory, Evidence, Policy," in A.V. Kneese and J.L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics*, vol. 3 (Amsterdam: Elsevier B.V./North Holland, 1993); and Lutz Kilian, "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature*, vol. 46, no. 4 (December 2008), pp. 871–909.

Table 1.

Energy-Consuming Sectors of the U.S. Economy, 2010

Sector	Energy Expenditures (Percentage of GDP)	Total Energy Use (Percent)	Primary Sources of Energy
Transportation	3.6	28	Oil (for gasoline, diesel, and jet fuel)
Electricity	2.4	40	Coal, natural gas, nuclear power, and renewable sources
Industrial Processing	1.5	16	Natural gas, oil, coal, and renewable sources
HVAC	0.8	15	Natural gas, oil, and renewable sources
Total	**8.4**	**100**	

Source: Congressional Budget Office's calculations based on data from Department of Energy, Energy Information Administration, *Short-Term Energy Outlook* (February 7, 2012) and *Annual Energy Review 2010* (October 19, 2011).

Notes: Industrial processing includes the nonfuel use of energy commodities as inputs in the production of plastics, resins, fertilizers, metals, and other chemicals.

Renewable sources of energy include hydropower, wood, biofuels, wind, waste, geothermal, and solar.

GDP = gross domestic product; HVAC = heating, ventilation, and air conditioning.

by that energy. The magnitude of those costs—whether incurred on a temporary or persistent basis—hinges, in part, on the options available for consumers to lower their expenditures on energy. In the near term, consumers can respond to higher energy prices in a number of ways—for example, by changing the temperature on their thermostat, switching to energy-efficient light bulbs, driving less or more slowly, or vacationing away from home less frequently. Those responses limit the cost increases that consumers face. Over the long term, consumers have more options for reducing their exposure to disruptions in energy markets because they have more time to budget for and make energy-saving decisions. For example, they can decide where to live or locate a business, what type of vehicle or fleet to purchase, and whether to buy heating and air conditioning units that are more energy-efficient. The more near-term and long-term alternatives consumers have available for responding to disruptions in energy markets, the less exposure they have to those disruptions.

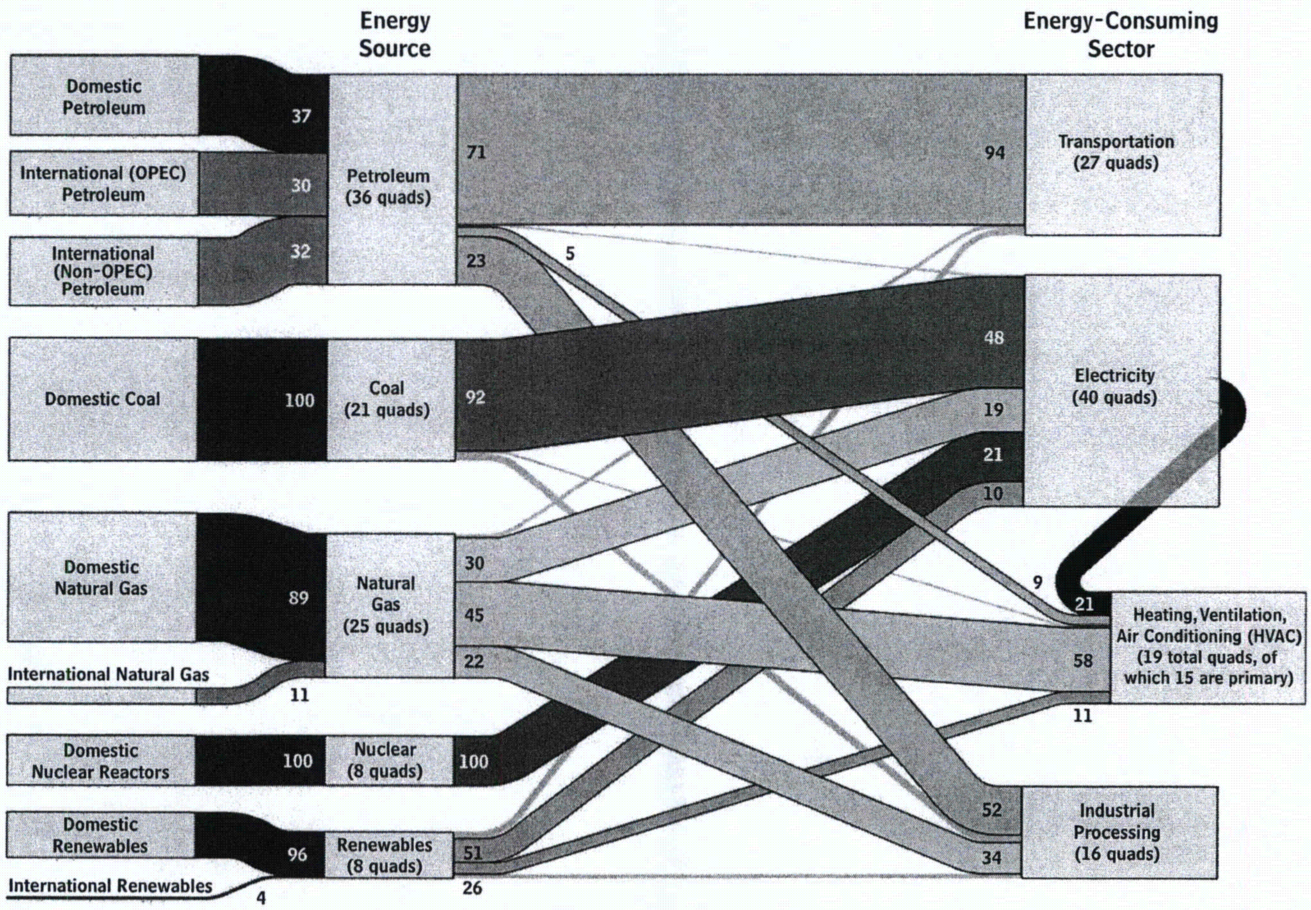
The direct costs—greater spending on some goods and services—would cause U.S. households and businesses to reduce their consumption of other goods and services, particularly if there were limited near-term alternatives for consumers to use less energy. That reallocation of resources among sectors and to energy producers would impose *indirect costs* on the economy that many economists consider to be the primary channel through which disruptions in energy supply affect the economy.[2] In particular, aggregate demand would be diminished in the near term for a number of reasons. Higher energy prices would shift income and wealth within the United States to energy producers and owners of the sources of energy, such as coal mines or oil and natural gas fields. That shift could temporarily reduce the demand for goods and services in the economy. Similarly, if the increase in energy prices stemmed from an increase in the price of crude oil, more money would be paid to foreign producers and owners of oil assets. The increased buying power overseas would not immediately translate into increased demand for U.S. exports. Furthermore, a large and sudden change in the price of an important consumer good—caused, for example, by a disruption in the supply of energy—could have a short-term impact on consumer spending by affecting consumer confidence. People might postpone some purchases out of concern about how the disruption would affect the economy. Those reductions in demand would tend to lead businesses to temporarily reduce investment and employment, thereby diminishing

2. See Kilian, "The Economic Effects of Energy Price Shocks." For related discussion, see Keith Crane and others, *Imported Oil and U.S. National Security* (Santa Monica, Calif.: RAND Corp., 2009); Lutz Kilian, "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?" *Review of Economics and Statistics*, vol. 90, no. 2 (May 2008), pp. 216–240; and James D. Hamilton, "Oil and the Macroeconomy," in Steven N. Durlauf and Lawrence E. Blume, eds., *The New Palgrave Dictionary of Economics*, vol. 6 (New York: Palgrave Macmillan, 2008), pp. 172–177.

Figure 1.

Energy Flows, by Source of Energy and Energy-Consuming Sector, 2010

(Percent)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: Unlabeled flows represent amounts of less than 10 percent, except in the renewables category, where the unlabeled flows are less than 15 percent. In the HVAC sector, primary energy is that which comes directly from one of the five energy sources; total energy is primary energy plus electricity used for HVAC.

OPEC = Organization of Petroleum Exporting Countries; quad = a unit of energy equal to a quadrillion British thermal units.

household income and further lowering consumer spending. An increase in crude oil prices would also have a permanent effect on the economy, as the increase in payments to foreign producers and owners of oil assets would represent a transfer of wealth out of the United States.

The ultimate effect on the economy of an increase in energy prices would depend on the response of the Federal Reserve to expected changes in inflation and employment. Under typical economic circumstances, an increase in energy prices that reduced demand would also increase the costs of production, leading to higher inflation. However, if the Federal Reserve raised short-term interest rates to avoid an increase in inflation, it would exacerbate the drop in output and the rise in unemployment.[3]

3. In the current environment, however, the Federal Reserve has indicated a desire to keep interest rates exceptionally low for an extended period; as a result, it would probably be less inclined to raise short-term interest rates in the face of an increase in energy prices over the next couple of years. That restraint would probably lead to a smaller effect on economic output in the near term from an increase in energy prices, but a larger effect on near-term inflation.

As one example, a sustained $50 per-barrel rise in oil prices from about $100 (the price in April 2012) would be expected to boost gasoline prices by $1.20, to more than $5.00 per gallon. Consumers would probably reduce the amount of gasoline they used by a small amount; on net, consumers' annual expenditures on gasoline would rise by about $150 billion, and consumption of other goods and services would fall. The Congressional Budget Office (CBO) estimates, on the basis of historical experience, that such an increase in prices would reduce real (inflation-adjusted) GDP over the subsequent four quarters by ½ percent to 1 percent below what it would be if oil prices remained near their current level. At today's oil prices, changes of more or less than that amount would have roughly proportionate effects on the economy; thus, an additional increase of $10 per barrel would reduce GDP by 0.1 percent to 0.2 percent.

By CBO's estimate, the projected overall effect on the economy would differ somewhat from what occurred between the beginning of 2004 and early 2006, when the price of crude oil doubled from $30 to $60 per barrel. In a 2006 report, CBO estimated that the doubling in the price of oil lowered GDP by about 1 percent by the end of that period.[4] With oil prices now at roughly $100 per barrel, expenditures for petroleum products make up a larger share of the economy than they did in early 2004. Consumer outlays for motor vehicle fuels were 1.7 percent of GDP in the fourth quarter of 2003 but 2.6 percent of GDP in the fourth quarter of 2011. Because a $30 increase now would be a smaller percentage increase relative to today's higher prices, such an increase would have a smaller effect on the economy today than it did from 2004 to 2006. But a doubling of oil prices today would have a larger economic effect.

Potential Effects of Disruptions in Key Energy Markets

A disruption in the market for an energy commodity would probably increase the price of that commodity, but the amount of the increase would depend on the attributes of the market. Disruptions can come from shocks to the supply of energy, such as the hurricanes in the Gulf of Mexico in 2005 or the political unrest that occurred in Libya in 2011. Both events caused the price of oil to increase. (Energy prices can also increase because of significant changes in the demand for energy. For example, the dramatic increase in Chinese demand for energy in the 2000s pushed up the price of energy consumed in many other countries, including the United States.)[5] This report is primarily about disruptions in the supply of energy, but U.S. consumers are vulnerable to disruptions in supply or demand for energy. To the extent that a particular commodity is not part of a global market but is instead traded primarily in regional or local markets, such disruptions may not affect the price of energy paid by U.S. consumers if those disruptions occur in other countries. However, a more localized market will tend to concentrate the economic harm when disruptions occur in that market.

Any disruption has the potential to raise prices unless producers of the affected commodity are able to offset the disruption by quickly boosting their own production or drawing down their own stores of the commodity. The price increase from any such disruption would be similar for all consumers in the same global, regional, or local market as that in which the disruption occurred. Because producers of oil have a limited ability to increase production to offset disruptions and because oil is traded in a global market, disruptions anywhere in the world would be expected to raise oil prices for all consumers. In contrast, producers of coal, natural gas, nuclear power, and renewable energy maintain excess production capacity or storage to offset disruptions. Also, because those commodities are traded in regional or local markets, disruptions outside the United States, Canada, and a few other nearby trading partners would probably not affect their price in the United States.

Oil

The market for crude oil has the following key characteristics:

- A substantial amount of oil is produced in countries that are vulnerable to geopolitical, military, or civil disruptions;
- Oil is supplied in a global market that rapidly transmits the effect of disruptions to the prices paid in all oil-consuming nations, regardless of the amount of oil those nations produce domestically;

4. See Congressional Budget Office, *The Economic Effects of Recent Increases in Energy Prices* (July 2006).

5. See Congressional Budget Office, *China's Growing Demand for Oil and Its Impact on U.S. Petroleum Markets* (April 2006).

Table 2.

Production of Oil and Consumption of Oil Products

(Millions of barrels per day, estimated, in 2010)

	Top 20 Countries That Produce Oil		Top 20 Countries That Consume Oil Products	
1	Russia	9.7	United States	19.2
2	Saudi Arabia[a]	8.9	China	9.4
3	United States	5.5	Japan	4.5
4	Iran[a]	4.1	India	3.1
5	China	4.1	Russia	3.0
6	Canada	2.7	Saudi Arabia	2.7
7	Mexico	2.6	Brazil	2.6
8	Nigeria[a]	2.5	Germany	2.5
9	United Arab Emirates[a]	2.4	South Korea	2.3
10	Iraq[a]	2.4	Canada	2.2
11	Kuwait[a]	2.3	Mexico	2.1
12	Venezuela[a]	2.1	France	1.9
13	Brazil	2.1	Iran	1.8
14	Angola[a]	1.9	United Kingdom	1.6
15	Norway	1.9	Italy	1.5
16	Libya[a]	1.7	Spain	1.4
17	Algeria[a]	1.5	Indonesia	1.4
18	Kazakhstan	1.5	Singapore	1.1
19	United Kingdom	1.2	Netherlands	1.0
20	Qatar[a]	1.1	Australia	1.0
	Other	11.7	Other	20.0

Source: Congressional Budget Office based on data from Department of Energy, Energy Information Administration, "International Energy Statistics: Crude Oil Production Including Lease Condensate, All Countries" and "International Energy Statistics: Total Petroleum Consumption, All Countries" (April 23, 2012).

Note: Production numbers represent the volume of oil produced from reservoirs underground. During processing, additives and other refining steps contribute to a larger volume of oil products relative to the oil inputs. Consumption numbers represent the volume of oil products consumed, including gasoline, diesel, and jet fuel.

a. Indicates membership in the Organization of Petroleum Exporting Countries (OPEC). The only OPEC country not included in the list of producers above is Ecuador. Collectively, OPEC members produced 32 million barrels of oil per day in 2010 and consumed 8 million barrels of oil products per day.

- Most oil-producing countries have a limited spare capacity to increase production over the short term in response to such disruptions; and
- The United States has very little ability to affect the world price of oil by increasing the supply of oil to the market.

Compounding the above effects, consumers of oil products (such as gasoline) have very few options for reducing consumption or switching to other fuels when disruptions occur (see pages 21–22 for more information about the consumption of oil).

Risks of Disruptions. Disruptions in the production of oil are most likely to occur because of instability in oil-producing countries.[6] More than 100 countries produce oil, but a much smaller group produces a large share of the world's oil (see Table 2): In 2010, the 12 countries that constitute the Organization of Petroleum Exporting Countries (OPEC) supplied 43 percent of the world's oil; Russia, the United States, and China accounted for another 26 percent.

6. The instability of oil-producing countries is described in more detail in Gail Cohen, Frederick Joutz, and Prakash Loungani, "Measuring Energy Security: Trends in the Diversification of Oil and Natural Gas Supplies," *Energy Policy*, vol. 39, no. 9 (September 2011), pp. 4860–4869.

OPEC was created by a desire of the organizing countries to collectively determine production amounts to keep oil prices within a target band. In addition to possible disruptions in individual oil-producing countries, disruptions in supply could also occur if OPEC members coordinated to reduce their production.[7] The production decisions by most OPEC members are made by the government (whereas in the United States, private firms set production amounts). Because, collectively, OPEC is the largest producer of oil in the world, a decision by that organization to reduce production could have repercussions throughout the world.

Significant production outages or threats of such outages anywhere in the world are likely to increase oil prices for all consumers; for example, oil prices increased significantly around the world following the Arab oil embargo in 1973; the Iranian revolution in 1979; the Persian Gulf conflict in 1990; Venezuelan civil unrest in 2002; Gulf of Mexico hurricanes Dennis, Katrina, and Rita in 2005; and the Libyan uprising in 2011. The extent of such increases depends on the ability of consumers to substitute other fuels for oil, although there is limited potential for such substitutions in the short term.

A Global Market. A defining characteristic of the oil market is its global nature: The network of shipping, pipeline, and transport options that moves oil around the world means that oil from anywhere in the world is generally bought and sold at a single price (though the price may vary depending on the quality of the oil and the costs of transporting it to the market). Consequently, disruptions in the supply of oil anywhere in the world rapidly result in higher oil prices worldwide. For example, disruptions in Iran—a country from which it is illegal for U.S. companies to import oil—that were not offset by increased production elsewhere would increase the price of every barrel of oil consumed in the United States, including the 39 percent produced domestically (as of 2011). A change in the price of any country's oil that is not caused by changes in its quality will be accompanied by a similar change in the price of every other country's oil (see the leftmost graph in Figure 2).[8]

7. For example, in the 1970s some oil-exporting countries in the Middle East reduced their production of oil in response to U.S. foreign policy actions in the region.

Such changes in global oil prices translate directly into price changes for the products made from refining crude oil, such as gasoline.[9] As a result, gasoline prices tend to rise and fall at the same time everywhere in the world. That outcome can be seen in the path of gasoline prices between 1999 and 2011 in Japan, Canada, and the United States (see Figure 3). Although gasoline prices in the three countries differed because of fees and taxes in each country, the changes in prices were consistent across countries. That result holds true even though over the time period evaluated, Japan produced almost no oil, the United States produced 30 percent to 40 percent of the oil it used each year, and Canada was a net exporter of oil. Thus, even if the United States increased production to become a net exporter of crude oil, U.S. consumers would still be exposed to gasoline prices that rose and fell in response to disruptions around the world.

The global nature of the oil market comes with benefits and costs for U.S. consumers. The global market benefits U.S. consumers by giving them access to less expensive oil; a market limited to North America or just the United States would have far higher oil prices because the demand for oil in the United States exceeds the supply from U.S. or North American producers. The United States currently imports 61 percent of the oil it consumes.[10] More than 50 percent of the imported oil comes from Canada, Mexico, and other non-OPEC members;

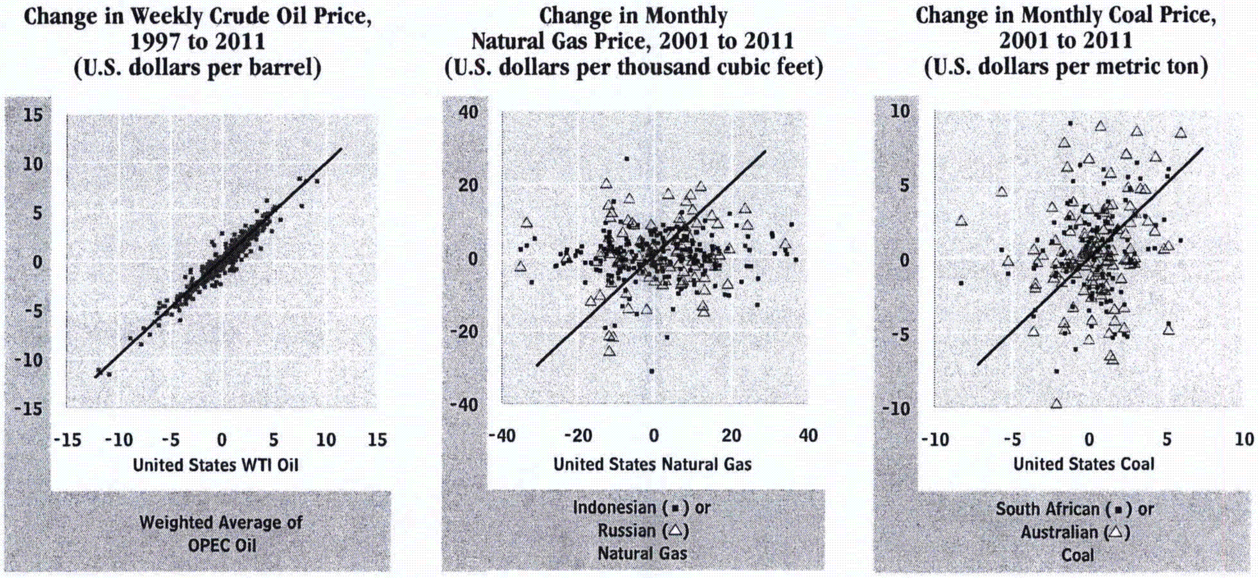
8. Crude oil is a mixture of hundreds of different chemicals. Its quality varies by region of the world, among other factors. Higher-quality crude oil contains less water, sulfur, and organic matter (such as dirt) and more of the components that are easier to burn (like propane and butane).

9. Some countries impose controls on gasoline prices. As a result, consumers may not pay the full cost of gasoline, and gasoline prices do not fluctuate with the world market. For example, Iran has historically offered heavily subsidized gasoline to its citizens; in December 2010, however, some of those subsidies were removed, and gasoline prices in that country nearly quadrupled.

10. In 2011, the United States imported only 45 percent of the liquid components required to make petroleum products, of which oil is the largest; that percentage is smaller than the 61 percent mentioned above because it includes other fuel additives and processes that increase the total volume of oil when it is converted to petroleum products. Thus, the United States would need to increase oil production by almost 160 percent in order to produce enough oil domestically to meet its demand for petroleum products. For more information, see Department of Energy, Energy Information Administration, *This Week in Petroleum* (May 25, 2011).

Figure 2.

Comparison of Changes in Prices for Crude Oil, Natural Gas, and Coal in the United States and in Other Countries



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "World Crude Oil Prices," July 13, 2011 (for oil prices); and Bloomberg (for monthly data on prices for coal and natural gas).

Notes: The diagonal line through each graph at 45 degrees indicates when changes in prices in the markets being compared correspond exactly.

For natural gas, U.S. data are for Henry Hub natural gas, the price for Russian gas is for natural gas delivered to the border of Germany, and the price for Indonesian gas is for liquefied natural gas delivered to Japan. U.S. coal is a representative coal produced in the United States, South African coal is coal produced in Richards Bay, and Australian coal is represented by an index of all coal used in the production of electricity in Australia.

OPEC = Organization of Petroleum Exporting Countries; WTI = West Texas Intermediate.

the remainder is imported from OPEC members.[11] Another benefit of a global market is that it spreads domestic disruptions in supply over a larger market, which reduces any resulting increase in U.S. prices when a disruption in U.S. production occurs. But one cost of such a global market is that U.S. consumers are affected by supply shocks that occur anywhere in the world. That drawback is significant in the case of oil, because oil is produced by many countries that, relative to the United States, are less stable and more susceptible to shocks.

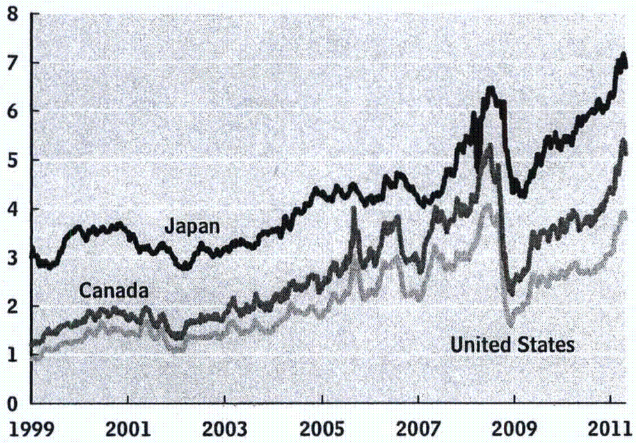
Attempts to isolate the United States from the global market for oil would almost certainly fail, because demand for oil in the United States exceeds domestic supply and because isolation would require a fundamentally different energy market, with restrictions on prices and exports that would probably not be feasible (see Box 1). Unless all imports and exports of oil were banned, any imports of oil from abroad—such as from Canada or Mexico—would still allow the world price to be transmitted through such countries to the United States. The United States' trading partners would choose to sell oil to the United States only when the U.S. price was higher than the world price (causing the U.S. price to fall toward the world price) and deliver it elsewhere when the U.S. price was lower than the world price (causing the U.S. price to rise toward the world price). Without such

11. In 2011, the United States became a net exporter of petroleum products (such as gasoline, diesel, and jet fuel) but continued to be a net importer of crude oil. In that year, the United States had net exports of 3 million barrels of petroleum products and net imports of 459 million barrels of oil. See Department of Energy, Energy Information Administration, "U.S. Imports and Exports" (January 9, 2012).

Figure 3.

Average Retail Gasoline Prices in Three Countries

(Nominal dollars per gallon)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "U.S. Regular Weekly Retail: Weekly U.S. Regular Conventional Retail Gasoline Prices," November 21, 2011 (for U.S. gasoline prices); Natural Resource Canada, "Average Retail Prices for Regular Gasoline in 2011," November 2011 (for average Canadian gasoline prices); and The Institute of Energy Economics of Japan, "The Oil Information Center," November 2011, http://oil-info.ieej.or.jp/price/price.html (for regular gasoline prices averaged across Japan).

Notes: Absolute differences in gasoline prices between countries vary because of different fees and taxes imposed over time by the countries.

Over the period shown above, Canada was a net exporter of oil, the United States produced 30 percent to 40 percent of the oil it used, and Japan produced almost no oil.

imports from abroad, demand for oil in the United States could be met only with prices sufficiently high to cause demand to fall to the level of domestic production.

Response of Other Oil-Producing Countries to Disruptions. In the near term, only a few countries, of which Saudi Arabia is the most significant, have the ability to increase production to compensate for a supply disruption elsewhere; that ability gives those countries considerable power to determine the extent to which disruptions in oil production affect oil prices. If those countries with spare production capacity do not act to offset disruptions, then even small disruptions can affect the world's supply of oil and ultimately its price.[12] The size of recent disruptions to oil production has ranged from a few hundred thousand barrels a day (as occurred in June 2008, when protestors disrupted production in Nigeria) to more than 1.5 million barrels per day (as occurred when Libya stopped exporting oil in early 2011 because of political unrest).

The spare production capacity maintained by Saudi Arabia is unique in the market; it averaged 1.9 million barrels per day (ranging from 0.5 to 4.0 million barrels per day) between 2003 and 2011 (see Figure 4). On average over that period, Saudi Arabia accounted for 84 percent of the world's spare capacity. Nearly all of that country's spare capacity is controlled by Saudi Aramco (the government-owned oil company); thus, the Saudi Arabian government can unilaterally decide to increase production to limit the effect on worldwide prices of a disruption elsewhere in the supply of oil, or to allow such a disruption to increase oil prices. In fact, Saudi Arabia tends to adjust its production in the same direction as movements in oil prices. When oil prices rise, Saudi Arabia tends to boost its production, thus preventing prices from rising even further. And as prices fall, Saudi Arabia tends to reduce its production. Although the reasons underlying those decisions to increase or decrease production probably differ at various times, they always greatly influence world oil prices.

