Nuclear

In pursuit of a Renaissance

The Story in Brief

Virtually every credible plan for dealing with climate change includes increases in the use of nuclear power—the only non-emitting technology currently capable of producing electricity at multi-gigawatt scale. Advanced reactor designs are available to support such a resurgence, but getting new plants built will require substantial work on technical, regulatory, and business issues, as well as renewal of a diminished nuclear manufacturing and construction infrastructure.

Rising and volatile fossil fuel prices and growing concern about greenhouse gas emissions are driving a "nuclear renaissance" around the world. Plant construction activities are proceeding in 12 countries, and development plans in the United States are closer to commercialization than they've been in almost 30 years. A recent report by the Intergovernmental Panel on Climate Change cites nuclear power as one of the key mitigation technologies for dealing with greenhouse gas emissions on a global scale.

EPRI, too, has looked closely at climate change mitigation options. At the request of its board of directors, EPRI examined the technical potential for reducing carbon dioxide (CO_2) emissions in the U.S. electricity sector. EPRI found that no one technology would be a so-called silver bullet. But within the portfolio of technologies needed to significantly reduce climate impacts, nuclear energy loomed large. According to EPRI's analysis, significant nuclear expansion—64 gigawatts of new capacity by 2030—could avoid approximately 260 million metric tons of CO_2 emissions annually from the U.S. electricity sector. Additional nuclear power penetration worldwide, estimated by some to be five to ten times as many gigawatts, would produce commensurately larger reductions.

The impetus to limit CO_2 emissions is increasing around the world. While the Kyoto Protocol has not been successful in uniting all nations under a common framework for addressing climate change, it has sustained international pressure to reduce greenhouse gas emissions. The European Union has been a leading force in the climate change debate, implementing a multinational trading scheme for CO_2 emissions. China, which recently surpassed the United States as the world's largest CO_2 emitter, has also increased its awareness of and participation in international climate change discussions. Nuclear power is growing in China, and the country has stated it wants 16% of its electricity to come from renewables by 2020.

Pressure to limit CO_2 emissions is mounting in the United States as well. Some states and regions are already imposing limits on such emissions, and numerous corporations, institutions, and financial groups are pressing Congress to pass emission-control legislation. Clearly, expected legislative action on CO_2 and other greenhouse gases has helped promote interest in non-emitting energy sources, such as renewable energy and nuclear power. But in practical terms, what impact might such limits have on the decision to build a new nuclear plant? The question is complicated by uncertainty over what regulatory approach might be adopted—a carbon tax or an emissions cap-and-trade system, for example—and about how such a system would be administered.

Still, the seeming inevitability of federal legislation has electric utilities taking a fresh look at the impacts of carbon constraints on the cost-competitiveness of new plants. "In our financial modeling, we've looked at something as small as a $10-per-ton tax, and it has an enormous impact when we do the least-cost supply option forecast," says Randy Hutchinson, Entergy Nuclear's senior vice president, nuclear business development and new plant activities. "Nuclear power plants become much more competitive with other baseload options such as coal when a tax is included in the analysis."

Recent EPRI economic modeling of the U.S. electricity sector's potential to reduce greenhouse emissions compares different technology scenarios—including limited versus significant construction of new nuclear and advanced clean coal plants—out to 2050. Initial results emerging from this analysis indicate that costs to the U.S. economy of CO_2 emissions abatement are dramatically lower in scenarios where a full array of advanced technologies are developed, available, and aggressively deployed. A substantially expanded nuclear power fleet plays a large role in such scenarios.

Running such economic scenarios will be important for a company's commitment to new plants, but as Eugene Grecheck, vice president for nuclear support services at Dominion, points out, many company boards are looking beyond the details of coming mandatory carbon limits: "Boards tend to look further into the future, and won't wait for a mandatory cap. They realize that we need to start planning now for how to address carbon controls of some type." Bryan Dolan, Duke Energy's vice president for nuclear plant development, expresses a similar bottom-line view, held by many in the industry: "Anything imposing additional carbon constraints on the legislative front may sway decision-making more toward nuclear."

Nuclear's status as a CO_2 non-emitter is also changing minds among some longtime opponents of the technology. Patrick Moore, a cofounder of Greenpeace, told the U.S. House Appropriations Subcommittee on Energy and Water Development at a September 2006 hearing that in the 1970s he believed "nuclear energy was synonymous with nuclear holocaust." But a lot has changed in the 35 years since then, he said. "Nuclear energy is the only large-scale, cost-effective energy source that can reduce CO_2 emissions while continuing to satisfy a growing demand for power—cleanly and safely."

The environmental community is far from united in supporting a nuclear renaissance, but the change of position from activists such as Moore reflects a broader rethinking of the nuclear option among opinion leaders and the public at large. Over the past five years, opinion polls have consistently shown increasing public acceptance of the technology, encouraged by major coverage in virtually all the national newspapers and newsmagazines on the "greening of nuclear power."

Building on Success

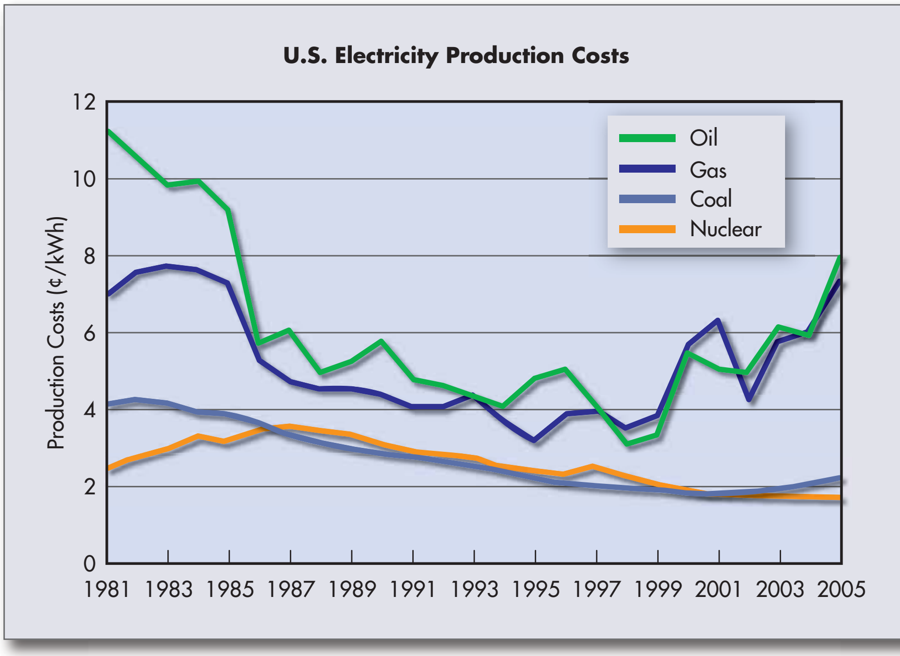
While the ability to generate emission-free electricity will certainly help promote public acceptance, renewed interest in new nuclear plants is just as grounded in the fundamentals of the power business, says Tom Mulford, manager of EPRI's Advanced Nuclear Technology Program. "The current U.S. nuclear fleet is extremely safe and reliable, and it's currently operating at a capacity factor of more than 90%. A number of financial analysts have concurred that the nuclear resurgence is tied largely to the sustained high performance of the existing reactor fleet."