Some analysts suggest that OPEC (of which Saudi Arabia is a member) would like to avoid price increases that provide sufficient incentive for consumers to make long-run decisions to reduce their use of oil.[13] If so, OPEC would

12. The Energy Information Administration defines spare capacity as the volume of production that can be brought on within 30 days and sustained for at least 90 days. The responsiveness of oil production to changes in the price of oil is measured using the price elasticity of supply. That elasticity is estimated to be 0.02 to 0.04 in the near term and 0.10 to 0.35 over the long run; in other words, a 10 percent increase in price would boost supply by 0.2 percent to 0.4 percent over the near term and by 1.0 percent to 3.5 percent over the long run. See James Smith, "World Oil: Market or Mayhem," *Journal of Economic Perspectives*, vol. 23, no. 3 (Summer 2009), pp.145–164.

13. Neelesh Nerurkar and Mark Jickling, *Oil Price Fluctuations*, CRS Report for Congress R42024 (Congressional Research Service, August 26, 2011).

Box 1.

Oil Independence and the Worldwide Oil Market

The worldwide market for oil makes it almost impossible for a large country like the United States to gain independence, or separation, from that market. In the United States, decisions about how much oil to import are made not by the government, but by private firms that extract, refine, and sell products made from oil—for example, gasoline, diesel, and jet fuel—to households and businesses. Those private firms enter into trading arrangements with other private firms or governments that produce oil based on the profitability and legality of such arrangements. For example, private U.S. firms produce much of the oil exported by Chad, but they are prohibited from purchasing oil from Iran because of U.S. trade sanctions against that country. Despite those sanctions, U.S. households and businesses still benefit from Iran's production of oil as long as Iran is able to sell its oil to other countries and firms that, in turn, require less oil from elsewhere in the world. (The largest importers of Iranian oil in 2008 were Japan, China, and India.)

The worldwide market for oil means that the demand for oil by consumers around the world will be satisfied with the least expensive oil, after accounting for transportation costs, quality, and trade sanctions, regardless of where it is produced. Disruptions in oil production in one country will cause the world oil market to readjust so that all countries and firms continue to receive oil at the new prevailing price. For example, in 2002, strikes in Venezuela—a large exporter of oil to the United States—reduced Venezuelan production by more than 60 percent. As a result, U.S. refiners purchased more oil from other countries or firms, and Venezuela began importing oil so that it could deliver oil to U.S. firms and other foreign parties with whom it had entered into contracts.

U.S. independence from the worldwide market for oil would require a degree of isolation that is almost certainly not feasible or desirable in such a global economy. The United States produces only about 40 percent of the oil it needs to satisfy U.S. consumer demand; thus, the United States cannot shut itself off from the world market without causing a shortage in U.S. supplies of oil and a resulting large and rapid increase in the price of oil and its products. As long as the United States imports oil, even in small quantities, the price of oil—whether imported or produced domestically—will be set in the world market.

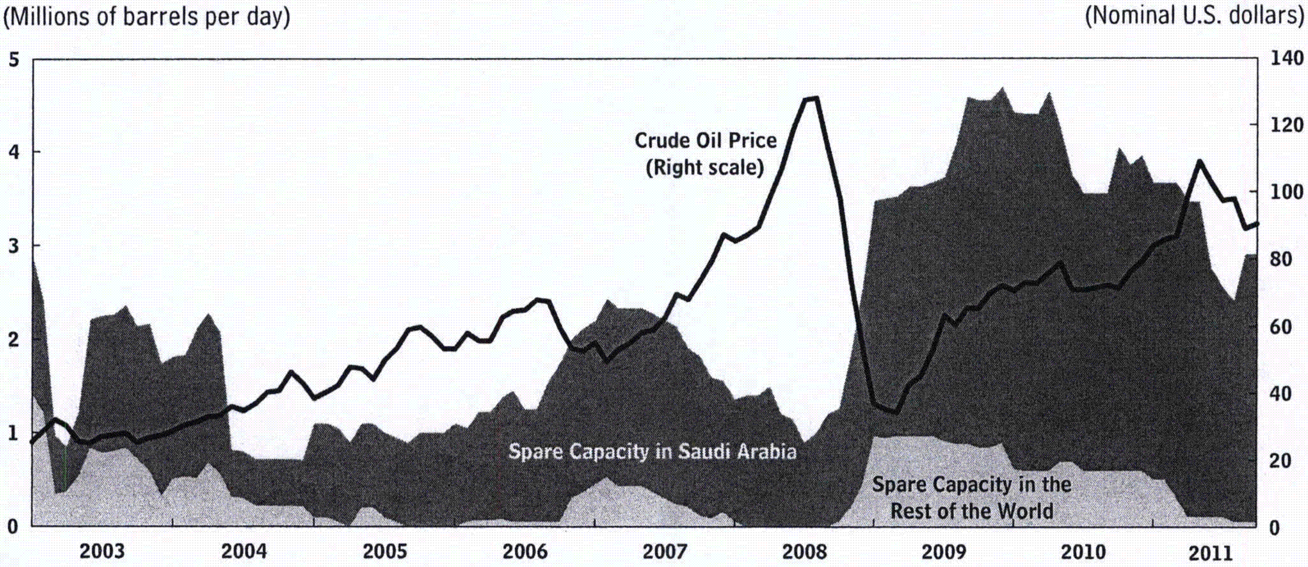
Even if the United States produced all of its oil, it could only cut itself off from the world market and its price fluctuations by prohibiting private firms from trading internationally (which would violate rules of the World Trade Organization). But such a strategy would require the periodic discovery of large oil fields in the United States coupled with a reduction in per capita U.S. oil consumption. Moreover, some multinational oil firms would probably respond to such a strategy by making decisions about where to explore for new oil fields on the basis of whether the price of oil was higher in the United States or elsewhere. Those investment decisions would probably reflect any differences between oil prices (that is, firms would respond to higher prices in the United States with more U.S. investment) and, through their effects on supply, would serve to connect global price movements to the U.S. market, despite U.S. efforts aimed at avoiding that outcome.

probably be more likely to intervene to reduce the effect of disruptions that create large increases in oil prices and less likely to implement coordinated action to raise prices when they are already high.

U.S. Reaction to Disruptions. Because the United States has no near-term spare production capacity and because it cannot rapidly reduce its consumption of oil products, this country has very few near-term options for responding to disruptions in oil markets. The most significant tool available in the short term is the substantial quantity of oil stored in the United States, particularly in the government's Strategic Petroleum Reserve (SPR); however, the release of that oil has not been used to offset most of

Figure 4.

Spare Oil Production Capacity in Saudi Arabia and in the Rest of the World, and the Price of Crude Oil



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "Short-Term Energy Outlook," January 4, 2012, www.eia.gov/forecasts/steo/query/index.cfm (for spare production capacity), and "World Crude Oil Prices," January 4, 2012 (for prices of West Texas Intermediate crude oil).

the supply disruptions that have occurred in the past. Use of the SPR would have two disadvantages: It could be offset if other oil-producing countries reduced their output, and its ability to lower world oil prices for an extended period would probably be small. (See page 23 for further discussion about the potential use of the SPR.)

Over the long run, the United States could explore for and develop additional oil resources, which would tend to increase the supply of oil. However, development of new oil resources in the United States—particularly oil fields in deep water off the coast—could take more than 10 years. Moreover, the ability of large government-owned oil producers elsewhere to strategically respond to such increased supply means that the ultimate effect of increased U.S. production would probably be dampened. That is, increasing production of oil in the United States might not increase the world's oil supply substantially or lower the price of oil significantly.

In addition, because any new productive capacity in the United States would be controlled by private firms and not the government (as it is for OPEC members), that new capacity would be used in amounts determined by its owners and not held as spare capacity to offset disruptions. If the United States was able to develop spare production capacity that could be held in reserve until disruptions occurred, that capacity would provide the country with enhanced ability to avoid sharp increases in oil prices. The feasibility of such a strategy would depend, in large part, on the geologic characteristics of oil fields that might serve as a source of oil reserves; starting and stopping production of oil from U.S. reserves (unlike reserves in Saudi Arabia) can be expensive. Moreover, such spare capacity would probably need to be owned by the U.S. government; private firms would require significant compensation not to produce oil at the rate they determined best maximized returns to their shareholders.

Natural Gas

Natural gas is widely used as an energy source, primarily to produce electricity and to provide heating and air conditioning. Very little natural gas is used for transportation (it accounts for less than 3 percent of transportation fuels), which means that recent discoveries of natural gas in the United States do not reduce U.S. vulnerability to oil price increases. The market for natural gas, like the market for oil, has limited spare production capacity to offset supply disruptions in the near term. However, several features of the natural gas market differentiate it from the oil market and allow disruptions to have a muted effect on U.S. prices.

Most importantly, U.S. producers and consumers of natural gas maintain a significant reserve of natural gas in storage (30 percent of annual domestic consumption in 2010), which is drawn down or added to fairly regularly; in contrast, oil storage in the United States represents a much smaller supply of annual world consumption (less than 4 percent in 2010).[14] That storage provides firms that use natural gas a significant cushion against temporary disruptions in supply. In addition, in some parts of the United States, more natural gas is produced than can be sold profitably, causing producers to dispose of the excess.[15] A persistent disruption that put upward pressure on natural gas prices could create sufficient incentives for firms to build additional infrastructure to enable them to sell their excess natural gas.

Another key factor is the high cost of transporting natural gas across oceans (where pipelines are not practical). As a result, natural gas is primarily consumed by the country producing it or traded within a regional market (for example, North America or Russia/Europe).[16] Thus, only disruptions within a particular region will affect natural gas prices within that region. For example, disruptions in natural gas supplies in Russia or Indonesia would not appreciably affect natural gas prices in the United States (see the middle graph in Figure 2 on page 7), but they would affect prices in Europe and Japan, respectively.[17] In 2010, the United States produced 89 percent of its natural gas domestically and imported the rest (primarily from Canada, Egypt, and Trinidad and Tobago).

Within each regional market, natural gas is transported in one of two ways:

- It is moved using pipelines between two geographic areas that are physically close, such as Canada or Mexico and the United States, or
- It is liquefied (converted temporarily to liquid form for ease of transport or storage) and then shipped via rail, truck, or tanker.

Disruptions in the supply of natural gas within the United States and among its trading partners tend to involve pipeline maintenance or leaks and thus to be smaller than disruptions in the supply of oil. The geographic diversity of natural gas production and the redundancy of pipelines cause such disruptions to have a limited effect on natural gas prices within the United States. Natural gas was produced in more than 30 states in 2010, from either onshore or offshore sources, and significant pipeline capacity exists to transport that gas within various regions of the country. However, because limited pipeline capacity exists in the United States to move natural gas between the West and the East, pipeline disruptions can affect prices in certain parts of the country. For example, disruptions associated with Hurricane Katrina near the Gulf of Mexico in 2005 increased natural gas costs in the East (which is dependent on gas from the Gulf) but not in the West (which receives gas from elsewhere).[18] Persistent disruptions, such as would occur if a large natural gas field ceased operation, would increase natural gas prices until new supplies were developed within the United States or by its natural gas trading partners.

14. Just as with oil, some of the natural gas in storage is kept as permanent inventory to maintain pressure in pipelines and underground reservoirs. Every year, about half of that stored reserve is used and subsequently replaced; most of the withdrawals occur during the winter months, when demand for natural gas (which is used for heating) is highest.

15. For example, see Department of Energy, Energy Information Administration, "Over One-Third of Natural Gas Produced in North Dakota Is Flared or Otherwise Not Marketed," *Today in Energy* (November 23, 2011).

16. Major consumer markets are North America, Europe, and Asia (primarily China and Japan), and major sources of production are the United States, Russia, South Africa, Indonesia, and Australia. Natural gas in the United States is sold at market prices based on supply and demand conditions; outside the United States, however, most natural gas (for example, from Russia, Norway, and Australia) is sold at a price indexed to the price of oil. Although such indexing (meaning that natural gas prices rise and fall with oil prices) adds transparency to a market that otherwise lacks competition, it also tends to keep natural gas prices high in those areas.

17. However, sometimes global events, such as the 2008 world recession, can cause natural gas prices worldwide to move in similar directions.

18. See Energy and Environmental Analysis, *Hurricane Damage to Natural Gas Infrastructure and Its Effect on the U.S. Natural Gas Market* (report prepared for The Energy Foundation, November 2005).

Neither temporary nor persistent disruptions in the market for liquefied natural gas would be likely to affect natural gas prices in the United States. That is because liquefied natural gas constituted only about 1 percent of the U.S. natural gas supply in 2010. In addition, contracts for liquefied natural gas tend to be long term (typically 20 years), and the price is set as a fixed multiple of the price of oil; thus, changes in natural gas prices would probably not affect contract prices for liquefied natural gas unless oil prices also changed.

The significant new discoveries of natural gas in the United States over the past few years have caused some analysts to suggest that the United States and Canada might increase their capability to export liquefied natural gas to other parts of the world, particularly Europe, where natural gas prices were more than three times U.S. prices in 2011. Such increased export capacity would cause the U.S. regional market for natural gas to become increasingly connected to the European market for natural gas. As a result, natural gas prices in the two regions would probably adjust to a similar level, rising in the United States and falling in Europe, and natural gas disruptions in either location would affect prices in both regions. However, if increased liquefaction capacity was not large enough to cause the two markets to become fully connected, new supplies of natural gas discovered within the U.S. market could offset the natural gas exported abroad, causing natural gas prices in the United States to remain lower than those in Europe.[19]

Coal

Almost half of the electricity generated in the United States comes from the burning of coal; electricity is produced from coal in every state except Vermont and Rhode Island. Because coal is not used for transportation, increased or decreased production of coal does not affect U.S. vulnerability to disruptions in oil markets.

Coal is expensive to transport abroad, so it is traded primarily within regional markets. In 2010, the United States produced more than 1 billion tons of coal and exported, on net, about 60 million tons, largely to Brazil, Canada, and Europe. Thus, only disruptions within the United States would be likely to affect U.S. coal prices. Foreign disruptions in the supply or production of coal, such as strikes in South Africa or Australia, would have little or no effect on U.S. coal prices (see the rightmost graph in Figure 2 on page 7).[20]

Within the United States, coal producers store large amounts of coal and have significant spare production capacity. Those two factors make the supply of coal, like the supply of natural gas, more stable than the supply of oil, and limit the likelihood and potential impact of supply disruptions.

Temporary disruptions in the supply of coal affect coal prices within regions of the United States only to the extent that one region of the country depends on coal from the region affected by the disruption and there is no redundancy in the transportation options connecting the regions. In 2010, coal was transported primarily via railroad (70 percent), truck (12 percent), and river barge (11 percent) across the United States from the 25 states where it was produced to those where it is consumed. Localized disruptions at a coal mine, such as a temporary shutdown, are unlikely to affect coal prices because electric power plants that rely on coal often receive it from multiple locations and maintain a multiweek supply onsite. Stocks of coal in 2010 represented 18 percent, or more than 9 weeks, of U.S. consumption, giving coal producers a buffer against the effects of temporary disruptions.

Persistent disruptions could increase coal prices if other U.S. producers did not respond by boosting their production. Between 2003 and 2004, rail congestion reduced the ability to haul coal from the western United States to electricity producers in the East, which increased the price of coal in the East but lowered it in the West.[21] When disruptions are not caused by transportation problems but by other events, such as an explosion or a large accident at an underground mine, other coal producers can often respond by increasing their production. Over the past decade, producers of coal in the United States maintained an average spare production capacity of

19. Recent discoveries of natural gas throughout the world suggest that prices may remain low worldwide, so the development of liquefaction facilities may not be warranted.

20. Global events can cause coal prices to move in similar directions in Russia, South Africa, and the United States; however, regional coal markets tend to be similar to those for natural gas.

21. Western coal, particularly from Wyoming and Colorado, has a lower sulfur content than coal from the eastern United States. Such coal is attractive to operators of electric power plants in eastern and midwestern states, which must comply with requirements under the Acid Rain Program to emit less sulfur dioxide.

17 percent, meaning that they could expand the number of hours or days they operated to increase production by 17 percent using existing mines, permits, and equipment.[22] If coal prices increased following a large persistent disruption and that spare capacity was exhausted, prices would probably remain elevated until new supplies could be developed or until substitutes for coal (such as natural gas or nuclear power used to generate electricity) caused the demand for coal to decrease.

Nuclear Power

Nuclear power is used exclusively to generate electricity. In 2010, the United States had 65 working nuclear power plants that operated a total of 104 reactors and generated 21 percent of all electricity. Nuclear facilities are typically always running because they have low operation and maintenance costs (in contrast to their high construction and licensing costs).

Electricity in the United States is primarily traded within multistate regions that surround its area of production. (Some of those regions also include parts of Canada.) For that reason, the 2011 nuclear outage in Japan and the 1986 Chernobyl disaster in Russia had no effect on U.S. electricity prices, nor would similar events in the future.[23]

If a disruption occurred at a U.S. nuclear power plant, the electricity that was lost would be replaced by power generated from more expensive sources, causing the average cost of electricity to increase. The August 2011 earthquake in the eastern United States caused two nuclear power plants to shut down for several days. High-cost backup generators that operate using different fuels were rapidly activated, and the cost of electricity generation immediately increased by more than 50 percent. Within a few hours, however, other low-cost backup generating units had ramped up, and costs subsequently fell back to near original levels.[24]

If a nuclear accident caused U.S. regulators or the public to question the reliability or safety of many or all U.S. nuclear facilities, then other backup electricity generators could face considerable strain. Such a large disruption affecting the source of 21 percent of the electricity generated in the United States would probably increase the price of other commodities (such as coal) that are used to generate electricity.

Renewable Sources

Most energy generated in the United States from renewable sources is derived from hydropower, wood, and biofuels (primarily transportation fuels produced mainly from renewable plant matter, but not wood). In 2010, those three sources provided 31 percent, 25 percent, and 23 percent, respectively, of the renewable energy generated in the United States. Other sources of renewable energy are wind power (accounting for 11 percent of the renewable energy generated in 2010), waste (6 percent), geothermal energy (3 percent), and solar power (1 percent). Hydropower and geothermal energy tend to be highly dependable sources of energy and not prone to short-term disruptions; in contrast, wind and solar power are inherently irregular and prone to naturally occurring interruptions.

Disruptions to the supply of renewable energy can come in the form of temporary interruptions (such as periods of no wind or limited sun) or events with long-lasting consequences (such as forest fires or droughts). Some types of disruptions—particularly droughts, which affect hydropower and the growth of organic material for the production of biofuels (for example, corn for ethanol)—can reduce the reliability of renewable energy over the long term. The frequency of temporary interruptions often requires that other energy sources, such as natural gas, serve as a backup, increasing the cost of renewable energy. As the network of renewable-energy facilities expands and becomes more geographically diversified, however, temporary interruptions in one location could be offset by production from other locations not experiencing an interruption.

22. See Department of Energy, Energy Information Administration, *Annual Coal Report 2009*, DOE/EIA-0584, "Table 12, Capacity Utilization by Coal Mines by State" (2009), as well as the same report and table from earlier years.

23. The only way such an effect could occur would be through world oil prices, but the United States generates less than 1 percent of its electricity using oil, and worldwide less than 1 percent of electricity was generated using oil in 2008, on average. Moreover, the prevalence of coal and natural gas as sources of electricity around the world combined with the high cost of oil makes it unlikely that any country would substitute oil for nuclear power as a source of electricity. Thus, nuclear outages overseas would be unlikely to affect U.S. electricity prices.

24. See Department of Energy, Energy Information Administration, "Mid-Atlantic electricity market reacts to Tuesday's earthquake," *Today in Energy* (August 25, 2011), www.eia.gov/todayinenergy/detail.cfm?id=2810.

What Role Can the Government Play in Enhancing Energy Security?

Action by the government to reduce the effects of disruptions to energy markets could be warranted both because the direct costs of such disruptions may impose hardships on segments of the population and because the indirect costs affect the nation as a whole. But in the case of a long-term disruption, government actions to ameliorate its impact could interfere with the adjustments consumers would make in response to higher prices.

Government actions might take the form of increasing the ease with which consumers can shift to alternative energy sources following a disruption. Or they might attempt to increase or diversify the domestic supply of energy to reduce the magnitude of disruptions experienced by U.S. consumers. Policies that were designed to increase the cost of energy to reflect all of the costs associated with its production and use, including indirect and environmental costs, would provide an economic incentive to reduce the use of energy and to develop and use alternative technologies. Some such policy options are discussed in more detail in the last section of this report.

Addressing inefficiencies in markets other than energy markets could also make consumers less vulnerable to price disruptions. For example, businesses commonly invest less money than is socially optimal in research and development—in part because they do not take into account the benefits to society from knowledge spillovers that would accrue to other businesses. That lower amount of spending on the development of technology means that consumers have less access to more energy-efficient technologies or alternative forms of energy, for example; thus, they incur higher direct costs from a disruption than would otherwise be the case. Policies that took into account the spillover benefits resulting from research and development on energy alternatives could lead to a better use of resources and could lessen the burden of higher energy prices on U.S. consumers.

Adopting policies that reduced the likelihood of disruptions occurring within energy markets in the United States could also improve energy security. For example, policies might increase safety standards in coal mines or at nuclear power plants, thus reducing the likelihood of disruptions in the production of coal or nuclear energy. Or policies might increase redundancy in electricity transmission lines or pipelines, which would reduce the vulnerability of the infrastructure used to transport electricity and oil to an accidental breakdown or a terrorist attack. Other policies might involve foreign policy actions or investments in military equipment that could help ensure key routes for oil tankers are kept open. Although this report examines the consequences of disruptions that might occur in the production of energy, it does not discuss the underlying probability that those disruptions would occur. Thus, the effect of policies that might lessen that probability is outside the scope of this report.

Energy Security for Electricity

Although the electricity sector of the U.S. economy consumes more energy than any other sector, households and businesses are largely unaffected by disruptions in the supply of commodities that underlie electricity generation.[25] The effects of such disruptions on the electricity bills of households and businesses are limited by features that distinguish the electricity sector from the next-largest energy-consuming sector, transportation:

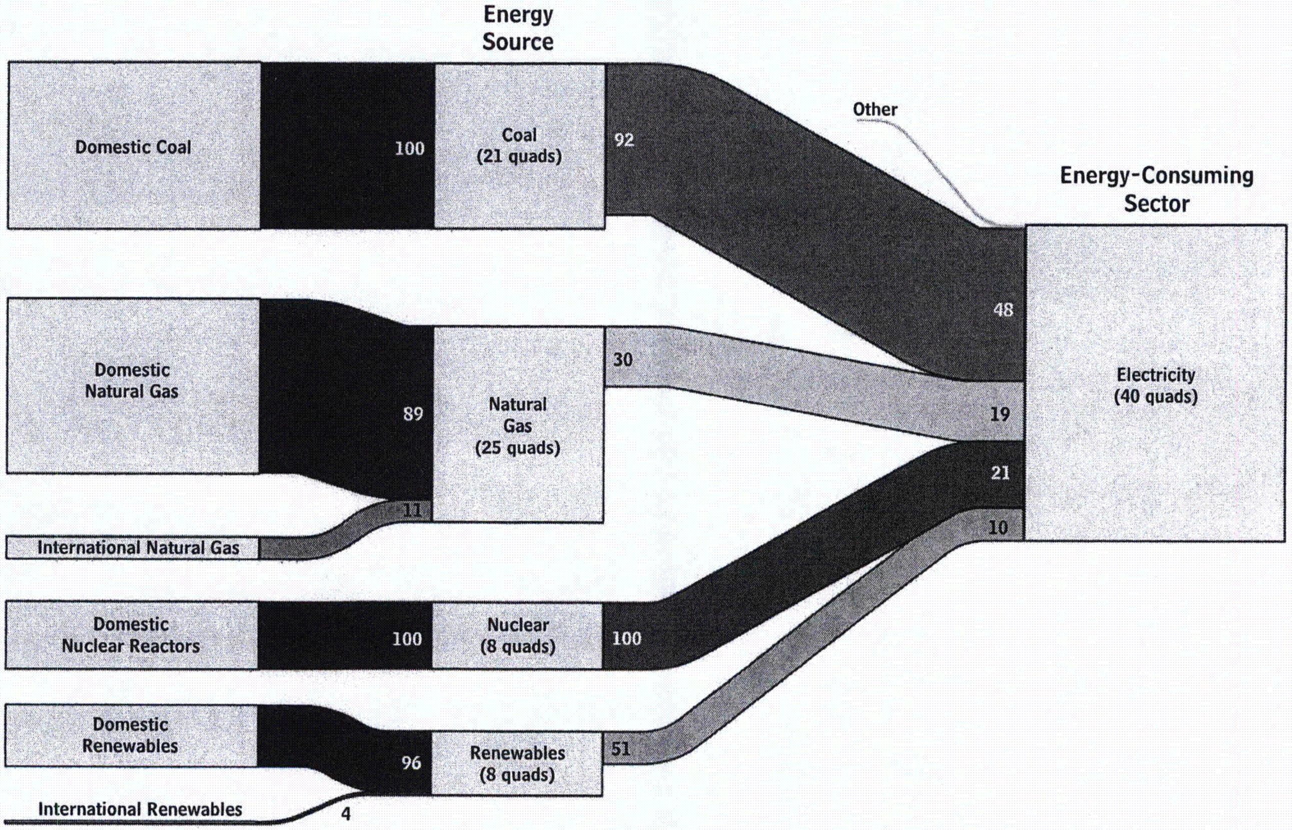
- Several different commodities can be consumed in the generation of electricity.
- Generation in the United States is organized into eight multistate regions that are part of the North American Electric Reliability Corporation (NERC); each region is responsible for maintaining sufficient spare capacity to respond to disruptions. That spare capacity offers electricity providers significant flexibility to choose among electricity generating units and fuels.
- Consumers of electricity can often choose among various options to reduce their electricity usage in the near and long terms when price increases occur.

25. This section focuses on disruptions in the supply of energy commodities and not disruptions to the infrastructure used to distribute electricity to consumers. For more information on the latter, see Richard Campbell, *Regulatory Incentives for Electricity Transmissions—Issues and Cost Concerns,* CRS Report for Congress R42068 (Congressional Research Service, October 28, 2011); John Moteff, *Critical Infrastructures: Background, Policy, and Implementation,* CRS Report for Congress RL30153 (Congressional Research Service, July 11, 2011); and Richard Campbell, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues,* CRS Report for Congress R41886 (Congressional Research Service, June 15, 2011).

Figure 5.

Energy Flows for the Electricity Sector, 2010

(Percent)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: The flow labeled "Other" represents about 1 percent of electricity energy input, primarily from oil.

quad = a unit of energy equal to a quadrillion British thermal units.

In 2010, almost all electricity in the United States was generated from coal, nuclear power, natural gas, and renewable sources (see Figure 5). By contrast, less than 1 percent of electricity was produced from oil. In general, the markets for commodities that are used to produce electricity are stable and not prone to large or long-lasting disruptions; that stability tends to keep average electricity prices within a much narrower band than gasoline prices (see Figure 6).

Regional Generation, Spare Capacity, and Flexibility

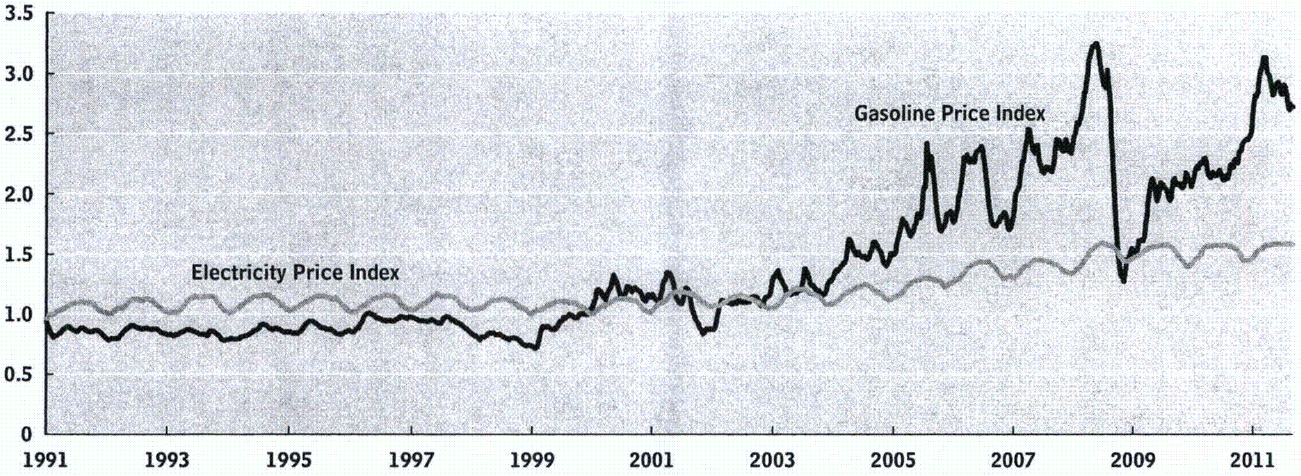
Domestic disruptions in the supply of the commodities used to produce electricity can have an effect on the price of electricity, but the effect will vary because of the regional nature of electricity generation and the options available for transporting fuels. Electricity generation in the United States is divided into three primary zones, across which there is little trade: the Western Interconnection (considered one region, spanning all or part of 13 western states), the Texas Interconnection, and the Eastern Interconnection (see the top panel of Figure 7). The latter encompasses 34 states divided into six regions across and within which electricity is traded. NERC regulates each of the eight regions (under authority granted to it in 2007 by the Federal Energy Regulatory Commission) to ensure that generation capacity is sufficiently large to withstand outages or unplanned disruptions in fuel delivery.

Because each region uses a different combination of fuels to generate electricity and has its own network of rails and pipelines to connect suppliers of energy commodities

Figure 6.

Prices for Gasoline and Electricity in the United States

(January 2000 = 1.0)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "U.S. Regular Weekly Retail: Weekly U.S. Regular Conventional Retail Gasoline Prices," November 21, 2011 (for gasoline prices), and "Detailed Sales and Revenue Data by State, Monthly Back to 1990," November 2011 (for electricity prices).

Note: The price indexes for gasoline and electricity were created by dividing all historical prices by their respective price on January 1, 2000.

with electricity providers, disruptions can affect each region differently (see the middle and bottom panels of Figure 7). For example, several regions in the Eastern Interconnection rely more heavily on coal to generate electricity than regions elsewhere in the United States. Thus, coal disruptions affect electricity generation in the East more than in the West. Similarly, although all regions rely on natural gas as a fuel source, there is limited pipeline capacity to move natural gas between the West and the East, so natural gas disruptions typically are isolated to one-half of the country.

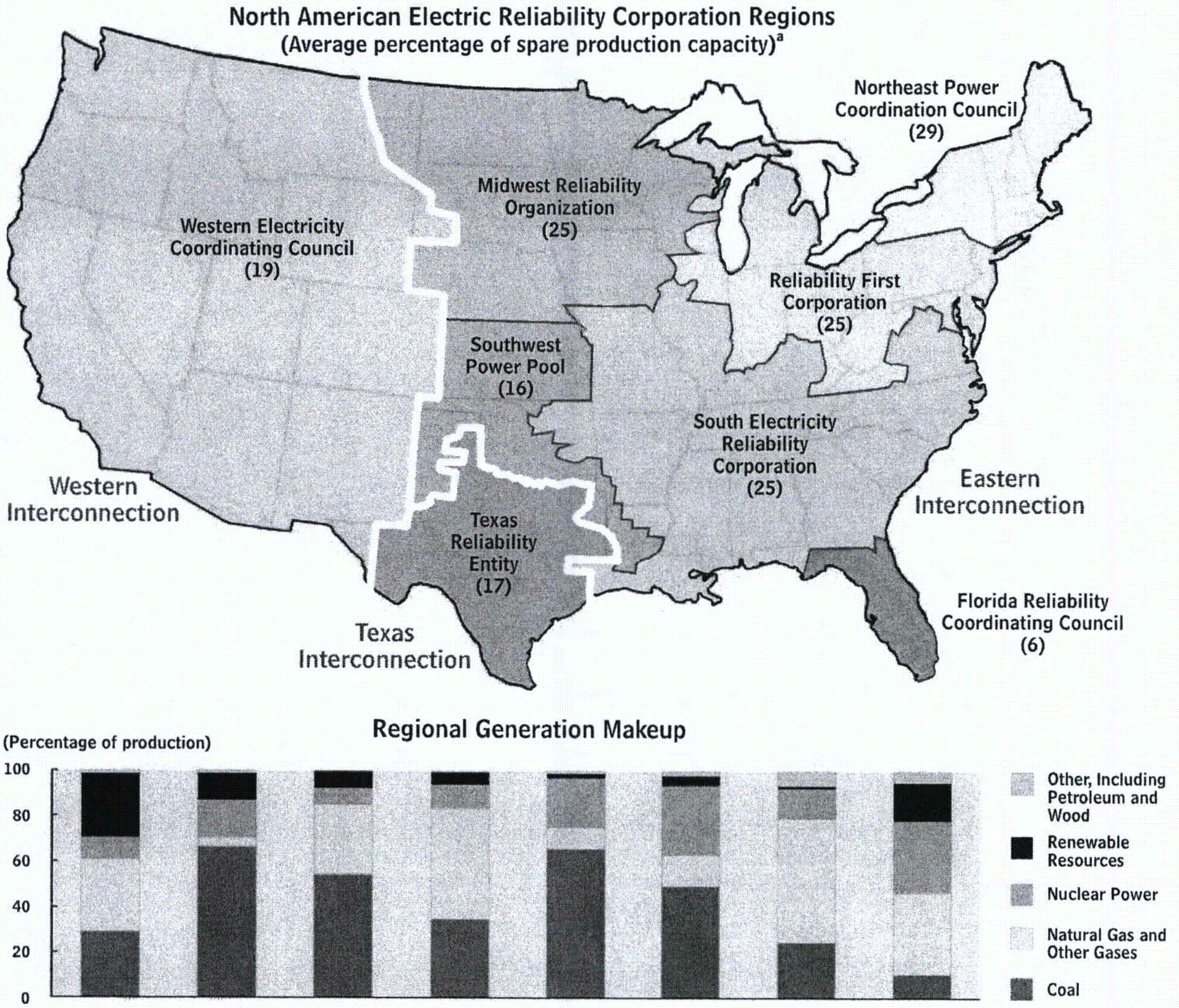
Each NERC region has excess capacity designed to respond to temporary disruptions in the fuel sources it uses. In 2009, the eight NERC regions averaged 22 percent excess capacity, measured as the unused available capacity of the region at peak summer load as a percentage of available capacity. That excess capacity totaled 200 gigawatts and ranged from approximately 3 gigawatts to 60 gigawatts in individual regions. (For comparison, the largest providers of electricity generate roughly 1.5 gigawatts, and more than 97 percent of providers deliver less than 0.5 gigawatts at peak summer capacity; thus, 60 gigawatts of spare capacity represents the output of more than 40 individual plants and probably many more.) That spare capacity means that when western coal is not available to electricity providers in the East, they can shift generation to facilities that rely on coal from Illinois or Appalachia or increase generation from natural gas or renewable sources (see Box 2).

In addition to shifting generation between facilities, some producers have the ability to switch the fuels used by particular facilities. So even though coal-burning facilities are typically designed to process a specific type of coal, they can substitute coal from another source, typically up to 20 percent, without incurring additional costs. Some producers also can substitute natural gas for coal within the same facility. As of 2009, about 1 percent of electricity was produced by burning coal and natural gas together; that share could increase if natural gas prices remain low and the cost to retrofit a facility for such switching becomes less expensive than the cost of building a new natural gas facility. Biomass can also be burned with coal (at volumes of up to 10 percent without affecting performance) to generate electricity.[26] In 2008, coal-burning facilities substituted biomass for coal to generate 1.3 percent of electricity.

26. See David Ortiz and others, *Near-Term Opportunities for Integrating Biomass into the U.S. Electricity Supply* (Santa Monica, Calif.: RAND, 2011), www.rand.org/pubs/technical_reports/TR984.html.

Figure 7.

The Electricity Sector in the United States, 2009



Number of Nuclear, Natural Gas, and Coal Plants

	Western Electricity Coordinating Council	Midwest Reliability Organization	Southwest Power Pool	Texas Reliability Entity	Reliability First Corporation	South Electricity Reliability Corporation	Florida Reliability Coordinating Council	Northeast Power Coordination Council
Nuclear Power	4	7	1	2	14	26	3	8
Natural Gas and Other Gases	459	158	104	174	259	400	94	198
Coal	65	95	15	18	173	185	15	22

Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, www.eia.gov/cneaf/electricity/chg_str_fuel/html/fig02.html (map shown is an approximation of regions); "Electric Power Annual 2009: Table 4.3, Net Internal Demand, Actual or Planned Capacity Resources, and Capacity Margins by North American Electric Reliability Corporation Region, Summer," November 23, 2010 (for spare production capacity); "State Historical Tables for 2009: Net Generation by State by Type of Producer by Energy Source," November 23, 2010 (for regional generation makeup); and "State Historical Tables for 2009: Existing Capacity by Energy Source," November 23, 2010 (for the number of plants).

Note: The number of plants in each North American Electric Reliability Corporation (NERC) region is approximate because the number of plants is provided on a statewide basis and NERC boundaries do not coincide with state boundaries.

a. Spare production capacity is as reported to the Energy Information Administration.

Box 2.

Disruptions in the Delivery of Electricity

Although electricity providers have significant capacity to absorb disruptions in the fuel supply, such capacity is not unlimited; an extended outage or large multiplant disruption (such as the loss of many regional plants following a severe weather event) would threaten reliability in a region, particularly during times of peak electricity usage in summer or winter months. In the past decade, there have been multiple examples of events that prevented electricity providers from delivering adequate power to businesses and households, resulting in rolling blackouts (or periods when power was not delivered to certain areas). For example, an unexpected cold spell in Texas in February 2011 caused the natural gas pipeline there to lose pressure, reducing its flow to electricity producers that use natural gas. As a result, 82 power plants temporarily shut down, and parts of the state experienced a day of rolling blackouts. Blackouts also occurred in California during its 2000–2001 energy crisis, when demand rose to record levels and supply from hydropower dropped. In both of those situations, events strained regional providers beyond the point at which spare capacity could be tapped to resolve the stress. Most other commonly known incidents of blackouts—including the 2003 blackout that affected 55 million people in the Northeast for several days—involve transmission issues, which can be caused by a storm or other event that compromises the integrity of the transmission grid.

Electricity Pricing and Demand

Temporary disruptions in fuel supplies that cause an increase in the cost of generating electricity are unlikely to result in large price increases for households and businesses that rely on electricity. In part, that is because of the way in which increases in costs are passed on to households and businesses. Although the nature of contracts between electricity producers, distributors, and consumers varies across the United States, the electricity rates offered to households and businesses typically are regulated by a local public utility commission. Such commissions compensate for the lack of competition in the distribution of electricity to consumers by regulating changes in electricity prices.

Once or twice a year, distributors of electricity negotiate a rate change and the term for that change. Once a rate change is approved, the electricity producer is contractually required to deliver electricity at the agreed-upon rate for the duration of the contract term. For that reason, the cost of any disruption is initially borne by the producers and distributors of electricity, although it is ultimately passed on to households and businesses. Any increase in the costs to generate electricity will take several months to appear on the bills of households and businesses, by which time the extent and total cost of the outage are better understood and households and businesses have had time to make adjustments.

Households and businesses can respond to any increase in electricity prices by reducing their energy usage. Recent estimates by the Department of Energy suggest that households and businesses in the United States can reduce their energy costs by 10 percent for every 3 degrees they raise the temperature on their thermostat during the summer (or reduce the temperature during the winter).[27] Other responses also are available to households and businesses. Following the 2011 nuclear power disruptions in Japan, some businesses—for example, the University of Tokyo—reduced their peak power usage by 30 percent to 40 percent by turning off lights and air-conditioning, shutting down some elevators, and running energy-intensive processes at night.[28]

The willingness of households and businesses to make such behavioral adjustments tends to be short term in

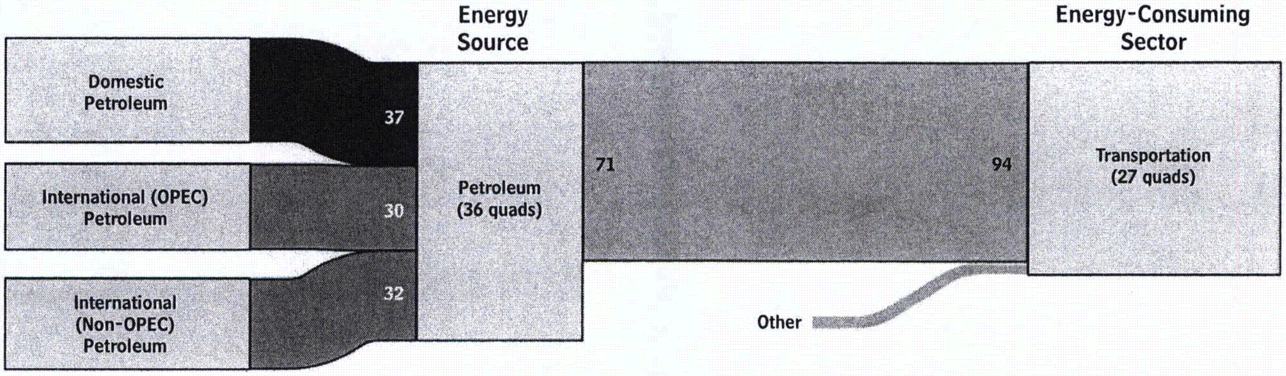
27. See Department of Energy, "Energy Savers: Thermostats and Control Systems," www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720 (accessed August 31, 2011). Also, research from the Department of Energy indicates that the short-term elasticity of demand for electricity is -0.10, meaning that a 10 percent increase in electricity prices will reduce demand by 1 percent; in contrast, the long-term elasticity of demand is -0.50 (a 10 percent increase in electricity prices will reduce demand by 5 percent). For more details, see Steven Wade, *Price Responsiveness in the AEO2003 NEMS Residential and Commercial Buildings Sector Models* (Department of Energy, Energy Information Administration, 2003).

28. See David Cyranoski, "Japan Rethinks its Energy Policy," *Nature*, vol. 473 (May 18, 2011), p. 263.

Figure 8.

Energy Flows for the Transportation Sector, 2010

(Percent)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: The flow labeled "Other" represents about 6 percent of transportation energy input, primarily from natural gas and renewables.

OPEC = Organization of Petroleum Exporting Countries; quad = a unit of energy equal to a quadrillion British thermal units.

nature. Eventually, households and businesses revert to their original behaviors and pay higher costs. In response to permanent increases in electricity prices, however, households and businesses would be expected to make other types of adjustments, such as purchasing energy-efficient appliances or converting to natural gas for heating and cooling. Over the past several decades, for example, households and businesses have shifted away from fuel oil and to a much greater use of electricity and natural gas to provide heating (see Box 3). Although such changes take more time to implement and cost more initially, they are more difficult to reverse once they have been implemented. Also, they lessen the exposure of households and businesses to subsequent increases in electricity prices.

Energy Security for Transportation

Disruptions in supplies of the commodities that power the transportation sector would probably impose increased costs on U.S. households and businesses because, unlike the electricity sector, the transportation sector lacks features that would allow it to more easily absorb such price increases. The primary underlying difference between the two sectors is that the transportation sector relies almost exclusively on petroleum products for its fuel, whereas the electricity sector relies on various energy sources (see Figure 8). The nation's dependence on a single source of fuel for transportation, in combination with two other features, increases its vulnerability to disruptions:

- Refineries are needed to convert oil into usable products like gasoline, diesel, jet fuel, and asphalt. Surplus refining capacity exists in the United States, but it is heavily concentrated near the Gulf of Mexico, where exposure to hurricanes or other events might disrupt the production of oil products.

- Consumers of gasoline, diesel, and jet fuel have few other options available to them over the near term to satisfy their transportation needs (see Figure 9). Thus, disruptions in oil markets or refining will cause households and businesses to pay more for their transportation fuel and raise the costs of goods and services that rely on transportation for their production.

The U.S. government can respond in a number of ways to concerns about the costs that disruptions to oil markets impose on U.S. consumers and the economy. Some of those policy options could reduce—but no policy could eliminate—the costs borne by consumers as a result of disruptions. In general, policies designed to lessen the consumption of oil (for example, greater fuel efficiency requirements) would be more effective at reducing the vulnerability of consumers to disruptions than policies designed to increase the domestic production of oil.

Box 3.

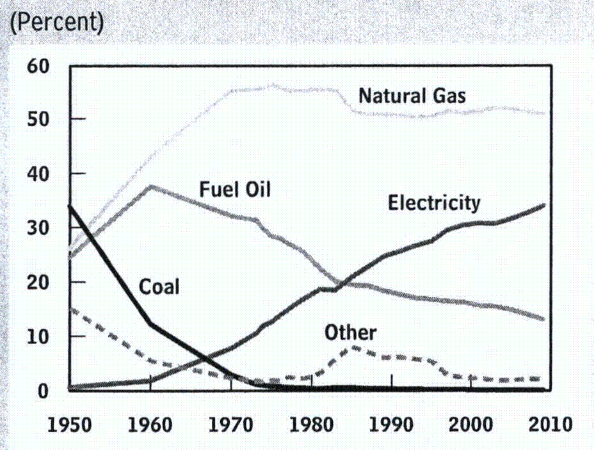
Reduced Vulnerability to High Heating Costs

Appliances used for heating, ventilation, and air conditioning (HVAC) expose households and businesses to changes in the price of natural gas, oil, electricity, and renewable sources of power, all of which are used to run those appliances. The energy used for HVAC accounts for 15 percent of energy consumption in the United States (excluding electricity; when electricity is included, HVAC accounts for 19 percent of energy consumption). HVAC represents the third-largest sector (after transportation and electricity) of U.S. energy consumption.

Over the past several decades, in response to vulnerability to disruptions in the world oil market and resulting higher prices for oil, U.S. households and businesses have shifted to furnaces and boilers that rely more on electricity and natural gas and less on oil for heating buildings. In the 1950s, about 60 percent of heating was fueled by oil and coal (see the figure). The use of oil as a fuel source for heating peaked in the early 1960s and has since declined, most rapidly during the 1970s, when oil prices were particularly high. The use of coal as a fuel source for heating fell in the 1950s and 1960s because it was difficult to handle compared with alternatives and because it contributed more to indoor air pollution. Such transitions illustrate how long-run adaptations can occur within a sector when consumers are exposed to higher prices. As a result of those changes, U.S. households and businesses are less vulnerable to disruptions in the supply of heating fuels today than they were in the 1950s, 1960s, and 1970s.

Nevertheless, individual households and businesses in certain regions of the country that remain dependent on specific fuels may experience periods of high prices for the fuels they use. That exposure to disruptions could be particularly burdensome if, for example, a cold spell that caused periods of high heating use occurred at the same time as a disruption in the supply of oil that caused oil prices to increase. Households and businesses in the Northeast—where the use of oil for heating tends to be concentrated—are more vulnerable in that regard than households and businesses elsewhere that have largely transitioned to other sources of fuel.[1]

Sources of Fuel for Heating



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *Annual Energy Review 2010*, Table 2.7, "Type of Heating in Occupied Housing Units, Selected Years, 1950–2009" (October 19, 2011).

Notes: Fuel oil includes kerosene and liquefied petroleum gas.

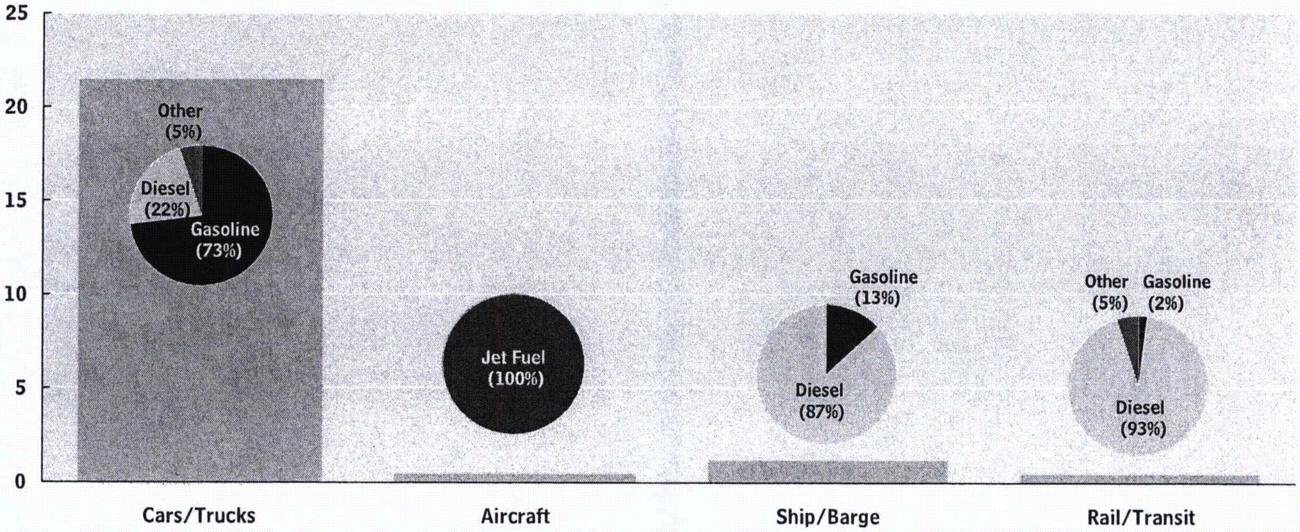
Other sources of fuel include wood (the source of the spike between 1983 and 1995), solar power, briquettes, coal dust, waste material, and purchased steam.

1. See Department of Energy, Energy Information Administration, "Household Heating Fuels Vary Across the Country," *Today in Energy* (October 28, 2011), and "State Heating Oil and Propane Program Season Begins," *Today in Energy* (October 19, 2011).

Figure 9.

U.S. Usage of Fuel for Transportation, 2009

(Amount of energy consumed, in quads)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "Estimated Consumption of Vehicle Fuels in the United States, by Fuel Type," November 2011, www.eia.gov/cneaf/alternate/page/atftables/attf_c1.html; and Bureau of Transportation Statistics, Research and Innovative Technology Administration, National Transportation Statistics, Table 4-5, "Fuel Consumption by Mode of Transportation in Physical Units," November 2011, www.bts.gov/publications/national_transportation_statistics/html/table_04_05.html.

Notes: A quad is a unit of energy equal to a quadrillion British thermal units. The Energy Information Administration includes pipelines as a type of transportation. Pipelines consume natural gas (0.6 quad) and are used to transport natural gas and oil around the country. Unspecified military use consumes an additional 0.7 quad of energy.

For the cars/trucks category, "Other" includes ethanol (0.83 quad), natural gas (0.04 quad, including liquefied natural gas, compressed natural gas, and liquefied petroleum gas), biodiesel (0.04 quad), and electricity and hydrogen (less than 0.01 quad); for the rail/transit category, "Other" includes electricity (0.02 quad) and compressed natural gas (0.01 quad).

Refinery Capacity

U.S. firms maintain 148 operable refineries, producing enough refined petroleum products (such as gasoline and various types of fuel oil) to make the United States a net exporter of those products in 2011, even though much of the crude oil used by such facilities is imported. Temporary or persistent disruptions at a small number of refineries could probably be accommodated by the refining industry because refineries were, on average, operating at 14 percent below full capacity (and 11 refineries were idle) in 2011. However, almost half of U.S. refining capacity is near the Gulf of Mexico, which means that a hurricane or other event that affected that area could create temporary or long-term disruptions for a large share of U.S. refining capacity. Temporary disruptions (as occurred following several hurricanes in 2005) could probably be at least partially offset by refiners' drawing down stores of refined petroleum products and would cause only temporary increases in gasoline prices. Long-term disruptions could reduce the availability of refined products. For example, many of the refineries near the Gulf of Mexico are designed to process the type of oil commonly produced in Mexico and Canada. Removing those refineries from operation would reduce U.S. capacity to refine oil from those countries (because other refiners cannot process that type of oil), which would decrease the availability of gasoline and other oil products to the U.S. market. Any event that caused refiners located near the Gulf of Mexico to temporarily or permanently shut down would increase prices for gasoline and diesel fuel for U.S. consumers.

Consumer Demand for Oil

The ultimate vulnerability of U.S. households and businesses to disruptions in the supply of oil is determined by their ability to change their behavior when oil prices increase. In the United States, demand is relatively unresponsive to price changes in the near term because households and businesses have almost no ability to substitute one fuel for another in their transportation decisions or to substantially reduce their consumption of gasoline at low cost.[29] As a result, households and businesses are limited in their ability to reduce the costs associated with higher oil prices. Over the longer term, their flexibility increases slightly because they can make decisions that might reduce their oil consumption. For example, they could buy a more fuel-efficient vehicle (such as a hybrid vehicle, which uses both electricity and gasoline) or choose to live near public transportation or their place of employment, all of which would lessen their reliance on gasoline.

Policy Options to Dampen the Effects of Disruptions in Oil Supplies

The interconnectedness of the world oil market means that U.S. households and businesses will always be exposed to fluctuations in the price of oil, regardless of how much oil the United States imports or produces domestically. To the extent that the United States can adopt policies that increase the ability of U.S. consumers to accommodate disruptions in oil markets, however, future supply disruptions would be less costly to U.S. households, businesses, and the economy as a whole.

Policies to lessen the cost of those disruptions can take two forms: They can increase the domestic production of oil or decrease the domestic consumption of oil. Fundamentally, policies that increased the domestic production of oil would have an effect on world oil prices similar to that of policies that reduced the domestic demand for oil; in economic terms, an increase of 1 million barrels per day in production with unchanged demand is generally equivalent in terms of lowering world oil prices to a decrease of 1 million barrels per day in consumption with no change in supply. Either type of policy (boosting production or reducing consumption) would increase the amount of oil available to the world market and thus tend to lower the world price of oil. In general, the response of other oil-producing countries to a price reduction is difficult to predict. To the extent that new supply or lower U.S. consumption reduced oil prices, one or more large oil-exporting countries could respond by deciding to constrain production or the development of new fields, effectively neutralizing the U.S. policy.

Many policies have been proposed to address concerns about energy security—some to address temporary disruptions, others for persistent ones. They include, for example, the following:

- Releasing oil from the Strategic Petroleum Reserve,
- Facilitating development of insurance markets,
- Promoting alternatives to personal vehicles,
- Increasing domestic oil production,
- Developing alternative fuels that substitute for oil,
- Reducing gasoline consumption from gasoline-fueled vehicles, and
- Developing vehicles that use alternative fuels.

Policies targeting one type of disruption often have some implications for the other type as well. Policies that target temporary disruptions would be applicable for addressing the transition to a persistent increase in prices. Similarly, policies that target persistent disruptions would reduce the exposure of U.S. households and businesses to subsequent temporary disruptions.

Policies to Address Temporary Disruptions. Policies targeting temporary disruptions in the supply of oil take two general forms:

- Reducing the exposure of consumers to high prices by, for example, making oil from the Strategic Petroleum Reserve available to the world oil market or encouraging the development of insurance markets, or
- Providing U.S. households and businesses with more choices in the near term for reducing the use of personal vehicles when oil prices rise.

29. Households and businesses could reduce their fuel use slightly by driving more slowly and less often, but demand over the near term would remain largely unchanged despite higher oil prices. Estimates of the near-term elasticity of demand with regard to the price of gasoline range between -0.03 and -0.08; in the long run, the elasticity is estimated to be about -0.4. See Jonathan E. Hughes, Christopher R. Knittel, and Daniel Sperling, "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," *Energy Journal*, vol. 29, no. 1 (2008), pp. 113–134; and Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets* (January 2008).

Policies that aimed to decrease the use of personal vehicles would be more likely to reduce exposure to disruptions in oil markets because they would not rely on international coordination to be successfully implemented. (In contrast, policies to quickly make new supplies available to the world market would require international coordination.) Moreover, policies to decrease the use of personal vehicles would be more likely to have an extended benefit for consumers, even though they would probably be more costly to implement than making new supplies available to the world oil market.

Release Oil from the Strategic Petroleum Reserve. The release of oil from a large supply of stored oil would allow the United States to respond quickly to temporary oil disruptions by making additional supplies available to the world market. In 2010, U.S. stores of oil contained more than 1 billion barrels, including 727 million barrels in the SPR and the remainder in privately held inventories.[30] Releases from and deposits to private inventories occur regularly, reflecting decisions by individual firms and refineries in response to very short-term variability in their supply. The management of those inventories is not coordinated, however, so the release of their oil would probably not offset an extended disruption in production elsewhere—in Nigeria or Libya, for example. In contrast, a release from the SPR could be large enough to offset a modest disruption for several months. Such releases could constrain increases in oil prices and thus dampen any effects of those price increases on the economy.

Use of the SPR would have two disadvantages, however: First, it could be offset if other oil-producing countries reduced their output. Just as Saudi Arabia can increase production to offset temporary disruptions, it also can reduce production to offset additional supply to the market, such as releases from the SPR. In the past, Saudi Arabia and other OPEC members have stated their intention to maintain stable world oil prices and their willingness to offset additional supply to achieve that objective. Thus, before releasing oil from the SPR, U.S. officials would probably need to coordinate with Saudi Arabia to ensure that the release would not be offset. For example, following the June 2011 decision by member countries of the International Energy Agency to release 60 million barrels of oil onto the world market, Saudi Arabia increased production by about 10 percent in the three months after the release, an action probably anticipated by U.S. officials.

The release of oil from the SPR would have a greater ability to reduce oil prices if done in coordination with countries that have strategic reserves and countries that produce oil. The International Energy Agency estimates that the SPR represents about half of oil reserves held around the world by oil-importing countries and available for emergency use. That total capacity for releases increases the ability of large oil-consuming countries to respond to disruptions in the supply of oil.

Second, a release of oil from the SPR would probably have little impact on world oil prices over an extended period. A unilateral release by the United States might be large enough to offset a small short-term disruption; the SPR can accommodate a maximum release of 4.4 million barrels per day for up to three months (and declining amounts thereafter).[31] However, as the United States released oil from the SPR, the world market would assume that the United States probably wanted to replenish its reserve (to afford it the capacity to respond to future disruptions), and those anticipated purchases in the future would probably increase the price of oil before the SPR was actually refilled. Moreover, a release from the SPR would not be able to offset large disruptions in oil markets. For example, a closure of the Strait of Hormuz—which would affect the availability of almost 20 percent of world oil that is traded—could not be offset by a unilateral release of oil from the SPR.

Facilitate Development of Insurance Markets. Establishing markets that provided consumers with insurance against increases in energy prices and encouraging the use of such markets could also serve to dampen temporarily the effects of a supply disruption on the economy. The effectiveness of such an approach would depend on how the burden of higher prices was distributed by those markets.

30. The SPR was created in 1975 in response to concerns about interruptions in the supply of oil to the United States. Oil in the SPR is stored in four large underground caverns near the Gulf of Mexico; the reserve contained 696 million barrels of oil as of March 30, 2012. Large releases in response to energy supply disruptions can occur only with the authorization of the President.

31. See Anthony Andrews and Robert Pirog, *The Strategic Petroleum Reserve and Refined Product Reserves: Authorization and Drawdown Policy,* CRS Report for Congress R41687 (Congressional Research Service, March 11, 2011).

Consumers could pay others to make certain that gasoline and diesel prices remained within a specific range. For example, gasoline retailers could allow consumers to prepay for gasoline at prices based on future expectations of gasoline prices in the same way that some electric utilities offer customers the option to lock in electricity prices for certain periods. Under such an arrangement, consumers would pay a fee to retailers or investors who provided the insurance, which would decrease their costs if prices rose above that range, on average, but decrease their savings if prices fell below that range. Adopting a regulatory framework that encouraged the use of such insurance or even providing small subsidies for it could reduce the economywide effects of energy supply disruptions.

Such an insurance market could benefit the economy to the extent that it transferred risk from consumers of oil to investors who were better able to bear that risk. Those investors would reduce indirect costs on the economy when oil prices rose if, for example, they lived outside the United States or if they could absorb such price changes more easily than the average consumer. However, if the risk was transferred back to U.S. consumers through widely held investments, such insurance would be less effective in reducing the economic harm that would come from higher oil prices.

Promote Alternatives to Personal Vehicles. Policies that encouraged alternatives to personal vehicle use—by increasing the availability of public transportation or reducing the need to use personal vehicles—could reduce the vulnerability of U.S. households and businesses to both temporary and long-term increases in oil prices.

The availability of public transportation that could readily be used when oil prices rose would offer consumers added flexibility to respond to those increases. Research suggests that important determinants leading to the use of public transportation are the price of the trip, the door-to-door travel time, and the reliability of service.[32] To address those factors, policies could provide subsidies to reduce fares or to promote more frequent operation (beyond rush hour, assuming firms also offer flexibility in working hours) of existing rail, subway, and bus service. Such changes could motivate consumers to increase their use of public transportation when oil prices increased. And those changes could be implemented within a few weeks, if sufficient staffing and finances were available.

Creating such additional capacity for public transportation could be costly. The construction of new fixed-track public transportation alternatives (such as rail and subway lines) would require significant time and money. A less expensive alternative would be to expand existing transit systems, such as by adding new bus service or increasing the number and location of bus stops. Not all communities would be appropriate locations for public transportation offerings, however, particularly those in areas with a geographically dispersed population.

In addition, policies that reduced people's use of their personal vehicles or lessened the associated costs would ultimately decrease the vulnerability of households and businesses to disruptions in oil markets. Widespread adoption of telecommuting work policies, the implementation of lower speed limits, or the promotion of ride-sharing or bicycle programs would reduce the consumption of transportation fuel.[33] Such policies would decrease fuel use by prompting some consumers to not drive or to drive more slowly (and thus burn less gasoline per mile traveled) when they did drive. In addition, the policies could be implemented quickly (although not all at the federal level). Such policies would allow some households and businesses to lessen their expenditures when oil prices rose, but they might be accompanied by reduced productivity or longer commutes.

Policies to Address Persistent Disruptions. Policies to address long-lasting changes in oil prices could take two broad approaches parallel to those used to address temporary disruptions:

32. See Daniel McFadden, "The Measurement of Urban Travel Demand," *Journal of Public Economics,* vol. 3, no. 4 (November 1974), pp. 303–328; and Brian D. Taylor and others, "Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across U.S. Urbanized Areas," *Transportation Research Part A: Policy and Practice,* vol. 43, no. 1 (January 2009), pp. 60–77.

33. The Government Accountability Office reports that the establishment in 1974 of a national speed limit of 55 miles per hour decreased fuel consumption in the United States by 0.2 percent to 3 percent, which the Department of Energy estimates to yield a savings of 175,000 to 275,000 barrels of oil per day; a reduction of 5 miles per hour in speed increases fuel economy by between 5 percent and 10 percent. See Government Accountability Office, *Energy Efficiency: Potential Fuel Savings Generated by a National Speed Limit Would Be Influenced by Many Other Factors,* GAO-09-153R (November 7, 2008).

- Increasing domestic production of oil or oil substitutes or
- Reducing the consumption of oil by, for example, increasing fuel-efficiency standards or encouraging the development of alternative transportation options that use less, or no, oil.

The first approach could lower oil prices (probably by only a small amount) on an ongoing basis but would still leave households and businesses exposed to price increases stemming from supply disruptions, although those increases would start from a lower level. The second approach would shift some households and businesses away from oil-fueled vehicles, which could reduce their exposure to disruptions in oil markets. Implementing any policy aimed at reducing vulnerability to persistent disruptions would require more time and financial resources than would implementing policies to address temporary disruptions.

Increase Domestic Oil Production. Policies designed to increase the domestic production of oil could lower world oil prices over the long run (though the effect would probably be small), but they would probably not reduce the vulnerability of U.S. households and businesses to disruptions in oil supplies. Such policies could include opening more of the Outer Continental Shelf or the Arctic to drilling, expediting regulatory approval of applications to drill, or reducing the fees charged to private firms (for example, the royalties paid to the government for each barrel of oil produced) when the government makes oil underlying federal lands available for extraction.[34]

Those policies would probably increase the amount of oil brought to the world market, which would lower world oil prices for the time that the additional supply was available. The magnitude of the price reduction would depend on the volume of oil produced and the response by other countries to the introduction of the new supply. To illustrate, the Energy Information Administration (EIA) estimates that opening the Arctic National Wildlife Refuge to drilling could boost domestic oil production by as much as 0.5 to 1.5 million barrels per day (an increase of 9 percent to 27 percent of U.S. production based on 2010 production levels), which could lower world oil prices by $0.41 to $1.44 per barrel in 2025, relative to a base case in which oil was $65 per barrel and assuming no change in oil production elsewhere in the world; that decline would be expected to reduce gasoline prices by 1 to 3 cents per gallon.[35] Production would not commence until 10 years after development was first allowed, and peak production would not occur until 10 years after that. Some oil fields on land can be developed more quickly (within a few years), but deepwater oil fields are expected to have the largest quantity of oil. Such development would not be expected to offset temporary supply disruptions but could increase long-run production in the United States.

EIA further estimates that such an increase in production would be largely offset by a corresponding decrease in output from other large oil-producing countries, resulting in little observable change in the price of oil. For example, Khalid Al Falih, chief executive officer of Saudi Aramco, recently said that Saudi Arabia would reduce its planned output capacity expansion given "massive capacity expansions coming out of countries like Brazil [and] Iraq."[36]

Thus, increasing production in the United States might not increase the world's oil supply substantially or lower the price of oil significantly. For example, oil and gasoline prices have not fallen over the past few years despite an increase in U.S. oil production during that period. Moreover, because any new productive capacity in the United States would be controlled by private firms and not the government (as it is for OPEC members), that new capacity would be used in amounts determined by the owners and not necessarily held as spare capacity to offset disruptions.

U.S. government agencies estimate that the amount of oil that is technically feasible to recover in the United States is 162 billion barrels (22 billion barrels of which has already been discovered); according to recent estimates, technically recoverable oil resources in the United States are equivalent to 78 years of supply at 2010 domestic

34. The Outer Continental Shelf is the submerged land, subsoil, and seabed that is off the coast of the United States at a distance between state jurisdiction (typically between 3 and 5 nautical miles offshore, depending on the state) and 200 miles offshore.

35. See Department of Energy, Energy Information Administration, *Analysis of Crude Oil Production in the Arctic National Wildlife Refuge* (May 2008). Prices are quoted in 2006 dollars.

36. Summer Said, "Saudis See No Reason to Raise Oil Output Capacity," *Wall Street Journal* (October 10, 2011).

production levels, or 29 years of supply if produced at the level of current consumption.[37] Determining the effect on world prices of finding and producing additional oil is difficult, given the uncertainty inherent in bringing the oil to market and the possible reaction of other oil-producing countries.

Even if world oil prices declined as a result of increased U.S. production, most households and businesses would not be substantially less vulnerable to future oil disruptions, for two reasons. First, an expectation by consumers of sustained lower prices would provide an incentive for households and businesses to make long-run decisions—that is, decisions that cannot easily be reversed in the near term—that ultimately increased their reliance on oil. For example, a reduction in gasoline prices would decrease the cost of using less-fuel-efficient vehicles or living far from work. Similarly, if industries expected lower oil prices, they would have less incentive to develop alternative fuel supplies (such as natural gas or electricity) for personal or public transportation. As a result, lower prices might induce households and businesses to increase their reliance on oil in the transportation sector and, thus, increase their exposure to disruptions in the supply of oil. Second, even though oil prices might be slightly lower if oil production was increased, a reduction in cost of a few dollars per barrel would be small compared with the price fluctuations that are common to the oil market. Between 2001 and 2011, price changes of $60 to $90 per barrel of oil occurred. Thus, increased domestic production would leave the vulnerability of most consumers to disruptions in oil markets largely unchanged.[38]

Another consideration is that increased production of oil in the near term comes at the expense of a decreased capacity to produce oil farther in the future, when prices might be even higher and the ability to reduce those prices might be valued even more highly by households and businesses. Consumption of oil by China, India, and Brazil is expected to rise by 2 percent to 4 percent annually between 2008 and 2035; in contrast, oil consumption is expected to increase by 0.3 percent annually in the United States over that period.[39] Such growth in world consumption is expected to put upward pressure on oil prices (unless sufficient new sources of oil are identified and developed), causing the value of oil inventories to rise, regardless of whether that oil is held above ground or left underground in its original reservoirs. Thus, by not developing all of its oil resources now, the United States is retaining more flexibility in the future should oil prices rise dramatically.

Even though increased domestic oil production would probably not enhance U.S. energy security as defined in this report, policymakers might choose to evaluate the need for increased production according to other criteria. For example, increased domestic production on federal lands would raise royalty payments to the federal government and thus have a positive budgetary effect. To the extent that increases in domestic production reduced the price of oil, they would also lessen the revenues earned by oil-producing countries that are hostile toward the United States. Increased production of domestic oil could reduce imports of oil as long as U.S. consumption did not step up by a corresponding amount. Moreover, increased domestic oil production could boost employment and output in the United States. The short-term effects of such changes, however, would probably be small relative to the size of the U.S. economy.[40] Increased domestic production would also have negative consequences, such as a higher risk of spills and other environmental impacts.

37. See Behrens, Ratner, and Glover, *U.S. Fossil Fuel Resources*. In 2010, the United States produced 2 billion barrels of oil and consumed 5.4 billion barrels.

38. Greater domestic production could reduce the vulnerability of some households to disruptions in oil markets. Firms that produce oil earn higher profits when oil prices increase, particularly when such disruptions do not affect firms' costs, but only the price of oil. Thus, greater production of oil in the United States would increase the profits earned by those firms that produce oil when a disruption elsewhere occurs. To some extent, those profits would be returned to U.S. households in the form of dividends, higher salaries and wages for workers of the firms producing oil, and increased domestic investment in the production and processing of oil. Those profits also would be distributed to stockholders and used for investments outside the United States. To the extent that the people who purchase fuel for transportation are not the same as those who would receive financial benefits from the firms producing oil, increases in oil prices would redistribute wealth from consumers of transportation fuel to owners of firms that produce oil regardless of how much oil is produced domestically.

39. See Department of Energy, Energy Information Administration, *International Energy Outlook 2011* (September 19, 2011), Table B4.

40. See the statement of Douglas W. Elmendorf, Director, Congressional Budget Office, before the Senate Budget Committee, *Policies for Increasing Economic Growth and Employment in 2012 and 2013* (November 15, 2011), p. 48.

Develop Alternative Fuels That Substitute for Oil. Policies that promote the development of alternative fuels—ones that can be mixed with or used instead of gasoline and diesel—could improve the ability of U.S. households and businesses to respond to permanent changes in oil prices. Examples of such policies include subsidies for the development of natural gas resources, biofuels, or coal gasification.[41] (All of those types of fuel can be mixed directly with or chemically converted to gasoline.) Persistent disruptions in oil markets could be partially or fully offset if domestic firms decided to expand their capacity to synthetically create transportation fuels, even though those fuels, because of their direct substitutability, would be sold at the same price as oil-based transport fuels. If the production of substitute fuels was sufficiently large and those fuels were held in reserve (or only subsidized when the government determined it was warranted), that domestic capacity for synthetic fuels could operate similarly to Saudi Arabia's spare capacity for producing oil. As such, the spare capacity would benefit consumers of oil around the world. If it was maintained as permanent capacity, the effect on oil prices would probably be small—similar to the effect of increased domestic oil production—because it could be offset by other oil-producing countries.

Nevertheless, policies to promote alternative fuels would involve significant uncertainties as to their economic feasibility and the consequences of their enactment. Conversion of coal, natural gas, and organic matter to gasoline is expensive, inefficient, and unproven on a large scale.[42] In addition, greater use of coal and natural gas for transportation could increase the domestic price of those commodities and thus raise costs for electricity or other energy-consuming sectors of the economy.

Reduce Gasoline Consumption by Gasoline-Fueled Vehicles. Policies designed to reduce the demand for oil, such as raising automobile fuel-efficiency requirements or increasing the gasoline tax, could reduce the vulnerability of U.S. households and businesses to permanent changes in oil prices.

Higher fuel-efficiency standards would require the production of new vehicles that use less fuel per mile, which would reduce the exposure of U.S. consumers to disruptions in oil prices.[43] An increase in the gasoline tax would raise the cost of consuming oil-based fuels and, in doing so, provide a financial incentive for households and businesses to find long-run alternatives to consuming such fuels. Analogous to policies that would boost the production of oil, policies that reduced fuel consumption would probably also result in slightly lower fuel prices. But even with lower prices, fuel consumption under those policies would be lower, on balance.

An increase in the gasoline tax could be implemented more quickly than policies to increase fuel-efficiency standards, which would take a longer time to have a significant effect. Near-term responses to a higher gasoline tax (or to higher gasoline prices that occur for other reasons) could include carpooling, driving more slowly, or vacationing closer to home. Long-run responses could include buying smaller, more fuel-efficient cars; living closer to work or public transit; or selecting jobs on the basis of their telecommuting options. The heating industry provides an illustrative example of the speed with which a transition of that magnitude could be made: As a result of higher oil prices in the 1970s and the availability of alternative heating fuels, U.S. consumers gradually shifted over the subsequent 40 years from oil to electricity and natural gas as their primary heating fuels (see Box 3 on page 20). An increase in the gasoline tax would also

41. Coal gasification is a process that converts solid coal—through several energy-intensive steps—into gasoline and diesel fuel. Natural gas can also be chemically converted to gasoline through a similar energy-intensive process.

42. For more details on the costs and feasibility of biofuels, see Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals* (July 2010). The production of biofuels has also been found to raise the cost of food; see Congressional Budget Office, *The Impact of Ethanol Use on Food Prices and Greenhouse Gas Emissions* (April 2009). And the increased reliance on biofuels introduces weather uncertainty into considerations of crop yields from one year to the next; see Darrel Good and Scott Irwin, *2007 U.S. Corn Production Risks: What Does History Teach Us?* Marketing and Outlook Brief 2010-01 (Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 2010).

43. In April 2010, the National Highway Traffic Safety Administration and the Environmental Protection Agency finalized a rule to increase corporate average fuel economy standards for light-duty vehicles (including cars, sport utility vehicles, pickup trucks, minivans, and crossover vehicles) from 29.7 miles per gallon in 2012 to 34.1 mpg by 2016. Then in 2011, they issued a joint proposed rule that would further tighten corporate average fuel economy standards for those vehicles—to 49.6 mpg—from 2017 through 2025.

bring revenues into the U.S. Treasury and, thus, have a positive budgetary effect.

Such policies would be effective only to the extent that they increased the cost of consuming gasoline and, consequently, created an incentive for consumers to reduce their use of gasoline. As a result, vehicle users would pay more to consume gasoline, or vehicle producers would pay more to implement higher fuel-efficiency requirements. (Some or all of the producers' costs would probably be passed on to vehicle buyers, which would impose larger costs on certain industries, such as trucking, and on individuals who need to drive a lot.)

Develop Vehicles That Use Alternative Fuels. Policies that promote flexibility in the fuels that households and businesses use for transportation would reduce their vulnerability to changes in oil prices. Such policies might include the promotion of natural gas or electric vehicles, federal support for high-speed electric rail, or new public transportation relying on alternative fuels. To the extent that those policies diversified the sources of energy used in the transportation sector, they would reduce the vulnerability to changing world oil prices for those consumers who would shift away from using oil for transportation—as well as for those consumers who would still ordinarily use oil—by offering them additional transportation alternatives that are not dependent on oil. Some limited steps have already been taken toward diversifying fuel use for transportation; for example, municipal vehicles rely increasingly on natural gas.

Some policies to develop vehicles that use alternative fuels could require significant investments in infrastructure and technology and, thus, might not produce a positive return for many years, if at all. Development of a distribution network to deliver natural gas to vehicles and construction of high-speed rail would both have high capital costs, which would probably have to be borne at least partially by taxpayers. In addition, as the transportation sector came to rely more heavily on other commodities, such as natural gas, those commodities could increase in cost, which might raise costs for consumers in other energy-consuming sectors of the economy.

Lists of Tables and Figures

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About This Document

This Congressional Budget Office (CBO) report was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources. In keeping with CBO's mandate to provide objective, impartial analysis, this report makes no recommendations.

Andrew Stocking of CBO's Microeconomic Studies Division wrote the report under the guidance of Joseph Kile and David Moore (formerly of CBO). Bob Arnold, Perry Beider, Terry Dinan, Wendy Edelberg, Kathy Gramp, Mark Hadley, Mark Lasky, Chad Shirley, Natalie Tawil, and Steven Weinberg of CBO provided helpful comments on drafts.

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Summary

Nuclear energy issues facing Congress include power plant safety and regulation, radioactive waste management, research and development priorities, federal incentives for new commercial reactors, nuclear weapons proliferation, and security against terrorist attacks.

The earthquake and resulting tsunami that severely damaged Japan's Fukushima Daiichi nuclear power plant on March 11, 2011, raised questions in Congress about the disaster's possible implications for nuclear safety regulation, U.S. nuclear energy expansion, and radioactive waste policy. The tsunami knocked out all electric power at the six-reactor plant, resulting in the overheating of several reactor cores, loss of cooling in spent fuel storage pools, major hydrogen explosions, and releases of radioactive material to the environment. The Nuclear Regulatory Commission (NRC) issued orders to U.S. nuclear plants March 12, 2012, to begin implementing safety improvements in response to Fukushima.

Significant incentives for new commercial reactors were included in the Energy Policy Act of 2005 (EPACT05, P.L. 109-58), such as tax credits and loan guarantees. Together with volatile fossil fuel prices and the possibility of greenhouse gas controls, the federal incentives for nuclear power helped spur renewed interest by utilities and other potential reactor developers. License applications for as many as 31 new reactors have been announced, and NRC issued licenses for four reactors at two plant sites in early 2012. However, falling natural gas prices and other circumstances have made it unlikely that many more of the proposed nuclear projects will move toward construction in the near term.

DOE's nuclear energy research and development program includes advanced reactors, fuel cycle technology and facilities, and infrastructure support. The Obama Administration's FY2013 funding request totals $770.4 million, which is $88.3 million (10.3%) below the enacted FY2012 funding level. DOE is requesting $65 million for FY2013 to provide technical support for licensing small modular light water reactors (LWRs), $2 million below the FY2012 funding level. The House-passed version of the FY2013 Energy and Water appropriations bill (H.R. 5325) increased nuclear R&D by $89.9 million from FY2012, while the Senate Appropriations Committee recommended a $20.1 million increase (S. 2465).

Disposal of highly radioactive waste has been one of the most controversial aspects of nuclear power. The Nuclear Waste Policy Act of 1982 (P.L. 97-425), as amended in 1987, required DOE to conduct a detailed physical characterization of Yucca Mountain in Nevada as a permanent underground repository for high-level waste. The Obama Administration decided to "terminate the Yucca Mountain program while developing nuclear waste disposal alternatives," according to the DOE FY2010 budget justification. Alternative waste management strategies were evaluated by the Blue Ribbon Commission on America's Nuclear Future, which issued its final report to the Secretary of Energy on January 26, 2012. The report recommended options for temporary storage, treatment, and permanent disposal of highly radioactive nuclear waste, along with an evaluation of nuclear waste technologies. It did not recommend specific sites for new nuclear waste facilities or evaluate the suitability of Yucca Mountain. No funding was provided in FY2012 or requested for FY2013 to continue NRC licensing of the Yucca Mountain repository, although the issue is currently the subject of a federal appeals court case. The House-passed FY2013 Energy and Water bill provided DOE with $25 million to resume Yucca Mountain licensing, along with $10 million for NRC. The Senate Appropriations Committee authorized a pilot program to develop one or more voluntary nuclear waste storage sites.

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Most Recent Developments

The Nuclear Regulatory Commission (NRC) on February 9, 2012, approved the first licenses to build new U.S. commercial nuclear reactors in more than three decades. The combined operating licenses (COLs) allow Southern Company to construct and operate two new Westinghouse AP1000 reactors at the Vogtle nuclear power plant in Georgia. On March 30, 2012, NRC approved COLs for two additional AP1000 reactors at the existing Summer nuclear plant in South Carolina. Each of the new reactors, scheduled for completion between 2016 and 2019, is expected to cost from $5 billion to $7 billion.

NRC on March 12, 2012, issued its first nuclear plant safety requirements based on lessons learned from the March 2011 Fukushima disaster in Japan. NRC ordered U.S. nuclear plant operators to begin implementing safety enhancements related to the loss of power caused by natural disasters, reactor containment venting, and monitoring the water levels of reactor spent fuel pools. The Fukushima nuclear plant was hit by an earthquake and tsunami that knocked out all electric power at the six-reactor plant, resulting in the overheating of the reactor cores in three of the units and a heightened overheating risk at several spent fuel storage pools at the site. The overheating of the reactor cores caused major hydrogen explosions and releases of radioactive material to the environment. Several House and Senate hearings have been held on the accident, and several bills on nuclear safety have been introduced in the 112th Congress. Proposed bills would delay all new nuclear licenses and permits until stronger safety standards were in place (H.R. 1242), expand evacuation planning around U.S. nuclear reactors (H.R. 1268), and initiate U.S. efforts to strengthen international nuclear safety agreements (S. 640, H.R. 1326).

The Obama Administration requested $770.4 million for nuclear energy research and development in its FY2013 budget, submitted to Congress February 12, 2012. Including advanced reactors, fuel cycle technology, infrastructure support, and safeguards and security, the total nuclear energy request is $88.3 million (10.3%) below the enacted FY2012 funding level. Funding for safeguards and security in FY2012 was provided under a separate appropriations account, Other Defense Activities, but it is included under the Nuclear Energy account in the FY2013 request. The largest proposed reductions for FY2013 are Reactor Concepts (35.9%), Radiological Facility Management (26.6%), and Nuclear Energy Enabling Technologies (12.5%). The House-passed FY2013 Energy and Water Development appropriations bill would increase nuclear R&D by $89.9 million from FY2012 (H.Rept. 112-462), while the Senate Appropriations Committee recommended a $20.1 million increase (S.Rept. 112-164),

Nuclear energy funding for FY2012 was included in the Consolidated Appropriations Act, 2012 (P.L. 112-74), approved by Congress December 17, 2011. The funding measure included $67 million to commercialize small modular reactors and $60 million for nuclear waste disposal research.

The Blue Ribbon Commission on America's Nuclear Future, established by the Obama Administration to recommend a new strategy for nuclear waste management, issued its final report to the Secretary of Energy on January 26, 2012.[1] President Obama has moved to terminate previous plans to open a national nuclear waste repository at Yucca Mountain, NV. In its final

[1] Blue Ribbon Commission on America's Nuclear Future, *Report to the Secretary of Energy*, January 2012, http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf.

report, the Blue Ribbon Commission recommended a "consent-based" approach to siting nuclear waste facilities and that the roles of local, state, and tribal governments be negotiated for each potential site. The development of consolidated waste storage and disposal facilities should begin as soon as possible, the Commission urged. A new waste management organization should be established to develop the repository, along with associated transportation and storage systems, according to the Commission. The new organization should have "assured access" to the Nuclear Waste Fund, which holds fees collected from nuclear power plant operators to pay for waste disposal. Under existing law, the Nuclear Waste Fund cannot be drawn down without congressional appropriations. The House appropriations bill would provide DOE with $25 million for FY2013 to resume Yucca Mountain licensing, along with $10 million for NRC in a floor amendment (H.R. 5325). The Senate Appropriations Committee on April 26, 2012, authorized a pilot program to develop one or more voluntary nuclear waste storage sites (S. 2465).

President Obama's State of the Union Address on January 25, 2011, called for nuclear power to be included in a national goal of generating 80% of U.S. electricity "from clean energy sources" by 2035. Along with nuclear power and renewable energy, "clean energy" would include "efficient" natural gas plants and clean coal technologies, to the extent that they reduced carbon emissions compared with conventional coal-fired plants. The President's proposed Clean Energy Standard could provide a significant boost to U.S. nuclear power expansion, particularly in areas of the country with relatively limited renewable energy resources. Senator Bingaman, Chairman of the Senate Energy and Natural Resources Committee, introduced legislation to establish a national clean energy standard March 1, 2012 (S. 2146).

Nuclear Power Status and Outlook

After nearly 30 years in which no new orders had been placed for nuclear power plants in the United States, a series of license applications that began in 2007 prompted widespread speculation about a U.S. "nuclear renaissance." The renewed interest in nuclear power largely resulted from the improved performance of existing reactors, federal incentives in the Energy Policy Act of 2005 (P.L. 109-58), the possibility of carbon dioxide controls that could increase costs at fossil fuel plants, and volatile prices for natural gas—the favored fuel for new power plants for the past two decades.

Four of the proposed new U.S. reactors received licenses from the Nuclear Regulatory Commission (NRC) in early 2012. NRC approved combined construction permit and operating licenses (COLs) for Southern Company to build and operate two new Westinghouse AP1000 reactors at the Vogtle nuclear power plant in Georgia on February 9, 2012. On March 30, 2012, NRC approved COLs for two additional AP1000 reactors at the existing Summer nuclear plant in South Carolina. Substantial site preparation and infrastructure work has already taken place at both sites, and the owners of both projects announced plans to move to full construction after receiving their COLs.[2]

[2] Southern Company, "Southern Company Subsidiary Receives Historic License Approval for New Vogtle Units, Full Construction Set to Begin," February 9, 2012, http://www.southerncompany.com/news/iframe_pressroom.aspx; SCANA, "NRC Approves COLs for SCE&G, Santee Cooper Nuclear Units," March 30, 2012, http://www.scana.com/en/investor-relations/news-releases/nrc-approves-cols-for-sceg-santee-cooper-nuclear-units.htm.

However, the future of all other proposed new U.S. reactors is uncertain. High construction cost estimates—a major reason for earlier reactor cancellations—continue to undermine nuclear power economics. A more recent obstacle to nuclear power growth has been the development of vast reserves of domestic natural gas from previously uneconomic shale formations, which has held gas prices low and reduced concern about future price spikes. Moreover, uncertainty over U.S. controls on carbon emissions may be further increasing caution by utility companies about future nuclear projects.

The March 11, 2011, earthquake and tsunami that severely damaged Japan's Fukushima Daiichi nuclear power plant could also affect plans for new U.S. reactors, although U.S. nuclear power growth was already expected to be modest in the near term. Following the Fukushima accident, preconstruction work was suspended on two planned reactors at the South Texas Project. Tokyo Electric Power Company (TEPCO), which owns the Fukushima plant, had planned to invest in the South Texas Project expansion, but TEPCO's financial condition plunged after the accident. New U.S. safety requirements resulting from the Fukushima disaster could raise investor concerns about higher costs. On the other hand, after the accident the Obama Administration reiterated its support for nuclear power expansion as part of its clean energy policy.[3]

The recent applications for new power reactors in the United States followed a long period of declining nuclear generation growth rates. Until the COLs were issued for the Vogtle and Summer projects, no nuclear power plants had been ordered in the United States since 1978, and more than 100 reactors had been canceled, including all ordered after 1973. The most recent U.S. nuclear unit to be completed was the Tennessee Valley Authority's (TVA's) Watts Bar 1 reactor, ordered in 1970 and licensed to operate in 1996. But largely because of better operation and capacity expansion at existing reactors, annual U.S. nuclear generation has risen by about 20% since the startup of Watts Bar 1.[4]

The U.S. nuclear power industry currently comprises 104 licensed reactors at 65 plant sites in 31 states and generates about 20% of the nation's electricity.[5] TVA's board of directors voted August 1, 2007, to resume construction on Watts Bar 2, which had been suspended in 1985; the renewed construction project was to cost about $2.5 billion and be completed in 2013. However, TVA announced on April 5, 2012, that completing Watts Bar 2 would cost up to $2 billion more than expected and take until 2015.[6] At TVA's request, NRC in March 2009 reinstated the construction authorization for the two-unit Bellefonte (AL) nuclear plant, which had been deferred in 1988 and canceled in 2006.[7] The TVA board voted on August 18, 2011, to complete construction of Bellefonte 1 after the Watts Bar 2 project is finished. Completing Bellefonte 1 was projected at that time to cost $4.9 billion, with operation to begin by 2020.[8]

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[3] Oral Testimony of Energy Secretary Steven Chu at the House Energy and Commerce Committee – As Prepared for Delivery, March 16, 2011, http://www.energy.gov/news/10178.htm.

[4] Energy Information Administration, *Electric Power Monthly*, Net Generation by Energy Source, April 2011, http://www.eia.gov/cneaf/electricity/epm/epm_sum.html.

[5] U.S. Nuclear Regulatory Commission, *Information Digest 2008-2009*, NUREG-1350, Vol. 20, August 2008, p. 32, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v20/sr1350v20.pdf.

[6] Mary Powers, "Credit Agencies See Watts Bar-2 Cost Impact," *Nucleonics Week*, April 12, 2012, p. 1.

[7] Nuclear Regulatory Commission, "In the Matter of Tennessee Valley Authority (Bellefonte Nuclear Plant Units 1 and 2)," 74 *Federal Register* 10969, March 13, 2009.

[8] Tennessee Valley Authority, "TVA Board Implements Vision," press release, August 18, 2011, http://www.tva.com/news/releases/julsep11/board_meeting/index.htm.

Annual electricity production from U.S. nuclear power plants is much greater than that from oil and hydropower and other renewable energy sources. Nuclear generation has been overtaken by natural gas in recent years, and it remains well behind coal, which accounts for about 45% of U.S. electricity generation.[9] Nuclear plants generated more than half the electricity in four states in 2011—Connecticut, New Jersey, South Carolina, and Vermont.[10] The 790 billion net kilowatt-hours of nuclear electricity generated in the United States during 2011[11] was about the same as the nation's entire electrical output in the early 1960s, when the oldest of today's operating U.S. commercial reactors were ordered.[12]

Reasons for the 30-year halt in U.S. nuclear plant orders included high capital costs, public concern about nuclear safety and waste disposal, and regulatory compliance issues.

High construction costs may pose the most serious obstacle to nuclear power expansion. Construction costs for reactors completed since the mid-1980s ranged from $2 to $6 billion, averaging more than $3,900 per kilowatt of electric generating capacity (in 2011 dollars), far higher than commercial fossil fuel technologies. The nuclear industry predicts that new plant designs could be built for less than that if many identical plants were built in a series, but current estimates for new reactors show little if any reduction in cost.[13]

In contrast, average U.S. nuclear plant operating costs per kilowatt-hour dropped substantially since 1990, and expensive downtime has been steadily reduced. Licensed U.S. commercial reactors generated electricity at an average of 89% of their total capacity in 2011, according to the Energy Information Administration (EIA).[14]

Seventy-three commercial reactors have received 20-year license extensions from the Nuclear Regulatory Commission (NRC), giving them up to a total of 60 years of operation. License extensions for 13 additional reactors are currently under review, and more are anticipated, according to NRC.[15] The FY2012 Consolidated Appropriations Act (P.L. 112-74) provided $25 million for DOE to study further reactor life extension to 80 years, and DOE requested $21.7 million for that program in FY2013.

Existing nuclear power plants appear to hold a strong position in electricity wholesale markets. In most cases, nuclear utilities have received favorable regulatory treatment of past construction costs, and average existing nuclear plant operating costs are estimated to be competitive with

[9] Energy Information Administration, *Electric Power Monthly*, Net Generation by Energy Source, February 2012, http://www.eia.gov/cneaf/electricity/epm/epm_sum.html. Net generation excludes electricity used for power plant operation.

[10] Nuclear Regulatory Commission, *Information Digest, 2011-2012*, NUREG-1350, Volume 23, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v23/sr1350v23-sec-2.pdf.

[11] Ibid.

[12] All of today's 104 operating U.S. commercial reactors were ordered from 1963 through 1973; see "Historical Profile of U.S. Nuclear Power Development," U.S. Council for Energy Awareness, 1992.

[13] For a comparison of generating costs, see CRS Report RL34746, *Power Plants: Characteristics and Costs*, by Stan Mark Kaplan.

[14] Energy Information Administration, "U.S. Nuclear Generation and Generating Capacity," http://www.eia.gov/cneaf/nuclear/page/nuc_generation/gensum.html.

[15] Nuclear Regulatory Commission, *Fact Sheet on Reactor License Renewal*, August 8, 2011, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-reactor-license-renewal.html.

Table 1. Announced Nuclear Plant License Applications

Announced Applicant	Site	Reactor Type	Units	Status
COL issued				
Southern	Vogtle (GA)	Westinghouse AP1000	2	COL application submitted 3/13/08; engineering, procurement, and construction (EPC) contract signed 4/8/08; ESP and limited construction approved 8/26/09; conditional DOE loan guarantee announced 2/16/10; NRC hearing held 9/27-28/11; COL approved February 9, 2012
SCE&G	Summer (SC)	Westinghouse AP1000	2	COL submitted 3/31/08; EPC contract signed 5/27/08; COL approved March 30, 2012
COL scheduled for completion				
Progress Energy	Levy County (FL)	Westinghouse AP1000	2	COL submitted 7/30/08; scheduled for completion in 2013
COL schedule under revision				
DTE Energy	Fermi (MI)	GE ESBWR	1	COL submitted 9/18/08
FPL	Turkey Point (FL)	Westinghouse AP1000	2	COL submitted 6/30/09; preconstruction work being conducted
Luminant Power (formerly TXU)	Comanche Peak (TX)	Mitsubishi US-APWR	2	COL submitted 9/19/08
Duke Energy	William States Lee (SC)	Westinghouse AP1000	2	COL submitted 12/13/07
Nuclear Innovation North America	South Texas Project	Toshiba ABWR	2	COL submitted 9/20/07; EPC contract signed with Toshiba 2/12/09; NRG Energy halted further investment 4/19/11
PPL	Bell Bend (PA)	Areva EPR	1	COL submitted 10/10/08
Progress Energy	Harris (NC)	Westinghouse AP1000	2	COL submitted 2/19/08; EPC contract signed 1/5/09
UniStar	Calvert Cliffs (MD)	Areva EPR	1	COL submitted 7/13/07 (Part 1), 3/13/08 (Part 2); Constellation withdrew from project 10/8/10
Dominion	North Anna	Mitsubishi US-APWR	1	COL submitted 11/27/07; ESP approved 11/20/07; reactor selection announced 5/7/10

Announced Applicant	Site	Reactor Type	Units	Status
Licensing suspended				
Entergy	Grand Gulf (MS)	Not specified	1	COL submitted 2/27/08; licensing suspended 1/9/09; ESP approved 3/27/07
Exelon	Victoria County (TX)	Not specified	2	COL application withdrawn and ESP application submitted 3/25/10
AmerenUE	Calloway (MO)	Areva EPR	1	COL submitted 7/24/08; license review suspended 6/23/09; ESP expected 2012
Entergy	River Bend (LA)	Not specified	1	COL submitted 9/25/08; licensing suspended 1/9/09
TVA	Bellefonte	Westinghouse AP1000	2	COL submitted 10/30/07; licensing deferred 9/29/10
Unistar	Nine Mile Point (NY)	Areva EPR	1	COL submitted 9/30/08; licensing suspended 12/1/09
Anticipated license applications				
Blue Castle	Utah	Not specified	1	ESP application expected in 2012
TVA	Clinch River (TN)	mPower small modular reactor	6	Construction permit application expected in 2014; operating license application expected in 2017
AmerenUE	Missouri	Westing. SMR	1	COL application expected in 2012
Unnamed	Unspecified	Unspecified	1	COL application expected in 2013
Southern	Unspecified	Unspecified	1	COL application expected in 2013
Total units announced			**38**	
Total currently active COLs			**20**	

Sources: NRC, *Nucleonics Week*, *Nuclear News*, Nuclear Energy Institute, company news releases.

Note: Applications are for COLs unless otherwise specified.

Nuclear Power Plant Safety and Regulation

Safety

Worldwide concern about nuclear power plant safety rose sharply after the Fukushima accident, which is generally considered to be much worse than the March 1979 Three Mile Island accident in Pennsylvania but not as severe as the April 1986 Chernobyl disaster in the former Soviet Union. Based on dose rates reported by Japanese authorities, the Natural Resources Defense Council (NRDC) estimated that the Fukushima accident subjected the population to a total radiation dose of 148,000 person-rem through April 5. In comparison, the total dose from Three Mile Island was estimated at 2,000 person-rem, while Chernobyl was estimated at 25.5 million person-rem.[28] The Fukushima disaster resulted in similar levels of radioactive contamination per

[28] Matthew McKinzie and Thomas B. Cochran, Natural Resources Defense Council, "The Collective Effective Dose (continued...)

square meter to that of Chernobyl, but the Fukushima contamination was much less widespread and affected a smaller number of people.[29] (For more background on the Fukushima accident, see CRS Report R41694, *Fukushima Nuclear Disaster*, by Mark Holt, Richard J. Campbell, and Mary Beth Nikitin.)

The Fukushima accident has raised particular policy questions for the United States because, unlike Chernobyl, the Fukushima reactors are similar to common U.S. designs. Although the Fukushima accident resulted from a huge tsunami that incapacitated the power plant's emergency diesel generators, the accident dramatically illustrated the potential consequences of any natural catastrophe or other situation that could cause an extended "station blackout" – the loss of alternating current (AC) power. Safety issues related to station blackout include standards for backup batteries, which now are required to provide power for 4-8 hours, and additional measures that may be required to assure backup power. The Institute of Nuclear Power Operations (INPO) released a detailed description of the Fukushima accident in November 2011.[30]

Safety concerns at U.S. reactors were also raised by hydrogen explosions at four of the Fukushima reactors—resulting from a high-temperature reaction between steam and nuclear fuel cladding—and the loss of cooling at the Japanese plant's spent fuel storage pools. Other safety issues that have been raised in the wake of Fukushima include the vulnerability of U.S. nuclear plants to earthquakes, floods, and other natural disasters, the availability of iodine pills to prevent absorption of radioactive iodine released during nuclear accidents, and the adequacy of nuclear accident emergency planning.

In response to such concerns, NRC on March 23, 2011, established a task force "made up of current senior managers and former NRC experts" to "conduct both short- and long-term analysis of the lessons that can be learned from the situation in Japan."[31] The Near-Term Task Force issued its report July 12, 2011, making recommendations ranging from specific safety improvements to broad changes in NRC's overall regulatory approach.[32] NRC staff subsequently identified several of those actions that "can and should be initiated without delay."[33] The NRC Commissioners largely agreed with the recommendations on October 18, 2011, and instructed the agency's staff

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Resulting from Radiation Emitted During the First Weeks of the Fukushima Daiichi Nuclear Accident," April 10, 2011, http://docs.nrdc.org/nuclear/files/nuc_11041301a.pdf. A person-rem is the equivalent of one person receiving a radiation dose of one rem. For background on radiation doses, see CRS Report R41728, *The Japanese Nuclear Incident: Technical Aspects*, by Jonathan Medalia.

[29] French Institut de Radioprotection et de Surete Nucleaire (IRSN), Assessment on the 66th Day of Projected External Doses for Populations Living in the North-West Fallout Zone of the Fukushima Nuclear Accident, Report DRPH/2011-10, p. 27, http://www.irsn.fr/EN/news/Documents/IRSN-Fukushima-Report-DRPH-23052011.pdf.

[30] Institute of Nuclear Power Operations, *Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station*, INPO 11-005, November 2011, available from the Nuclear Energy Institute at http://www.nei.org/resourcesandstats/documentlibrary/safetyandsecurity/reports/special-report-on-the-nuclear-accident-at-the-fukushima-daiichi-nuclear-power-station.

[31] Nuclear Regulatory Commission, "Nuclear Regulatory Commission Directs Staff on Continuing Agency Response to Japan Events; Adjust Commission Schedule," press release, March 23, 2011, http://pbadupws.nrc.gov/docs/ML1108/ML110821123.pdf.

[32] Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, *Recommendations for Enhancing Reactor Safety in the 21st Century*, Nuclear Regulatory Commission, Washington, DC, July 12, 2011, http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf.

[33] NRC, "Recommended Actions to Be Taken Without Delay from the Near-Term Task Force Report," SECY-11-0124, September 9, 2011.

to "strive to complete and implement the lessons learned from the Fukushima accident within five years—by 2016."[34] Tier 1 regulatory actions, which are to get underway immediately, include:

- *Seismic and flood hazard reevaluations and walkdowns.* Nuclear plant operators will be required to evaluate the implications of updated seismic and flooding models, including all potential flooding sources. Plant operators will be required to identify and verify the adequacy of flood and seismic protection features at their sites.
- *Station blackout regulatory actions.* NRC will issue an advance notice of proposed rulemaking (ANPR) with the goal of requiring that nuclear power plants be able to cope with the total loss of AC power (station blackout) for at least eight hours. The eight hour period is intended to give plant personnel enough time to restore AC power or, if that is not possible, to take actions to extend the plant's ability to cope with the loss of AC power to at least 72 hours. The eight-hour coping time would rely only on permanently installed equipment, while the 72-hour coping time could rely on off-site, portable equipment. Enough equipment and personnel would be required to protect all affected reactors at a multi-unit plant. While new regulations are being prepared, NRC is to order plant operators to protect emergency equipment from damage from external events and ensure that enough equipment is available to protect all reactors at a plant site.
- *Reliable hardened vents for Mark I containments.* NRC will order nuclear plants to install vents for the containments in Mark I reactors (the type at Fukushima). The vents would be designed to reduce containment pressure while preventing hydrogen in the containment from leaking into the reactor building, as occurred at Fukushima.
- *Spent fuel pool instrumentation.* NRC will order nuclear plants to install safety instrumentation to monitor spent fuel pool conditions, such as water level, temperature, and radiation levels, from the plant control room.
- *Strengthening and integrating accident procedures and guidelines.* NRC will order nuclear plants to modify emergency operating procedures to integrate severe accident management guidelines and extensive damage mitigation guidelines. The modifications would have to specify clear command-and-control strategies and establish training qualifications for emergency decisionmakers.
- *Emergency preparedness regulatory actions.* Pending a rulemaking, NRC will order nuclear plants to ensure adequate emergency preparedness training for multi-reactor station blackouts and other emergencies.

The NRC staff slightly modified its proposals for top priority actions and divided the remaining Task Force proposals into two lower tiers, which were determined to require further assessment and potentially long-term study. Included in the lower-tier actions were requirements for emergency water supply systems for spent fuel pools, secure power for emergency communications and data systems, confirmation of seismic and flooding hazards, and modifications to NRC's regulatory process.[35]

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[34] NRC, "Staff Requirements – SECY-11-0124 – Recommended Actions to Be Taken Without Delay from the Near-Term Task Force Report," October 18, 2011, http://pbadupws.nrc.gov/docs/ML1126/ML11269A204.pdf.

[35] R.W. Borchardt, NRC Executive Director for Operations, "Prioritization of Recommended Actions to Be Taken in (continued...)

On March 12, 2012, NRC issued its first nuclear plant safety requirements based on the lessons learned from Fukushima. NRC ordered U.S. nuclear plant operators to begin implementing safety enhancements related to the loss of power caused by natural disasters, reactor containment venting, and monitoring the water levels of reactor spent fuel pools. Nuclear plant operators were required to begin implementing the requirements immediately and come into full compliance no later than the end of 2016.[36] NRC also issued an advance notice of proposed rulemaking for new regulatory actions on station blackout March 20, 2012.[37]

Legislation introduced after the Fukushima accident includes the Nuclear Power Plant Safety Act of 2011 (H.R. 1242), introduced by Representative Markey on March 29, 2011. It would require NRC to revise its regulations within 18 months to ensure that nuclear plants could handle major disruptive events, a loss of off-site power for 14 days, and the loss of diesel generators for 72 hours. Spent fuel would have to be moved from pool to dry-cask storage within a year after it had cooled sufficiently, and emergency planning would have to include multiple concurrent disasters. NRC could not issue new licenses or permits until the revised regulations were in place.

Emergency Planning

Following the Three Mile Island accident, which revealed severe weaknesses in preparations for nuclear plant emergencies, Congress mandated that emergency plans be prepared for all licensed power reactors (P.L. 96-295, Sec. 109). NRC was required to develop standards for emergency plans and review the adequacy of each plant-specific plan in consultation with the Federal Emergency Management Agency (FEMA).

NRC's emergency planning requirements focus on a "plume exposure pathway emergency planning zone (EPZ)," encompassing an area within about 10 miles of each nuclear plant. Within the 10-mile EPZ, a range of responses must be developed to protect the public from radioactive releases, including evacuation, sheltering, and the distribution of non-radioactive iodine (as discussed above). The regulations also require a 50-mile "ingestion pathway EPZ," in which actions are developed to protect food supplies.[38] Nuclear plants are required to conduct emergency preparedness exercises every two years. The exercises, which are evaluated by FEMA and NRC, may include local, state, and federal responders and may involve both the plume and ingestion EPZs.[39]

The size of the plume exposure EPZ has long been a subject of controversy, particularly after the 9/11 terrorist attacks on the United States, in which nuclear plants were believed to have been a potential target. Attention to the issue was renewed by the Fukushima accident, in which some of the highest radiation dose rates have been measured beyond 10 miles from the plant.[40]

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Response to Fukushima Lessons Learned," SECY-11-0137, October 3, 2011.

[36] Nuclear Regulatory Commission, "Actions in Response to the Japan Nuclear Accident," May 1, 2012, http://www.nrc.gov/reactors/operating/ops-experience/japan-info.html.

[37] Nuclear Regulatory Commission, "Station Blackout," Advance notice of proposed rulemaking, *Federal Register*, March 20, 2012, p. 16175, http://www.gpo.gov/fdsys/pkg/FR-2012-03-20/pdf/2012-6665.pdf.

[38] 10 CFR 50.47, Emergency Plans.

[39] Nuclear Regulatory Commission, "Emergency Preparedness & Response," website, http://www.nrc.gov/about-nrc/emerg-preparedness.html.

[40] Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT), "Readings of Integrated Dose at (continued...)

Controversy over the issue intensified after NRC recommended on March 16, 2011, the evacuation of U.S. citizens within 50 miles of the Fukushima plant. The NRC recommendation was based on computer models that, using meteorological data and estimates of plant conditions, found that potential radiation doses 50 miles from the plant could exceed U.S. protective action guidelines.[41] Legislation introduced by Representative Lowey (H.R. 1268) would require evacuation planning within 50 miles of U.S. nuclear power plants.

In response to the 9/11 terrorist attacks, NRC modified its nuclear plant emergency planning requirements and began a comprehensive review of emergency planning regulations and guidance. The NRC staff sent a proposed final rule based on that review to the NRC Commissioners for approval on April 8, 2011, and the rule took effect December 23, 2011.[42] Among the changes included in the rule are new requirements for periodic updates of EPZ evacuation time estimates, mandatory backups for public alert systems, and protection of emergency responders during terrorist attacks. The new emergency planning regulations were prepared before the Fukushima accident, but the NRC staff recommended approval of the changes without waiting for further changes that might result from the lessons of the Japanese accident. Emergency planning changes resulting from Fukushima should be implemented later, the staff recommended.[43]

Domestic Reactor Safety Experience

Nuclear power safety has been a longstanding issue in the United States. Safety-related shortcomings have been identified in the construction quality of some plants, plant operation and maintenance, equipment reliability, emergency planning, and other areas. In one serious case, it was discovered in March 2002 that leaking boric acid had eaten a large cavity in the top of the reactor vessel in Ohio's Davis-Besse nuclear plant. The corrosion left only the vessel's quarter-inch-thick stainless steel inner liner to prevent a potentially catastrophic loss of reactor cooling water. Davis-Besse remained closed for repairs and other safety improvements until NRC allowed the reactor to restart in March 2004.

NRC's oversight of the nuclear industry is a subject of contention as well; nuclear utilities often complain that they are subject to overly rigorous and inflexible regulation, but nuclear critics charge that NRC frequently relaxes safety standards when compliance may prove difficult or costly to the industry.

In terms of public health consequences, the safety record of the U.S. nuclear power industry in comparison with other major commercial energy technologies has been excellent. During more than 3,500 reactor-years of operation in the United States,[44] the only incident at a commercial

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Monitoring Post out of 20 Km Zone of Fukushima Dai-ichi NPP," data series, http://www.mext.go.jp/english/incident/1304275.htm.

[41] Nuclear Regulatory Commission, "NRC Provides Protective Action Recommendations Based on U.S. Guidelines," press release, March 16, 2011, http://pbadupws.nrc.gov/docs/ML1108/ML110800133.pdf.

[42] Nuclear Regulatory Commission, "Enhancements to Emergency Planning Regulations," Final rule, *Federal Register*, November 23, 2011, p. 72560.

[43] Nuclear Regulatory Commission, "Final Rule: Enhancements to Emergency Preparedness Regulations," SECY-11-0053, April 8, 2011, http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0053scy.pdf.

[44] Nuclear Energy Institute, "Myths and Facts About Nuclear Energy," January 2012, p. 12, .http://www.nei.org/
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nuclear power plant that might lead to any deaths or injuries to the public has been the Three Mile Island accident, in which more than half the reactor core melted.[45] A study of 32,000 people living within five miles of the reactor when the accident occurred found no significant increase in cancer rates through 1998, although the authors noted that some potential health effects "cannot be definitively excluded."[46]

The relatively small amounts of radioactivity released by nuclear plants during normal operation are not generally believed to pose significant hazards, although some groups contend that routine emissions are unacceptably risky. There is substantial scientific uncertainty about the level of risk posed by low levels of radiation exposure; as with many carcinogens and other hazardous substances, health effects can be clearly measured only at relatively high exposure levels. In the case of radiation, the assumed risk of low-level exposure has been extrapolated mostly from health effects documented among persons exposed to high levels of radiation, particularly Japanese survivors of nuclear bombing in World War II, medical patients, and nuclear industry workers.[47]

NRC announced April 7, 2010, that it had asked the National Academy of Sciences (NAS) to "perform a state-of-the-art study on cancer risk for populations surrounding nuclear power facilities." Unlike in previous studies, NAS is to examine cancer diagnosis rates, rather than cancer deaths, potentially increasing the amount of data. The new study would also use geographic units smaller than counties to determine how far members of the study group are located from reactors, to more clearly determine whether there is a correlation between cancer cases and distance from reactors.[48]

NRC's 1986 Safety Goal Policy Statement declared that nuclear power plants should not increase the risk of accidental or cancer deaths among the nearby population by more than 0.1%.[49] Later NRC guidance established a "subsidiary benchmark" for the probability of accidental core damage (fuel melting): Core damage frequency should average no more than one in 10,000 per reactor per year.[50] In addition, NRC set a benchmark that reactor containments should be successful at least 90% of the time in preventing major radioactive releases during a core-damage accident. Therefore, the benchmark probability of a major release from containment failure

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resourcesandstats/documentlibrary/reliableandaffordableenergy/factsheet/myths—facts-about-nuclear-energy-january-2012.

45 Nuclear Regulatory Commission, "Backgrounder on the Three Mile Island Accident," March 15, 2011, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html.

46 Evelyn O. Talbott et al., "Long Term Follow-Up of the Residents of the Three Mile Island Accident Area: 1979-1998," Environmental Health Perspectives, published online October 30, 2002, at http://ehp.niehs.nih.gov/docs/2003/5662/abstract.html.

47 National Research Council, Committee to Assess the Health Risks from Exposure to Low Levels of Ionizing Radiation, *Beir VII: Health Risks from Exposure to Low Levels of Ionizing Radiation, Report in Brief*, http://dels-old.nas.edu/dels/rpt_briefs/beir_vii_final.pdf.

48 Nuclear Regulatory Commission, "NRC Asks National Academy of Sciences to Study Cancer Risk in Populations Living Near Nuclear Power Facilities," press release, April 7, 2010, http://www.nrc.gov/reading-rm/doc-collections/news/2010/10-060.html.

49 NRC, "Safety Goals for the Operations of Nuclear Power Plants," policy statement, *Federal Register*, August 21, 1986, p. 30028, http://www.nrc.gov/reading-rm/doc-collections/commission/policy/51fr30028.pdf.

50 NRC Staff Requirements Memorandum on SECY-89-102, "Implementation of the Safety Goals," Memorandum to James M. Taylor fro Samuel J. Chilk, June 15, 1990, http://pbadupws.nrc.gov/docs/ML0037/ML003707881.pdf.

during a core melt accident would average less than one in 100,000 per reactor per year.[51] (For the current U.S. fleet of about 100 reactors, that rate would yield an average of one core-damage accident every 100 years and a major release every 1,000 years.) On the other hand, some groups challenge the complex calculations that go into predicting such accident frequencies, contending that accidents with serious public health consequences may be more frequent.[52]

Reactor Safety in the Former Soviet Bloc

The Chernobyl accident was by far the worst nuclear power plant accident to have occurred anywhere in the world. At least 31 persons died quickly from acute radiation exposure or other injuries, and thousands of additional cancer deaths among the tens of millions of people exposed to radiation from the accident may occur during the next several decades.

According to a 2006 report by the Chernobyl Forum organized by the International Atomic Energy Agency, the primary observable health consequence of the accident was a dramatic increase in childhood thyroid cancer. The Chernobyl Forum estimated that about 4,000 cases of thyroid cancer have occurred in children who after the accident drank milk contaminated with high levels of radioactive iodine, which concentrates in the thyroid. Although the Chernobyl Forum found only 15 deaths from those thyroid cancers, it estimated that about 4,000 other cancer deaths may have occurred among the 600,000 people with the highest radiation exposures, plus an estimated 1% increase in cancer deaths among persons with less exposure. The report estimated that about 77,000 square miles were significantly contaminated by radioactive cesium.[53] Greenpeace issued a report in 2006 estimating that 200,000 deaths in Belarus, Russia, and Ukraine resulted from the Chernobyl accident between 1990 and 2004.[54]

Licensing and Regulation

For many years, a top priority of the U.S. nuclear industry was to modify the process for licensing new nuclear plants. No electric utility would consider ordering a nuclear power plant, according to the industry, unless licensing became quicker and more predictable, and designs were less subject to mid-construction safety-related changes required by NRC. The Energy Policy Act of 1992 (P.L. 102-486) largely implemented the industry's licensing goals.

Nuclear plant licensing under the Atomic Energy Act of 1954 (P.L. 83-703; U.S.C. 2011-2282) had historically been a two-stage process. NRC first issued a construction permit to build a plant and then, after construction was finished, an operating license to run it. Each stage of the licensing process involved adjudicatory proceedings. Environmental impact statements also are required under the National Environmental Policy Act.

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[51] U.S. NRC, Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Revision 1, November 2002, http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/rg/01-174.

[52] Public Citizen Energy Program, "The Myth of Nuclear Safety," http://www.citizen.org/cmep/energy_enviro_nuclear/nuclear_power_plants/reactor_safety/articles.cfm?ID=4454.

[53] The Chernobyl Forum: 2003-2005, *Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts*, International Atomic Energy Agency, April 2006.

[54] Greenpeace. *The Chernobyl Catastrophe: Consequences on Human Health*, April 2006, p. 10.

Over the vehement objections of nuclear opponents, the Energy Policy Act of 1992 provided a clear statutory basis for one-step nuclear licenses. Under the new process, NRC can issue combined construction permits and operating licenses (COLs) and allow completed plants to operate without delay if they meet all construction requirements—called "inspections, tests, analyses, and acceptance criteria," or ITAAC. NRC would hold preoperational hearings on the adequacy of plant construction only in specified circumstances.

DOE's Nuclear Power 2010 program had paid up to half the cost of several COLs and early site permits to test the revised licensing procedures. However, the COL process cannot be fully tested until construction of new reactors is completed. At that point, it could be seen whether completed plants will be able to operate without delays or whether adjudicable disputes over construction adequacy may arise. Section 638 of the Energy Policy Act of 2005 (EPACT05, P.L. 109-58) authorizes federal payments to the owner of a completed reactor whose operation is held up by regulatory delays. The nuclear industry is asking Congress to require NRC to use informal procedures in determining whether ITAAC have been met, eliminate mandatory hearings on uncontested issues before granting a COL, and make other changes in the licensing process.[55]

A fundamental concern in the nuclear regulatory debate is the performance of NRC in issuing and enforcing nuclear safety regulations. The nuclear industry and its supporters have regularly complained that unnecessarily stringent and inflexibly enforced nuclear safety regulations have burdened nuclear utilities and their customers with excessive costs. But many environmentalists, nuclear opponents, and other groups charge NRC with being too close to the nuclear industry, a situation that they say has resulted in lax oversight of nuclear power plants and routine exemptions from safety requirements.

Primary responsibility for nuclear safety compliance lies with nuclear plant owners, who are required to find any problems with their plants and report them to NRC. Compliance is also monitored directly by NRC, which maintains at least two resident inspectors at each nuclear power plant. The resident inspectors routinely examine plant systems, observe the performance of reactor personnel, and prepare regular inspection reports. For serious safety violations, NRC often dispatches special inspection teams to plant sites.

NRC's reactor safety program is based on "risk-informed regulation," in which safety enforcement is guided by the relative risks identified by detailed individual plant studies. NRC's risk-informed reactor oversight system, inaugurated April 2, 2000, relies on a series of performance indicators to determine the level of scrutiny that each reactor should receive.[56]

Reactor Security

Nuclear power plants have long been recognized as potential targets of terrorist attacks, and critics have long questioned the adequacy of requirements for nuclear plant operators to defend against such attacks. All commercial nuclear power plants licensed by NRC have a series of

[55] Nuclear Energy Institute, *Legislative Proposal to Help Meet Climate Change Goals by Expanding U.S. Nuclear Energy Production*, Washington, DC, October 28, 2009, p. 5, http://www.nei.org/resourcesandstats/documentlibrary/newplants/policybrief/2009-nuclear-policy-initiative.

[56] For more information about the NRC reactor oversight process, see http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/index.html.

physical barriers against access to vital reactor areas and are required to maintain a trained security force to protect them.

A key element in protecting nuclear plants is the requirement that simulated terrorist attacks, monitored by NRC, be carried out to test the ability of the plant operator to defend against them. The severity of attacks that plant security must prepare for is specified in the "design basis threat" (DBT).

EPACT05 required NRC to revise the DBT based on an assessment of terrorist threats, the potential for multiple coordinated attacks, possible suicide attacks, and other criteria. NRC approved the DBT revision based on those requirements on January 29, 2007. The revised DBT does not require nuclear power plants to defend against deliberate aircraft attacks. NRC contended that nuclear facilities were already required to mitigate the effects of large fires and explosions, no matter what the cause, and that active protection against airborne threats was being addressed by U.S. military and other agencies.[57] After much consideration, NRC voted February 17, 2009, to require all new nuclear power plants to incorporate design features that would ensure that, in the event of a crash by a large commercial aircraft, the reactor core would remain cooled or the reactor containment would remain intact, and radioactive releases would not occur from spent fuel storage pools.[58] The rule change was published in the Federal Register June 12, 2009.[59]

NRC rejected proposals that existing reactors also be required to protect against aircraft crashes, such as by adding large external steel barriers. However, NRC did impose some additional requirements related to aircraft crashes on all reactors, both new and existing, after the 9/11 terrorist attacks of 2001. In 2002, as noted above, NRC ordered all nuclear power plants to develop strategies to mitigate the effects of large fires and explosions that could result from aircraft crashes or other causes. An NRC regulation on fire mitigation strategies, along with requirements that reactors establish procedures for responding to specific aircraft threats, was approved December 17, 2008.[60] The fire mitigation rules were published in the Federal Register March 27, 2009.[61]

Other ongoing nuclear plant security issues include the vulnerability of spent fuel pools, which hold highly radioactive nuclear fuel after its removal from the reactor, standards for nuclear plant security personnel, and nuclear plant emergency planning. NRC's March 2009 security regulations addressed some of those concerns and included a number of other security enhancements.

EPACT05 required NRC to conduct force-on-force security exercises at nuclear power plants every three years (which was NRC's previous policy), authorized firearms use by nuclear security

[57] NRC Office of Public Affairs, *NRC Approves Final Rule Amending Security Requirements*, News Release No. 07-012, January 29, 2007.

[58] Nuclear Regulatory Commission, *Final Rule—Consideration of Aircraft Impacts for New Nuclear Power Reactors, Commission Voting Record*, SECY-08-0152, February 17, 2009.

[59] Nuclear Regulatory Commission, "Consideration of Aircraft Impacts for New Nuclear Power Reactors," Final Rule, 74 *Federal Register* 28111, June 12, 2009. This provision is codified at 10 CFR 50.150.

[60] Nuclear Regulatory Commission, "NRC Approves Final Rule Expanding Security Requirements for Nuclear Power Plants," press release, December 17, 2008, http://www.nrc.gov/reading-rm/doc-collections/news/2008/08-227.html.

[61] Nuclear Regulatory Commission, "Power Reactor Security Requirements," Final Rule, 74 *Federal Register* 13925, March 27, 2009.

personnel (preempting some state restrictions), established federal security coordinators, and required fingerprinting of nuclear facility workers.

(For background on security issues, see CRS Report RL34331, *Nuclear Power Plant Security and Vulnerabilities*, by Mark Holt and Anthony Andrews.)

Decommissioning

When nuclear power plants reach the end of their useful lives, they must be safely removed from service, a process called *decommissioning*. NRC requires nuclear utilities to make regular contributions to dedicated funds to ensure that money is available to remove radioactive material and contamination from reactor sites after they are closed.

The first full-sized U.S. commercial reactors to be decommissioned were the Trojan plant in Oregon, whose decommissioning completion received NRC approval on May 23, 2005, and the Maine Yankee plant, for which NRC approved most of the site cleanup on October 3, 2005. The Trojan decommissioning cost $429 million, according to reactor owner Portland General Electric, and the Maine Yankee decommissioning cost about $500 million.[62] Decommissioning of the Connecticut Yankee plant cost $790 million and was approved by NRC on November 26, 2007.[63] NRC approved the cleanup of the decommissioned Rancho Seco reactor site in California on October 7, 2009.[64] The decommissioning of Rancho Seco was estimated to cost $500 million, excluding future demolition of the cooling towers and other remaining plant structures.[65]

After nuclear reactors are decommissioned, the spent nuclear fuel (SNF) accumulated during their operating lives remains stored in pools or dry casks at the plant sites. About 2,800 metric tons of spent fuel is currently stored at nine closed nuclear power plants. "Until this SNF is removed from these nine sites, the sites cannot be fully decommissioned and made available for other purposes," DOE noted in a 2008 report.[66] President Obama's decision to terminate development of an underground spent fuel repository at Yucca Mountain, NV, has increased concerns about the ultimate disposition of spent fuel at decommissioned sites. (For more information, see CRS Report R42513, *U.S. Spent Nuclear Fuel Storage*, by James D. Werner.)

Nuclear Accident Liability

Liability for damages to the general public from nuclear incidents is addressed by the Price-Anderson Act (primarily Section 170 of the Atomic Energy Act of 1954, 42 U.S.C. 2210). EPACT05 extended the availability of Price-Anderson coverage for new reactors and new DOE nuclear contracts through the end of 2025. (Existing reactors and contracts were already covered.)

[62] Sharp, David, "NRC Signs Off on Maine Yankee's Decommissioning," *Associated Press*, October 3, 2005.

[63] E-mail communication from Bob Capstick, Connecticut Yankee Atomic Power Company, August 28, 2008.

[64] Nuclear Regulatory Commission, "NRC Releases Rancho Seco Nuclear Plant for Unconditional Use," press release, October 7, 2009, http://www.nrc.gov/reading-rm/doc-collections/news/2009/09-165.html.

[65] "20 Years Later, Rancho Seco Ready for Final Shutdown," *Sacramento County Herald*, June 9, 2009, http://m.news10.net/news.jsp?key=190656.

[66] DOE Office of Civilian Radioactive Waste Management, Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites, DOE/RW-0596, Washington, DC, December 2008, p. 1, http://www.energy.gov/media/ES_Interim_Storage_Report_120108.pdf.

Under Price-Anderson, the owners of commercial reactors must assume all liability for nuclear damages awarded to the public by the court system, and they must waive most of their legal defenses following a severe radioactive release ("extraordinary nuclear occurrence"). To pay any such damages, each licensed reactor with at least 100 megawatts of electric generating capacity must carry the maximum liability insurance reasonably available, which was raised from $300 million to $375 million on January 1, 2010.[67] Any damages exceeding $375 million are to be assessed equally against all 100-megawatt-and-above power reactors, up to $111.9 million per reactor. Those assessments—called "retrospective premiums"—would be paid at an annual rate of no more than $17.5 million per reactor, to limit the potential financial burden on reactor owners following a major accident. According to NRC, all 104 commercial reactors are currently covered by the Price-Anderson retrospective premium requirement.[68]

For each nuclear incident, the Price-Anderson liability system currently would provide up to $12.6 billion in public compensation. That total includes the $375 million in insurance coverage carried by the reactor that suffered the incident, plus the $111.9 million in retrospective premiums from each of the 104 currently covered reactors, totaling $12.0 billion. On top of those payments, a 5% surcharge may also be imposed, raising the total per-reactor retrospective premium to $117.5 million and the total available compensation to about $12.6 billion. Under Price-Anderson, the nuclear industry's liability for an incident is capped at that amount, which varies over time depending on the number of covered reactors, the amount of available insurance, and an inflation adjustment. Payment of any damages above that liability limit would require congressional approval under special procedures in the act.

EPACT05 increased the limit on per-reactor annual payments to $15 million from the previous $10 million, and required the annual limit to be adjusted for inflation every five years. As under previous law, the total retrospective premium limit is adjusted every five years as well. Both the annual and total limits were most recently adjusted October 29, 2008.[69] For the purposes of those payment limits, a nuclear plant consisting of multiple small reactors (100-300 megawatts, up to a total of 1,300 megawatts) would be considered a single reactor. Therefore, a power plant with six 120-megawatt small modular reactors would be liable for retrospective premiums of up to $111.9 million, rather than $671.4 million (excluding the 5% surcharge).

The Price-Anderson Act also covers contractors who operate hazardous DOE nuclear facilities. EPACT05 set the liability limit on DOE contractors at $10 billion per accident, to be adjusted for inflation every five years. The first adjustment under EPACT, raising the liability limit to $11.961 billion, took effect October 14, 2009.[70] The liability limit for DOE contractors previously had been the same as for commercial reactors, excluding the 5% surcharge, except when the limit for commercial reactors dropped because of a decline in the number of covered reactors. Price-Anderson authorizes DOE to indemnify its contractors for the entire amount of their liability, so that damage payments for nuclear incidents at DOE facilities would ultimately come from the

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[67] American Nuclear Insurers, "Need for Nuclear Liability Insurance," January 2010, http://www.nuclearinsurance.com/library/Nuclear%20Liability%20in%20the%20US.pdf.

[68] Reactors smaller than 100 megawatts must purchase an amount of liability coverage determined by NRC but are not subject to retrospective premiums. Total liability for those reactors is limited to $560 million, with the federal government indemnifying reactor operators for the difference between that amount and their liability coverage (Atomic Energy Act Sec. 170 b. and c.).

[69] Nuclear Regulatory Commission, "Inflation Adjustment to the Price-Anderson Act Financial Protection Regulations," 73 *Federal Register* 56451, September 29, 2008.

[70] Department of Energy, "Adjusted Indemnification Amount," 74 *Federal Register* 52793, October 14, 2009.

Treasury. However, the law also allows DOE to fine its contractors for safety violations, and contractor employees and directors can face criminal penalties for "knowingly and willfully" violating nuclear safety rules.

EPACT05 limited the civil penalties against a nonprofit contractor to the amount of management fees paid under that contract. Previously, Atomic Energy Act §234A specifically exempted seven nonprofit DOE contractors and their subcontractors from civil penalties and authorized DOE to automatically remit any civil penalties imposed on nonprofit educational institutions serving as DOE contractors. EPACT05 eliminated the civil penalty exemption for future contracts by the seven listed nonprofit contractors and DOE's authority to automatically remit penalties on nonprofit educational institutions.

The Price-Anderson Act's limits on liability were crucial in establishing the commercial nuclear power industry in the 1950s. Supporters of the Price-Anderson system contend that it has worked well since that time in ensuring that nuclear accident victims would have a secure source of compensation, at little cost to the taxpayer. Extension of the act was widely considered a prerequisite for new nuclear reactor construction in the United States. Opponents contend that Price-Anderson inappropriately subsidizes the nuclear power industry by reducing its insurance costs and protecting it from some of the financial consequences of the most severe conceivable accidents. The possibility that damages to the public from the Fukushima accident could greatly exceed the Price-Anderson liability limits has prompted new calls for reexamination of the law.[71]

The United States is supporting the establishment of an international liability system that, among other purposes, would cover U.S. nuclear equipment suppliers conducting foreign business. The Convention on Supplementary Compensation for Nuclear Damage (CSC) will not enter into force until at least five countries with a specified level of installed nuclear capacity have enacted implementing legislation. Such implementing language was included in the Energy Independence and Security Act of 2007 (P.L. 110-140, section 934), signed by President Bush December 19, 2007. Supporters of the Convention hope that more countries will join now that the United States has acted. Aside from the United States, three countries have submitted the necessary instruments of ratification, but the remaining nine countries that so far have signed the convention do not have the required nuclear capacity for it to take effect. Ratification by a large nuclear energy producer such as Japan would allow the treaty to take effect, as would ratification by two significant but smaller producers such as South Korea, Canada, Russia, or Ukraine.

Under the U.S. implementing legislation, the CSC would not change the liability and payment levels already established by the Price-Anderson Act. Each party to the convention would be required to establish a nuclear damage compensation system within its borders analogous to Price-Anderson. For any damages not covered by those national compensation systems, the convention would establish a supplemental tier of damage compensation to be paid by all parties. P.L. 110-140 requires the U.S. contribution to the supplemental tier to be paid by suppliers of nuclear equipment and services, under a formula to be developed by DOE. Supporters of the convention contend that it will help U.S. exporters of nuclear technology by establishing a predictable international liability system. For example, U.S. reactor sales to the growing

71 Ellen Vancko, Union of Concerned Scientists, "The Impact of Fukushima on the US Nuclear Power Industry," presentation to the Center for Strategic and International Studies Conference on Nuclear Safety and Fukushima, April 7, 2011, https://csis.org/files/attachments/110407_vancko_nuclear_safety_0.pdf.

economies of China and India would be facilitated by those countries' participation in the CSC liability régime.

Federal Incentives for New Nuclear Plants

The nuclear power industry contends that support from the federal government would be needed for "a major expansion of nuclear energy generation."[72] Significant incentives for building new nuclear power plants were included in the Energy Policy Act of 2005 (EPACT05, P.L. 109-58), signed by President Bush on August 8, 2005. These include production tax credits, loan guarantees, insurance against regulatory delays, and extension of the Price-Anderson Act nuclear liability system (discussed above in the "Nuclear Accident Liability" section of this report). Relatively low prices for natural gas—nuclear power's chief competitor—and rising estimated nuclear plant construction costs have decreased the likelihood that new reactors would be built without federal support. Any regulatory delays and increased safety requirements resulting from the Fukushima accident could also pose an obstacle to nuclear construction plans.

As a result, numerous bills have been introduced in recent years to strengthen or add to the EPACT05 incentives (see "Legislation in the 112th Congress" at the end of this report). Nuclear power critics have denounced the federal support programs and proposals as a "bailout" of the nuclear industry, contending that federal efforts should focus instead on renewable energy and energy efficiency.[73]

Nuclear Production Tax Credit

EPACT05 provides a 1.8-cents/kilowatt-hour tax credit for up to 6,000 megawatts of new nuclear capacity for the first eight years of operation, up to $125 million annually per 1,000 megawatts. The credit is not adjusted for inflation.

The Treasury Department published interim guidance for the nuclear production tax credit on May 1, 2006.[74] Under the guidance, the 6,000 megawatts of eligible capacity (enough for about four or five reactors) are to be allocated among reactors that filed license applications by the end of 2008. If more than 6,000 megawatts of nuclear capacity ultimately qualify for the production tax credit, then the credit is to be allocated proportionally among any of the qualifying reactors that begin operating before 2021.

By the end of 2008, license applications had been submitted to NRC for more than 34,000 megawatts of nuclear generating capacity,[75] so if all those reactors were built before 2021 they would receive less than 20% of the maximum tax credit. However, the reactor licensing status

[72] Nuclear Energy Institute, "NEI Unveils Package of Policy Initiatives Needed to Achieve Climate Change Goals," press release, October 26, 2009, http://www.nei.org/newsandevents/newsreleases/nei-unveils-package-of-policy-initiatives-needed-to-achieve-climate-change-goals/.

[73] Nuclear Information and Resource Service, "Senate Appropriators Lard President Obama's Stimulus Package with up to $50 Billion in Nuclear Reactor Pork," press release, January 30, 2009, http://www.nirs.org/press/01-30-2009/1.

[74] Department of the Treasury, Internal Revenue Service, *Internal Revenue Bulletin*, No. 2006-18, "Credit for Production From Advanced Nuclear Facilities," Notice 2006-40, May 1, 2006, p. 855.

[75] Energy Information Administration, *Status of Potential New Commercial Nuclear Reactors in the United States*, February 19, 2009.

shown in **Table 1** indicates that only four new units, totaling about 4,600 megawatts of capacity, are currently licensed for construction and likely to be completed before 2021. Two other units, totaling about 2,300 megawatts, are scheduled to receive their licenses and could possibly go into service by 2021.

The Nuclear Energy Institute (NEI) has urged Congress to remove the 6,000 megawatt capacity limit for the production tax credit, index it for inflation, and extend the deadline for plants to begin operation to the start of 2025. NEI is also proposing that a 30% investment tax credit be available for new nuclear construction as an alternative to the production credit.[76]

Standby Support

Because the nuclear industry has often blamed licensing delays for past nuclear reactor construction cost overruns, EPACT05 authorizes the Secretary of Energy to provide "standby support," or regulatory risk insurance, to help pay the cost of regulatory delays at up to six new commercial nuclear reactors. For the first two reactors that begin construction, the DOE payments could cover all the eligible delay-related costs, such as additional interest, up to $500 million each. For the next four reactors, half of the eligible costs could be paid by DOE, with a payment cap of $250 million per reactor. Delays caused by the failure of a reactor owner to comply with laws or regulations would not be covered. Project sponsors will be required to pay the "subsidy cost" of the program, consisting of the estimated present value of likely future government payments.

DOE published a final rule for the "standby support" program August 11, 2006.[77] According to a DOE description of the final rule,

> Events that would be covered by the risk insurance include delays associated with the Nuclear Regulatory Commission's reviews of inspections, tests, analyses and acceptance criteria or other licensing schedule delays as well as certain delays associated with litigation in federal, state or tribal courts. Insurance coverage is not available for normal business risks such as employment strikes and weather delays. Covered losses would include principal and interest on debt and losses resulting from the purchase of replacement power to satisfy contractual obligations.[78]

Under the program's regulations, a project sponsor may enter into a conditional agreement for standby support before NRC issues a combined operating license. The first six conditional agreements to meet all the program requirements, including the issuance of a COL and payment of the estimated subsidy costs, can be converted to standby support contracts. No conditional agreements have yet been reached, according to DOE, primarily because the subsidy cost estimates have not been approved by the Office of Management and Budget (OMB).[79]

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[76] Nuclear Energy Institute, *Legislative Proposal to Help Meet Climate Change Goals by Expanding U.S. Nuclear Energy Production*, Washington, DC, October 28, 2009, p. 4, http://www.nei.org/resourcesandstats/documentlibrary/newplants/policybrief/2009-nuclear-policy-initiative.

[77] Department of Energy, "Standby Support for Certain Nuclear Plant Delays," *Federal Register*, August 11, 2006, p. 46306.

[78] DOE press release, August 4, 2006, http://nuclear.gov/home/08-04-06.html.

[79] Meeting with Rebecca F. Smith-Kevern, Director, DOE Office of Light Water Reactor Deployment, October 7, 2009.

The Nuclear Energy Institute has called for expanding the Standby Support program to $500 million for all six covered reactors, rather than just the first two. In addition, NEI proposed that if a reactor successfully begins operating without any delay payments, that plant's Standby Support coverage, instead of expiring unused, be allowed to "roll over" to the next plant with a conditional agreement.[80]

Loan Guarantees

Title XVII of EPACT05 authorizes federal loan guarantees for up to 80% of construction costs for advanced energy projects that reduce greenhouse gas emissions, including new nuclear power plants. Under such loan guarantee agreements, the federal government would repay all covered loans if the borrower defaulted. This would reduce the risk to lenders and allow them to provide financing at low interest rates. The Title XVII loan guarantees are widely considered crucial by the nuclear industry to obtain financing for new reactors. However, opponents contend that nuclear loan guarantees would provide an unjustifiable subsidy to a mature industry and shift investment away from environmentally preferable energy technologies.[81]

The total amount of Title XVII loan guarantees to be made available for nuclear power has been the subject of considerable congressional debate. President Obama's FY2011 budget request would have nearly tripled the current ceiling on federal loan guarantees for nuclear power plants, from $18.5 billion to $54.5 billion. A $36 billion increase would increase the number of reactors that could receive loan guarantees from about three or four to about a dozen, depending on their size. The Department of Defense and Full-Year Continuing Appropriations Act for FY2011 (P.L. 112-10) did not provide the requested increase, leaving the nuclear power loan guarantee ceiling at $18.5 billion. The Administration again requested a $36 billion nuclear loan guarantee increase for FY2012, but none of the increase was included in the FY2012 Consolidated Appropriations Act. No increase was requested for FY2013.

The Administration announced the first conditional nuclear power plant loan guarantee on February 16, 2010, totaling $8.33 billion for two proposed new reactors at Georgia's Vogtle nuclear plant site. Owners of the Vogtle project have reportedly estimated that the loan guarantee could reduce their financing costs by as much as $2 billion.[82] Other finalists for the first round of nuclear reactor loan guarantees were Calvert Cliffs 3 in Maryland, South Texas Plant 3 and 4, and Summer 2 and 3.[83] However, as noted earlier, the future of the proposed units at Calvert Cliffs and the South Texas Plant is currently uncertain, leaving only Summer 2 and 3 as clearly viable candidates.

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[80] Nuclear Energy Institute, op. cit.

[81] Thomas B. Cochran and Christopher E. Paine, *Statement on Nuclear Developments Before the Committee on Energy and Natural Resources, United States Senate*, Natural Resources Defense Council, March 18, 2009, http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Testimony&Hearing_ID=f25ddd10-c1f5-9e2e-528e-c4321cca4c1b&Witness_ID=9f14a78d-58d0-43fb-bf5b-21426d1d888e.

[82] K. Steiner-Dicks, "Weekly Intelligence Brief 7-13 June 2012," *Nuclear Energy Insider*, June 13, 2012.

[83] Letter from Office of Management and Budget Director Peter R. Orszag to House and Senate leaders, May 21, 2010, http://www.whitehouse.gov/omb/assets/legislative_letters/Pelosi_05212010.pdf.

0.5%-1.5%, subject to other conditions that are still under negotiation. Higher subsidy costs are being offered to two other partners in the project.[87]

The nuclear industry contends that historical experience indicates defaults are likely to be minimal and that nuclear plant subsidy costs should therefore be low.[88] However, nuclear power critics contend that nuclear power plants are likely to experience delays and cost overruns that could lead to much larger losses under the loan guarantee program. The Center for American Progress concluded that nuclear subsidy costs "should be at least 10 percent and possibly much more."[89]

Constellation Energy informed DOE on October 8, 2010, that it was withdrawing from loan guarantee negotiations on Calvert Cliffs 3, blaming "the Office of Management and Budget's inability to address significant problems with its methodology for determining the project's credit subsidy cost." Constellation's letter to DOE said OMB's "shockingly high" estimate of the subsidy cost for Calvert Cliffs 3 was 11.6%, or about $880 million. "Such a sum would clearly destroy the project's economics (or the economics of any nuclear project for that matter), and was dramatically out of line with both our own and independent assessments of what the figure should reasonably be," the letter stated.[90] Although OMB has not released its subsidy cost methodology, it may consider the default risk for a "merchant plant" such as Calvert Cliffs to be significantly higher than that of a rate-regulated plant such as Vogtle. A plant under traditional rate regulation is allowed to pass all prudently incurred costs through to utility ratepayers, while a merchant plant charges market rates for its power. A merchant plant, therefore, could potentially earn higher profits than a rate-regulated plant, but it also runs the risk of being unable to cover its debt payments if market rates for wholesale electric power drop too low or if its costs are higher than anticipated.

Congressionally Authorized Ceilings

Under the Federal Credit Reform Act (FCRA), federal loan guarantees cannot be provided without an authorized level in an appropriations act. The Senate-passed version of omnibus energy legislation in the 110th Congress (H.R. 6) would have explicitly eliminated FCRA's applicability to DOE's planned loan guarantees under EPACT05 (Section 124(b)). That provision would have given DOE essentially unlimited loan guarantee authority for guarantees whose subsidy costs were paid by project sponsors, but it was dropped from the final legislation (P.L. 110-140). Similar language was also included in subsequent legislative proposals, such as energy legislation reported by the Senate Committee on Energy and Natural Resources July 16, 2009 (S. 1462).

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87 Southern Alliance for Clean Energy, "Secret Documents Highlight Nuclear's Risk," press release, May 23, 2012, http://www.cleanenergy.org/index.php?/Press-Update.html?form_id=8&item_id=299.

88 Statement of Leslie C. Kass, Nuclear Energy Institute, to the Subcommittee on Domestic Policy, House Committee on Oversight and Government Reform, April 20, 2010, http://www.nei.org/newsandevents/speechesandtestimony/april-20-2010-kass. DOE is treating final subsidy cost determinations as proprietary, prompting some groups to call for the amounts to be made public.

89 Richard Caperton, *Protecting Taxpayers from a Financial Meltdown*, Center for American Progress, Washington, DC, March 8, 2010, p. 2, http://www.americanprogress.org/issues/2010/03/nuclear_financing.html.

90 Letter from Michael J. Wallace, Vice Chairman and Chief Operating Officer, Constellation Energy, to Dan Poneman, Deputy Secretary of Energy, October 8, 2010, http://media.washingtonpost.com/wp-srv/hp/ssi/wpc/constellationenergy.PDF?sid=ST2010100900005.

Pursuant to FCRA, the FY2007 continuing resolution (P.L. 110-5) established an initial cap of $4 billion on loan guarantees under the program, without allocating that amount among the various eligible technologies. The explanatory statement for the FY2008 omnibus funding act (P.L. 110-161) increased the loan guarantee ceiling to $38.5 billion through FY2009, including $18.5 billion specifically for nuclear power plants and $2 billion for uranium enrichment plants.[91]

The FY2009 omnibus funding act increased DOE's total loan guarantee authority for specified technology categories to $47 billion, in addition to the $4 billion in general authority provided in FY2007. Of the $47 billion, $18.5 billion continued to be reserved for nuclear power, $18.5 billion was for energy efficiency and renewables, $6 billion was for coal, $2 billion was for carbon capture and sequestration, and $2 billion was for uranium enrichment. The time limits on the loan guarantee authority were eliminated. The loan guarantee ceilings remained the same for FY2010 but were sharply reduced for non-nuclear technologies by the FY2011 Continuing Appropriations Act. The nuclear power loan guarantee ceiling remains at $18.5 billion.

Nuclear Solicitations

DOE issued a solicitation for up to $20.5 billion in nuclear power and uranium enrichment plant loan guarantees on June 30, 2008.[92] According to the nuclear industry, 10 nuclear power projects applied for $93.2 billion in loan guarantees, and two uranium enrichment projects asked for $4.8 billion in guarantees, several times the amount available.[93] Under the program's regulations, a conditional loan guarantee commitment cannot become a binding loan guarantee agreement until the project receives a COL and all other regulatory requirements are met, as noted above; and the first COLs were issued in early 2012.

In the uranium enrichment solicitation, DOE in July 2009 informed USEC Inc., which plans to build a new plant in Ohio, that its technology needed further testing before a loan guarantee could be issued.[94] DOE notified Congress in March 2010 that it would reprogram $2 billion of its unused FY2007 loan guarantee authority toward uranium enrichment, increasing the uranium enrichment total to $4 billion. The move would potentially allow guarantees to be provided to both USEC and the other applicant in the uranium enrichment solicitation, the French firm Areva, which is planning a plant in Idaho.[95] DOE offered a $2 billion conditional loan guarantee to Areva on May 20, 2010.[96]

DOE informed USEC in October 2011 that the centrifuge technology for its proposed new enrichment plant still needed further testing and offered to provide up to $300 million to help build a demonstration "train" of 720 centrifuges.[97] Energy Secretary Steven Chu sent letters to the

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[91] *Congressional Record*, December 17, 2007, p. H15585.

[92] http://www.lgprogram.energy.gov/keydocs.html.

[93] Marvin S. Fertel, *Statement for the Record to the Committee on Energy and Natural Resources, U.S. Senate*, Nuclear Energy Institute, March 18, 2009, p. 9, http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Testimony&Hearing_ID=f25ddd10-c1f5-9e2e-528e-c4321cca4c1b&Witness_ID=4de5e2df-53fe-49ba-906e-9b69d3674e41.

[94] Department of Energy, "800 to 1000 New Jobs Coming to Piketon," press release, July 28, 2009, http://www.lgprogram.energy.gov/press/072809.pdf.

[95] Maureen Conley, "DOE Finds $2 Billion More for SWU Plant Loan Guarantees," *NuclearFuel*, April 5, 2010, p. 3.

[96] Department of Energy, "DOE Offers Conditional Loan Guarantee for Front End Nuclear Facility in Idaho," press release, May 20, 2010, http://www.energy.gov/news/8996.htm.

[97] Maureen Conley, "Congress 'Frustrated' by Inaction on USEC Loan Guarantee," *NuclearFuel*, October 31, 2011, p. (continued...)

House and Senate Appropriations Committees on October 25, 2011, to request an unspecified funding transfer in FY2012 for the first $150 million of USEC assistance.[98] DOE's FY2013 budget request includes $150 million for the USEC centrifuge demonstration program. The House provided $100 million in the FY2013 Energy and Water Development Appropriations Bill (H.R. 5325, H.Rept. 112-462), while the Senate Appropriations Committee version of the bill recommended $150 million in transfer authority to fund the project (S. 2465, S.Rept. 112-164). An authorization of $150 million for the USEC centrifuge demonstration program is included in the House-passed National Defense Authorization Act for Fiscal Year 2013 (H.R. 4310).

DOE has recently provided other assistance to USEC. DOE agreed on May 15, 2012, to provide depleted uranium stockpiles (material left over from the enrichment process) to Energy Northwest for reenrichment at USEC's plant in Paducah, KY, for use as reactor fuel.[99] DOE agreed on March 13, 2012, to acquire low-enriched uranium from USEC in exchange for taking responsibility for low-value depleted uranium tails that USEC would otherwise have to dispose of, freeing $44 million of USEC's funds for the centrifuge project.[100] DOE announced June 13, 2012, that it would provide $88 million for the centrifuge demonstration program by taking over responsibility for disposal of additional depleted uranium from USEC. In return, DOE will take ownership of the equipment and technology used in the demonstration and lease it to USEC.[101]

Global Climate Change

Global climate change that may be caused by carbon dioxide and other greenhouse gas emissions is cited by nuclear power supporters as an important reason to develop a new generation of reactors. Nuclear power plants emit relatively little carbon dioxide, mostly from nuclear fuel production and auxiliary plant equipment. This "green" nuclear power argument has received growing attention in think tanks and academia. As stated by the Massachusetts Institute of Technology in its major study *The Future of Nuclear Power*: "Our position is that the prospect of global climate change from greenhouse gas emissions and the adverse consequences that flow from these emissions is the principal justification for government support of the nuclear energy option."[102] As discussed above, the Obama Administration is also including nuclear power as part of its clean energy strategy.

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[98] Steven Chu, Secretary of Energy, letters to Chairmen and Ranking Members of House and Senate Appropriations Committees and Subcommittees on Energy and Water Development, October 25, 2011. For more information on the USEC funding proposal, see CRS Congressional Distribution Memorandum *Business Outlook for USEC Inc.*, by Mark Holt, available from the author.

[99] USEC Inc., "Five-Party Arrangement Extends Paducah Gaseous Diffusion Plant Enrichment Operations," press release, May 15, 2012, http://www.usec.com/news/five-party-arrangement-extends-paducah-gaseous-diffusion-plant-enrichment-operations. The depleted uranium consists of "high assay" tails, which have relatively high levels of fissile U-235.

[100] USEC Inc., "Funding," web page, http://www.usec.com/american-centrifuge/what-american-centrifuge/plant/funding.

[101] Department of Energy, "Obama Administration Announces Major Step Forward for the American Centrifuge Plant," press release, June 13, 2012, http://energy.gov/articles/obama-administration-announces-major-step-forward-american-centrifuge-plant.

[102] Interdisciplinary MIT Study, *The Future of Nuclear Power*, Massachusetts Institute of Technology, 2003, p. 79.

However, environmental groups have contended that nuclear power's potential greenhouse gas benefits are modest and must be weighed against the technology's safety risks, its potential for nuclear weapons proliferation, and the hazards of radioactive waste.[103] They also contend that energy efficiency and renewable energy would be far more productive investments for reducing greenhouse gas emissions.[104]

Proposals to reduce carbon dioxide emissions – through taxation, a cap-and-trade system, or other regulatory controls – could significantly increase the cost of generating electricity with fossil fuels and improve the competitive position of nuclear power. A federal Clean Energy Standard that includes nuclear power, as proposed in President Obama's January 2011 State of the Union Address and in S. 2146, could provide a similar boost to nuclear energy expansion. Utilities that have applied for nuclear power plant licenses have often cited the possibility of federal greenhouse gas controls or other mandates as one of the reasons for pursuing new reactors. (For more on federal incentives and the economics of nuclear power and other electricity generation technologies, see CRS Report RL34746, *Power Plants: Characteristics and Costs*, by Stan Mark Kaplan.)

Nuclear Power Research and Development

The Obama Administration's FY2013 funding request for nuclear energy research and development totaled $770.4 million. Including advanced reactors, fuel cycle technology, infrastructure support, and safeguards and security, the total nuclear energy request was $88.3 million (10%) below the enacted FY2012 funding level. Funding for safeguards and security at DOE's Idaho facilities in FY2012 was provided under a separate appropriations account, Other Defense Activities, but it was included under the Nuclear Energy account in the FY2013 request. The largest proposed reductions for FY2013 were Reactor Concepts (36%), Radiological Facility Management (27%), and Nuclear Energy Enabling Technologies (13%).

Nuclear energy funding is included in the Energy and Water Development appropriations bills. The House passed its version of the Energy and Water bill for FY2013 on June 6, 2012 (H.R. 5325, H.Rept. 112-462). Excluding funding for Idaho safeguards and security, the House bill provided an increase of $89.9 million for the nuclear energy account, for a total of $765.4 million. The House bill included $93.4 million for Idaho safeguards and security under the Other Defense Activities Account. The Senate Appropriations Committee on April 26, 2012, recommended a $20.1 million increase for nuclear energy, including Idaho safeguards and security and $17.7 million in prior-year balances (S. 2465, S.Rept. 112-164).

Using reorganized budget categories established for FY2011, the Administration's FY2013 nuclear R&D budget request is consistent with DOE's *Nuclear Energy Research and*

[103] Gronlund, Lisbeth, David Lochbaum, and Edwin Lyman, *Nuclear Power in a Warming World*, Union of Concerned Scientists, December 2007.

[104] Travis Madsen, Tony Dutzik, and Bernadette Del Chiaro, et al., *Generating Failure: How Building Nuclear Power Plants Would Set America Back in the Race Against Global Warming*, Environment America Research and Policy Center, November 2009, http://www.environmentamerica.org/uploads/39/62/3962c378b66c4552624d09cbd8ebba02/Generating-Failure—Environment-America—Web.pdf.

Development Roadmap issued in April 2010.[105] The Roadmap lays out the following four main goals for the program:

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors;
- Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals;
- Develop sustainable nuclear fuel cycles; and
- Understand and minimize the risks of nuclear proliferation and terrorism.

Reactor Concepts

The Reactor Concepts program area includes the Next Generation Nuclear Plant (NGNP) demonstration project and research on other advanced reactors (often referred to as Generation IV reactors). This area also includes funding for developing advanced small modular reactors (discussed in the next section) and to enhance the "sustainability" of existing commercial light water reactors. The total FY2013 funding request for this program was $73.7 million, a reduction of $41.2 million from FY2012. The House provided an increase of $11.1 million from the FY2012 level, while the Senate Appropriations Committee's recommendation was the same as the request.

Most of the Administration's proposed reduction in Reactor Concepts would be for NGNP, a high-temperature gas-cooled reactor demonstration project authorized by the Energy Policy Act of 2005 (EPACT05, P.L. 109-58). The reactor is intended to produce high-temperature heat that could be used to generate electricity, help separate hydrogen from water, or be used in other industrial processes. DOE is requesting $21.2 million for the NGNP project for FY2013, down from $40 million provided in FY2012. Under EPACT05, the Secretary of Energy was to decide by the end of FY2011 whether to proceed toward construction of a demonstration plant. Secretary of Energy Steven Chu informed Congress on October 17, 2011, that DOE would not proceed with a demonstration plant design "at this time" but would continue research on the technology.[106] Potential obstacles facing NGNP include low prices for natural gas, the major competing fuel, and private-sector unwillingness to share the project's costs as required by EPACT05.[107] According to the DOE budget justification, the NGNP program in FY2013 will focus on fuels for very high temperature reactors, the graphite used in high-temperature reactor cores, and licensing issues. The House provided $50 million for NGNP, to allow DOE to continue developing a licensing framework and continue working with industry on the program. The Senate panel restricted NGNP activities to ongoing fuel-related research.

Funding for the Advanced Reactor Concepts subprogram would also be reduced sharply by the Administration request, from $21.9 million in FY2012 to $12.4 million in FY2013. Reactor

[105] Department of Energy, *Nuclear Energy Research and Development Roadmap*, Report to Congress, Washington, DC, April 2010, http://nuclear.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf.

[106] Idaho National Laboratory, *NGNP Project 2011 Status and Path Forward*, INL/EXT-11-23907, December 2011.

[107] Yanmei Xie, "Cheap Natural Gas, Cost-Share Disagreement Jeopardize NGNP," *Nucleonics Week*, April 28, 2011, p. 1.

concepts being developed by this subprogram are generally classified as "Generation IV" reactors, as opposed to the existing fleet of commercial light water reactors, which are generally classified as generations II and III. Such advanced reactors "could dramatically improve nuclear power performance including sustainability, economics, and safety and proliferation resistance," according to the FY2013 justification. Nuclear technology development under this program includes "fast reactors," using high-energy neutrons, and reactors that would use a variety of heat-transfer fluids, such as liquid sodium and supercritical carbon dioxide. International research collaboration in this area would continue under the Generation IV International Forum (GIF). The House provided an increase of $1.1 million over FY2012, while the Senate Appropriations Committee approved the Administration's proposed reduction.

DOE's FY2013 request for the Light Water Reactor Sustainability subprogram was $21.7 million, $3.3 million below the FY2012 appropriation. The program conducts research on extending the life of existing commercial light water reactors beyond 60 years, the maximum operating period currently licensed by the Nuclear Regulatory Commission. The program, which is to be cost-shared with the nuclear industry, is to study the aging of reactor materials and analyze safety margins of aging plants. Other research under this program is to focus on improving the efficiency of existing plants, through such measures as increasing plant capacity and upgrading instrumentation and control systems. Research on longer-life LWR fuel is aimed at eliminating radioactive leakage from nuclear fuel and increasing its accident tolerance, along with other "post-Fukushima lessons learned research needs," according to the budget justification. The House rejected the Administration's proposed reduction, while the Senate Appropriations Committee approved it.

Small Modular Light Water Reactors

Rising cost estimates for large conventional nuclear reactors—widely projected to be $6 billion or more—have contributed to growing interest in proposals for small modular reactors (SMRs). Ranging from about 40 to 350 megawatts of electrical capacity, such reactors would be only a fraction of the size of current commercial reactors. Several modular reactors would be installed together to make up a power block with a single control room, under most concepts. Current SMR proposals would use a variety of technologies, including high-temperature gas technology in the NGNP program and the light water (LWR) technology used by today's commercial reactors.

DOE requested $65 million for FY2013 to provide technical support for licensing small modular LWRs, $2 million below the FY2012 funding level. This program focuses on LWR designs because they are believed most likely to be deployed in the near term, according to DOE. Conferees on the FY2012 appropriations bill anticipated a five-year program totaling $452 million. The program is similar to DOE's support for larger commercial reactor designs under the Nuclear Power 2010 Program, which ended in FY2010. DOE will provide support for design certification, standards, and licensing. As with the Nuclear Power 2010 Program, at least half the costs of the LWR SMR program are to be covered by industry partners, according to DOE. The program will support two teams of reactor vendors and specific utilities or consortia who are interested in building the reactors at specific sites, according to the DOE justification. DOE announced a funding solicitation for the program on March 22, 2012.[108] Applications have been

[108] Department of Energy, "Obama Administration Announces $450 Million to Design and Commercialize U.S. Small Modular Nuclear Reactors," press release, March 22, 2012, http://www.ne.doe.gov/newsroom/2012PRs/
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submitted by four industry consortia, led by Babcock & Wilcox, Holtec, NuScale Power, and Westinghouse, proposing reactors ranging from 45-225 megawatts.[109]

The House approved $114 million for the SMR licensing program, $47 million above FY2012. The House Appropriations Committee report called the increase necessary to keep the program on track to receive $452 million over five years. The Senate panel provided the same funding as in the budget request.

An additional $18.5 million for FY2013 was requested by DOE under the Reactor Concepts program (described in the section above) for SMR advanced concepts R&D—$10.2 million below the FY2012 funding level. Unlike the SMR licensing support program, which focuses on conventional LWR technology, the SMR advanced concepts program would conduct research on technologies that might be deployed in the longer term, according to the budget justification. The House rejected the Administration's proposed reduction, while the Senate Appropriations Committee approved the budget request.

Small modular reactors would go against the overall trend in nuclear power technology toward ever-larger reactors intended to spread construction costs over a greater output of electricity. Proponents of small reactors contend that they would be economically viable despite their far lower electrical output because modules could be assembled in factories and shipped to plant sites, and because their smaller size would allow for simpler safety systems. In addition, although modular plants might have similar or higher costs per kilowatt-hour than conventional large reactors, their ability to be constructed in smaller increments could reduce electric utilities' financial commitment and risk.

Fuel Cycle Research and Development

The Fuel Cycle Research and Development Program conducts "long-term, science-based" research on a wide variety of technologies for improving the management of spent nuclear fuel, according to the DOE budget justification. The total FY2013 funding request for this program is $175.4 million, $10.8 million below the FY2012 appropriation. The House approved $138.7 million for Fuel Cycle R&D, $36.7 million below the request. The Senate Appropriations Committee recommended $193.1 million, $17.7 million above the request.

The range of fuel cycle technologies being studied by the program includes direct disposal of spent fuel (the "once through" cycle) and partial and full recycling, according to the budget justification. The Fuel Cycle R&D Program "will research and develop a suite of technology options that will enable future decision-makers to make informed decisions about how best to manage nuclear waste and used fuel from reactors," the budget justification says.

Much of the planned research on spent fuel management options will address the near-term recommendations of the Blue Ribbon Commission on America's Nuclear Future, which issued its final report on January 26, 2012.[110] The commission was chartered to develop alternatives to the

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nePR032212_print.html.

[109] World Nuclear Association, "Small Nuclear Power Reactors," May 2012, http://www.world-nuclear.org/info/inf33.html.

[110] Blue Ribbon Commission on America's Nuclear Future, "Blue Ribbon Commission on America's Nuclear Future (continued...)

planned Yucca Mountain, NV, spent fuel repository, which President Obama wants to terminate. The largest subprogram under Fuel Cycle Research and Development is Used Nuclear Fuel Disposition, with a request of $59.7 million, the same as the FY2012 funding level. Activities in that area include work toward the development and licensing of standardized spent fuel containers, studies of potential spent fuel disposal partnerships, and the accelerated characterization of potential geologic media for waste disposal.

The House report contended that much of the proposed research in the Used Fuel Disposition Program relates to waste program changes recommended by the Blue Ribbon Commission that have not been enacted by Congress. As a result, the panel reduced funding for Used Fuel Disposition to $38 million, $15 million of which would be for storage and transportation work related to the Yucca Mountain repository. The Senate panel's $17.7 million increase from the budget request consists of prior-year funds that would be used for a spent fuel storage pilot project (see the "Nuclear Waste Management" section for more details).

Other major research areas in the Fuel Cycle R&D Program include the development of advanced fuels for existing commercial reactors and advanced reactors, improvements in nuclear waste characteristics, and technology to increase nuclear fuel resources, such as uranium extraction from seawater.

Nuclear Energy Enabling Technologies

The Nuclear Energy Enabling Technologies (NEET) program "is designed to conduct research and development (R&D) in crosscutting technologies that directly support and enable the development of new and advanced reactor designs and fuel cycle technologies," according to the FY2013 DOE budget justification. The DOE funding request for the program was $65.3 million, $9.4 million below the FY2012 level. The House provided $75 million, nearly the same as in FY2012, while the Senate Appropriations Committee recommended the same funding as the request.

DOE's proposed funding cut would come entirely under the category of Crosscutting Technology Development, for which $26.2 million was requested, $9.7 million below FY2012. According to the budget justification, the cuts result from elimination of research on manufacturing methods and nonproliferation risk assessments. Continuing crosscutting research activities are to include development of innovative materials, advanced automation and information technologies, advanced sensors, and improved fuel performance. The Energy Innovation Hub for Modeling and Simulation, created in FY2010, had a request of $24.6 million, slightly above the FY2012 appropriation. The Modeling and Simulation Hub is creating a computer model of an operating reactor to allow a better understanding of nuclear technology, with the benefits of such modeling extending to other energy technologies in the future, according to the budget justification.

DOE requested $14.6 million for the National Scientific User Facility, the same as the FY2012 appropriation, to support partnerships by universities and other research organizations to conduct experiments "at facilities not normally accessible to these organizations," according to the

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Issues Final Report to Secretary of Energy," press release, January 26, 2012, http://brc.gov/index.php?q=announcement/brc-releases-their-final-report.

justification. Up to five such partnerships are currently anticipated, and the FY2013 funding will allow up to three new long-term and five "rapid turnaround" projects to be awarded.

Nuclear Waste Management

One of the most controversial aspects of nuclear power is the disposal of radioactive waste, which can remain hazardous for thousands of years. Each nuclear reactor produces an annual average of about 20 metric tons of highly radioactive spent nuclear fuel, for a nationwide total of about 2,000 metric tons per year. U.S. reactors also generate about 27,000 cubic meters of low-level radioactive waste per year, including contaminated components and materials resulting from reactor decommissioning.[111]

The federal government is responsible for permanent disposal of commercial spent fuel (paid for with a fee on nuclear power production) and federally generated radioactive waste, while states have the authority to develop disposal facilities for most commercial low-level waste. Under the Nuclear Waste Policy Act (NWPA, 42 U.S.C. 10101, et seq.), spent fuel and other highly radioactive waste is to be isolated in a deep underground repository, consisting of a large network of tunnels carved from rock that has remained geologically undisturbed for hundreds of thousands of years. As amended in 1987, NWPA designated Yucca Mountain in Nevada as the only candidate site for the national repository. The act required DOE to begin taking waste from nuclear plant sites by 1998—a deadline that even under the most optimistic scenarios will be missed by more than 20 years. DOE filed a license application with NRC for the proposed Yucca Mountain repository in June 2008.

The Obama Administration "has determined that developing the Yucca Mountain repository is not a workable option and the Nation needs a different solution for nuclear waste disposal," according to the DOE FY2011 budget justification. As a result, no funding for Yucca Mountain or DOE's Office of Civilian Radioactive Waste Management (OCRWM), which had run the program, was requested for FY2011. The Continuing Appropriations Act for FY2011 (P.L. 112-10) approved the funding termination. The Administration established the Blue Ribbon Commission on America's Nuclear Future on March 1, 2010, to develop an alternative waste management strategy.

DOE filed a motion with NRC to withdraw the Yucca Mountain license application on March 3, 2010. An NRC licensing panel rejected DOE's withdrawal motion June 29, 2010, on the grounds that NWPA requires full consideration of the license application by NRC. The full NRC Commission deadlocked on the issue September 9, 2011, leaving the licensing panel's decision in place and prohibiting DOE from withdrawing the Yucca Mountain application. However, the commission ordered at the same time that the licensing process be halted because of "budgetary limitations."[112] No funding was provided in FY2012 or requested for FY2013 to continue Yucca

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[111] DOE, Manifest Information Management System http://mims.apps.em.doe.gov. Average annual utility disposal from 2002 through 2011. Annual volume ranges from 68,441 cubic meters in 2005 to 5,326 cubic meters in 2009.

[112] Nuclear Regulatory Commission, "In the Matter of U.S. Department of Energy (High-Level Waste Repository)," CLI-11-07, September 9, 2011, http://www.nrc.gov/reading-rm/doc-collections/commission/orders/2011/2011-07cli.pdf.

Mountain licensing activities, although the issue is currently the subject of a federal appeals court case.[113]

The Blue Ribbon Commission issued its final report on January 26, 2012.[114] The commission recommended options for temporary storage, treatment, and permanent disposal of highly radioactive nuclear waste, along with an evaluation of nuclear waste research and development programs and the need for legislation. It did not recommend specific sites for new nuclear waste facilities or evaluate the suitability of Yucca Mountain.

The commission's proposed "consent-based" approach to the siting of waste facilities called for the roles of local, state, and tribal governments to be negotiated for each potential site. The development of consolidated waste storage and disposal facilities should begin as soon as possible, the commission urged. A new waste management organization should be established to develop the repository, along with associated transportation and storage systems, according to the commission. The new organization should have "assured access" to the Nuclear Waste Fund, which holds fees collected from nuclear power plant operators to pay for waste disposal. Under NWPA, DOE could not spend those funds without congressional appropriations.

In the FY2013 Energy and Water Development appropriations bill (H.R. 5325), the House Appropriations Committee sharply criticized the Administration's nuclear waste policy and provided $25 million for DOE to resume work on the Yucca Mountain repository license. An amendment on the House floor provided an additional $10 million to NRC for Yucca Mountain licensing (H.Amdt. 1188). The Senate Appropriations Committee provided no funds for Yucca Mountain but included language (§312, S. 2465) authorizing a pilot program to demonstrate one or more consolidated interim storage facilities for spent nuclear fuel and high level waste. Any proposed storage site would require the consent of the affected state governor, local government of jurisdiction, affected Indian tribes, and Congress. The Senate panel directed DOE to use $2 million of its program direction funding for the pilot program, along with $17.7 million in unobligated prior-year appropriations from the Nuclear Waste Fund.

Funding for the nuclear waste program in the past has been provided under two appropriations accounts. The Administration's last request for funding, in FY2010, was divided evenly between an appropriation from the Nuclear Waste Fund, which holds fees paid by nuclear utilities, and the Defense Nuclear Waste Disposal account, which pays for disposal of high-level waste from the nuclear weapons program. The Senate Appropriations Committee report for that year called for the Secretary of Energy to suspend fee collections, "given the Administration's decision to terminate the Yucca Mountain repository program while developing disposal alternatives," but the language was dropped in conference. Energy Secretary Steven Chu in October 2009 rejected requests from the nuclear industry and state utility regulators to suspend the fee, saying the revenues were still necessary, and nuclear utilities and regulators filed lawsuits to stop the fee in April 2010.[115] The U.S. Court of Appeals for the District of Columbia Circuit agreed with the

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[113] U.S. Circuit Court of Appeals for the District of Columbia Circuit, USCA Case #11-1271, Yucca Mountain Reply Brief of Petitioners Mandamus Action, February 13, 2012, http://www.naruc.org/policy.cfm?c=filings.

[114] Blue Ribbon Commission on America's Nuclear Future, *Report to the Secretary of Energy*, January 2012, http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf.

[115] National Association of Regulatory Utility Commissioners, "State Regulators Go to Court with DOE over Nuclear Waste Fees," news release, April 2, 2010, http://www.naruc.org/News/default.cfm?pr=193; Nuclear Energy Institute, "NEI, Electric Utilities File Suit to Suspend Collection of Fees for Reactor Fuel Management," news release, April 5, 2010, http://www.nei.org/newsandevents/newsreleases/nei-electric-utilities-file-suit-to-suspend-collection-of-fee-for-
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plaintiffs on June 1, 2012, and ordered DOE to prepare a new justification for continuing to collect the fees.[116]

The Yucca Mountain project faced regulatory uncertainty even before the Obama Administration's move to shut it down. A ruling on July 9, 2004, by the U.S. Court of Appeals for the District of Columbia Circuit overturned a key aspect of the Environmental Protection Agency's (EPA's) regulations for the planned repository.[117] The three-judge panel ruled that EPA's 10,000-year compliance period was too short, but it rejected several other challenges to the rules. EPA published new standards on October 15, 2008, that would allow radiation exposure from the repository to increase after 10,000 years.[118] The State of Nevada has filed a federal Appeals Court challenge to the EPA standards. (For more information on the EPA standards, see CRS Report RL34698, *EPA's Final Health and Safety Standard for Yucca Mountain*, by Bonnie C. Gitlin.)

NWPA required DOE to begin taking waste from nuclear plant sites by January 31, 1998. Nuclear utilities, upset over DOE's failure to meet that deadline, have won two federal court decisions upholding the department's obligation to meet the deadline and to compensate utilities for any resulting damages. Utilities have also won several cases in the U.S. Court of Federal Claims. DOE estimates that liability payments would eventually total $20.8 billion if DOE were to begin removing waste from reactor sites by 2020, the previous target for opening Yucca Mountain.[119] (For more information, see CRS Report R40996, *Contract Liability Arising from the Nuclear Waste Policy Act (NWPA) of 1982*, by Todd Garvey CRS Report R40202, *Nuclear Waste Disposal: Alternatives to Yucca Mountain*, by Mark Holt, CRS Report RL33461, *Civilian Nuclear Waste Disposal*, by Mark Holt, and CRS Report R42513, *U.S. Spent Nuclear Fuel Storage*, by James D. Werner.)

Nuclear Weapons Proliferation

Renewed interest in nuclear power throughout the world has led to increased concern about nuclear weapons proliferation, because technology for making nuclear fuel can also be used to produce nuclear weapons material. Of particular concern are uranium enrichment, a process to separate and concentrate the fissile isotope uranium-235, and nuclear spent fuel reprocessing, which can produce weapons-useable plutonium.

The International Atomic Energy Agency (IAEA) conducts a safeguards program that is intended to prevent civilian nuclear fuel facilities from being used for weapons purposes, but not all potential weapons proliferators belong to the system, and there are ongoing questions about its effectiveness. Several proposals have been developed to guarantee nations without fuel cycle

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reactor-fuel-management.

[116] U.S. Court of Appeals for the District of Columbia Circuit, *National Association of Regulatory Utility Commissioners v. U.S. Department of Energy*, No. 11-1066, decided June 1, 2012, http://www.cadc.uscourts.gov/internet/opinions.nsf/4B11622F4FF75FEC85257A100050A681/$file/11-1066-1376508.pdf.

[117] U.S. Court of Appeals for the District of Columbia Circuit, *Nuclear Energy Institute v. Environmental Protection Agency*, No. 01-1258, July 9, 2004.

[118] Environmental Protection Agency, "Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada," 73 *Federal Register* 61256, October 15, 2008.

[119] BRC Final Report, op. cit., p. 80.

facilities a supply of nuclear fuel in exchange for commitments to forgo enrichment and reprocessing, which was one of the original goals of the Bush Administration's Global Nuclear Energy Partnership, now called the International Framework for Nuclear Energy Cooperation.[120]

Several situations have arisen throughout the world in which ostensibly commercial uranium enrichment and reprocessing technologies have been subverted for military purposes. In 2003 and 2004, it became evident that Pakistani nuclear scientist A.Q. Khan had sold sensitive technology and equipment related to uranium enrichment to states such as Libya, Iran, and North Korea. Although Pakistan's leaders maintain they did not acquiesce in or abet Khan's activities, Pakistan remains outside the Nuclear Nonproliferation Treaty (NPT) and the Nuclear Suppliers Group (NSG). Iran has been a direct recipient of Pakistani enrichment technology.

IAEA's Board of Governors found in 2005 that Iran's breach of its safeguards obligations constituted noncompliance with its safeguards agreement, and referred the case to the U.N. Security Council in February 2006. Despite repeated calls by the U.N. Security Council for Iran to halt enrichment and reprocessing-related activities, and imposition of sanctions, Iran continues to develop enrichment capability at Natanz and at a site near Qom disclosed in September 2009. Iran insists on its inalienable right to develop the peaceful uses of nuclear energy, pursuant to Article IV of the NPT. Interpretations of this right have varied over time. Former IAEA Director General Mohamed ElBaradei did not dispute this inalienable right and, by and large, neither have U.S. government officials. However, the case of Iran raises perhaps the most critical question in this decade for strengthening the nuclear nonproliferation regime: How can access to sensitive fuel cycle activities (which could be used to produce fissile material for weapons) be circumscribed without further alienating non-nuclear weapon states in the NPT?

Leaders of the international nuclear nonproliferation regime have suggested ways of reining in the diffusion of such inherently dual-use technology, primarily through the creation of incentives not to enrich uranium or reprocess spent fuel. The international community is in the process of evaluating those proposals and may decide upon a mix of approaches. At the same time, there is debate on how to improve the IAEA safeguards system and its means of detecting diversion of nuclear material to a weapons program in the face of expanded nuclear power facilities worldwide.

(For more information, see CRS Report RL34234, *Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear Power*, coordinated by Mary Beth Nikitin; and CRS Report R41216, *2010 Non-Proliferation Treaty (NPT) Review Conference: Key Issues and Implications*, coordinated by Paul K. Kerr and Mary Beth Nikitin.)

Federal Funding for Nuclear Energy Programs

The following tables summarize current funding for DOE nuclear energy programs and NRC. The sources for the funding figures are Administration budget requests and committee reports on the Energy and Water Development Appropriations Acts, which fund DOE and NRC. The House passed its version of the FY2013 Energy and Water Development appropriations bill on June 6,

[120] The organization approved a new mission statement with the name change at its June 2010 meeting in Ghana. See http://www.gneppartnership.org.

2012 (H.R. 5325, H.Rept. 112-462). The Senate Appropriations Committee approved its version on April 26, 2012 (S. 2465, S.Rept. 112-164).

Table 2. Funding for the Nuclear Regulatory Commission

(budget authority in millions of current dollars)

	FY2010 Approp.	FY2011 Approp.	FY2012 Approp.	FY2013 Request	FY2013 House	FY2013 Sen. Comm.
Reactor Safety	806.8[a]	804.1[a]	800.1[a]	809.9	809.9	—[b]
Nuclear Materials and Waste	220.2	229.4	227.1	232.3	228.9	—
Yucca Mountain Licensing	29.0	10.0	0	0	10.0	—
Inspector General	10.9	10.1	10.9	11.0	11.0	11.9
Total NRC budget authority	1,066.9	1,052.3	1,038.1	1,053.2	1,059.8	1,054.1
—Offsetting fees	-912.2	-914.2	-909.5	-927.7	-921.7	-924.7
Net appropriation	**154.7**	**138.1**	**128.6**	**128.5**	**138.1**	**129.4**

a. Subcategories from NRC budget request.

b. Subcategories not specified.

Table 3. DOE Funding for Nuclear Activities (Selected Programs)

(budget authority in millions of current dollars)

	FY2010 Approp.	FY2011 Approp.	FY2012 Approp.	FY2013 Request	FY2013 House	FY2013 Senate
University programs	5.0	0	5.0	0	5.0	0
Reactor Concepts	—	168.5	115.5	73.7	126.7	73.7
Small Modular Reactor Licensing	—	—	67.0	65.0	114.0	65.0
Fuel Cycle R&D	136.0	187.6	187.4	175.4	138.7	193.2
Nuclear Energy Enabling Technologies	—	51.4	74.9	65.3	75.0	65.3
International Nuclear Energy Cooperation	—	3.0	3.0	3.0	3.0	3.0
Radiological Facilities Management	72.0	51.7	69.9	51.0	51.0	66.0
Idaho Facilities Management	173.0	183.6	155.0	152.0	162.0	152.0
Program Direction	73.0	86.3	91.0	90.0	90.0	92.0
Total, Nuclear Energy[b]	786.6	732.1	765.4	770.4	765.4	785.4
Civilian Nuclear Waste Disposal[c]	196.8	0	0	0	25.0	0

a. Not available.

b. Excludes funding provided under other accounts.

c. Funded by a 1-mill-per-kilowatt-hour fee on nuclear power, plus appropriations for defense waste disposal and homeland security.

Legislation in the 112th Congress

H.R. 301 (Forbes)

New Manhattan Project for Energy Independence. Establishes program to develop new energy-related technologies, including treatment of nuclear waste. Introduced January 18, 2011; referred to Committee on Science and Technology.

H.R. 617 (Matheson)

Radioactive Import Deterrence Act. Restricts imports of radioactive waste. Introduced February 10, 2011; referred to Committee on Energy and Commerce.

H.R. 909 (Nunes)

Roadmap for America's Energy Future. Includes provisions to triple the number of U.S. nuclear power plants, encourage recycling of spent nuclear fuel, develop nuclear waste disposal capacity, remove statutory limits on waste disposal at the proposed Yucca Mountain repository, establish a nuclear fuel supply reserve, and require NRC to establish expedited procedures for issuing new reactor combined construction and operating licenses. Introduced March 3, 2011; referred to multiple committees.

H.R. 1023 (Thornberry)

No More Excuses Energy Act of 2011. Includes provisions to prohibit NRC from considering nuclear waste storage when licensing new nuclear facilities, and to establish a tax credit for obtaining nuclear component manufacturing certification. Introduced March 10, 2011; referred to multiple committees.

H.R. 1242 (Markey)

Nuclear Power Plant Safety Act of 2011. Requires NRC to revise its regulation within 18 months to ensure that nuclear plants could handle major disruptive events, a loss of off-site power for 14 days, and the loss of diesel generators for 72 hours. Spent fuel would have to be moved from pool to dry-cask storage within a year after it had cooled sufficiently, and emergency planning would have to include multiple concurrent disasters. NRC could not issue new licenses or permits until the revised regulations were in place. Introduced March 29, 2011; referred to Committee on Energy and Commerce.

H.R. 1268 (Lowey)

Nuclear Power Licensing Reform Act of 2011. Requires evacuation planning within 50 miles of U.S. nuclear power plants and that reactor license renewals be subject to the same standards that would apply to new reactors. Introduced April 7, 2011; referred the Committee on Energy and Commerce.

H.R. 1280 (Ros-Lehtinen)/S. 109 (Ensign)

Requires congressional approval of agreements for peaceful nuclear cooperation with foreign countries. House bill introduced March 31, 2011; referred to Committee on Foreign Affairs. Senate bill introduced January 25, 2011; referred to Committee on Foreign Relations.

H.R. 1320 (Berman)

Nuclear Nonproliferation and Cooperation Act of 2011. Requires additional nonproliferation conditions for new peaceful nuclear cooperation agreements. Introduced April 1, 2011; referred to Committee on Foreign Affairs.

H.R. 1326 (Fortenberry)/S. 640 (Akaka)

Furthering International Nuclear Safety Act of 2011. Requires U.S. delegation to the Convention on Nuclear Safety to encourage member countries to use metrics in assessing safety improvements and publicly post national safety reports, and that U.S. agencies submit a strategic plan for international nuclear safety cooperation. Senate bill introduced March 17, 2011; referred to Committee on Foreign Relations. House bill introduced April 1, 2011; referred to Committee on Foreign Affairs.

H.R. 1436 (Christopher H. Smith)

Requires nuclear power facilities to notify NRC and state and local governments within 24 hours of an unplanned release of radionuclides above allowable limits. Introduced April 7, 2011; referred to Committee on Energy and Commerce.

H.R. 1694 (Engel)

Nuclear Disaster Preparedness Act. Requires the President to issue guidance for federal response to nuclear disasters, covering specific topics listed in the bill. Introduced May 3, 2011; referred to Committee on Transportation and Infrastructure.

H.R. 1710 (Burgess)

Nuclear Used Fuel Prize Act of 2011. Authorizes the Secretary of Energy to establish monetary prizes for advancements in used nuclear fuel management technology. Introduced May 4, 2011; referred to Committees on Science, Space, and Technology and Ways and Means.

H.R. 2075 (Engel)

Dry Cask Storage Act. Requires spent nuclear fuel to be moved from storage pools to dry casks within one year after it has sufficiently cooled. Owners of spent fuel could reduce their payments to the Nuclear Waste Fund to offset extra dry cask storage costs resulting from the act. Introduced June 1, 2011; referred to Committee on Energy and Commerce.

H.R. 2133 (Matheson)/S. 1220 (Conrad)

Fulfilling U.S. Energy Leadership (FUEL) Act. Among other provisions, authorizes nuclear fuel cycle research and development, including waste treatment processes and advanced waste forms. Requires the Secretary of Energy to consider recommendations of the Blue Ribbon Commission on America's Nuclear Future in implementing the authorized program and to submit a report to Congress comparing the Secretary's proposed long-term nuclear waste management solutions with the proposed Yucca Mountain repository. House bill introduced June 3, 2011; referred to multiple committees. Senate bill introduced June 16, 2011; referred to Committee on Finance.

H.R. 2354 (Frelinghuysen)

Energy and Water Development Appropriations for FY2012. Provides funding for NRC and DOE nuclear energy programs. Introduced and reported as an original measure by the House Appropriations Committee June 24, 2011 (H.Rept. 112-118). Passed House July 15, 2011, by vote of 219-196. Reported by Senate Appropriations Committee September 7, 2011 (S.Rept. 112-75). Considered on Senate floor November 16, 2011. Enacted as part of Consolidated Appropriations Act for FY2012 (P.L. 112-74), December 23, 2011.

H.R. 2367 (Pearce)

Government Waste Isolation Pilot Plant Extension Act of 2011. Would authorize disposal of government-owned non-defense transuranic waste in the Waste Isolation Pilot Plant (WIPP), in addition to currently authorized defense waste. Introduced June 24, 2011, referred to Committees on Energy and Commerce and Armed Services.

H.R. 3302 (Rooney)

Restore America Act of 2011. Among other provisions, would encourage tripling of U.S. nuclear power capacity, require licensing proceedings to continue for the proposed Yucca Mountain waste repository, remove statutory capacity limits on the repository, prohibit the President from blocking or hindering nuclear spent fuel recycling, establish a nuclear fuel reserve, and establish expedited reactor licensing procedures. Introduced November 1, 2011; referred to multiple committees.

H.R. 3308 (Pompeo)/S. 2064 (DeMint)

Energy Freedom and Economic Prosperity Act. Among other provisions, would terminate production tax credit for electricity generated by advanced nuclear plants. House bill introduced November 2, 2011; referred to Committees on Ways and Means and Energy and Commerce. Senate bill introduced February 6, 2012; placed on the Senate legislative calendar.

H.R. 3657 (Terry)

Nuclear Emergency Re-establishment of Obligations Act. Establishes criteria and procedures for the exercise of emergency authority by the NRC Chairman. Introduced December 13, 2011; referred to Committee on Energy and Commerce.

H.R. 3822 (Lowey)

Requires NRC to distribute safety-related fines collected from nuclear facilities to the counties in which the facilities are located to maintain radiological emergency preparedness plans. Introduced January 24, 2012; referred to Committee on Energy and Commerce.

H.R. 5325 (Frelinghuysen)/S. 2465 (Feinstein)

Energy and Water Development and Related Agencies Appropriations Act, 2013. Includes funding for DOE nuclear energy programs and NRC. House bill introduced and reported as an original measure by the Appropriations Committee on May 2, 2012, and passed House June 6, 2012, by vote of 255-165 (H.Rept. 112-462). Senate bill introduced and reported as an original measure by the Appropriations Committee April 26, 2012 (S.Rept. 112-164).

H.R. 4301 (Duncan)

Includes a requirement that NRC reach a determination on DOE's license application for the Yucca Mountain repository and removes existing statutory limits on the amount of waste that can be placed into the repository. Introduced March 29, 2012; referred to multiple committees.

H.R. 4625 (Joe Wilson)/S. 2176 (Graham)

Yucca Utilization to Control Contamination Act/Nuclear Waste Fund Relief and Rebate Act. Requires that payments into the Nuclear Waste Fund be returned to utilities unless the President certifies that Yucca Mountain is the selected site for a nuclear waste repository; that defense nuclear waste be transported to Yucca Mountain beginning in 2017; and that statutory requirements for disposal of nuclear waste be sufficient grounds for NRC to determine that waste from new or relicensed reactors will be disposed of in a timely manner. House bill introduced April 25, 2012; referred to Committee on Energy and Commerce. Senate bill introduced March 8, 2012; referred to Committee on Energy and Natural Resources.

S. 512 (Bingaman)

Nuclear Power 2021 Act. Authorizes a cost-shared program between DOE and the nuclear industry to develop and license standard designs by 2021 for two reactors below 300 megawatts of electric generating capacity, including at least one no larger than 50 megawatts. Introduced March 8, 2011; referred to Committee on Energy and Natural Resources.

S. 1320 (Murkowski)

Nuclear Fuel Storage Improvement Act of 2011. Authorizes the Secretary of Energy to provide payments to units of local government that, with the approval of the state governor, volunteer to host a "privately owned and operated temporary used fuel storage facility." Introduced June 30, 2011; referred to Committee on Environment and Public Works.

S. 1394 (Webb)

Allows a Commissioner of the Nuclear Regulatory Commission to continue to serve on the Commission if a successor is not appointed and confirmed in a timely manner. Introduced July 20, 2011; referred to Committee on Environment and Public Works.

S. 1510 (Bingaman)

Clean Energy Financing Act of 2011. Establishes Clean Energy Deployment Administration to provide financial assistance to commercial projects using clean energy technology, including nuclear power. Introduced and reported as an original measure by the Committee on Energy and Natural Resources August 30, 2011 (S.Rept. 112-47).

S. 2031 (Sherrod Brown)

Authorizes $150 million to demonstrate USEC centrifuge technology. Introduced December 17, 2011; referred to Committee on Energy and Natural Resources.

S. 2146 (Bingaman)

Clean Energy Standard Act of 2012. Establishes minimum U.S. annual percentages of clean energy use, including nuclear power, starting at 24% in 2015 and rising to 84% in 2035. Introduced March 1, 2012; referred to Committee on Energy and Natural Resources. Committee hearing held May 17, 2012.

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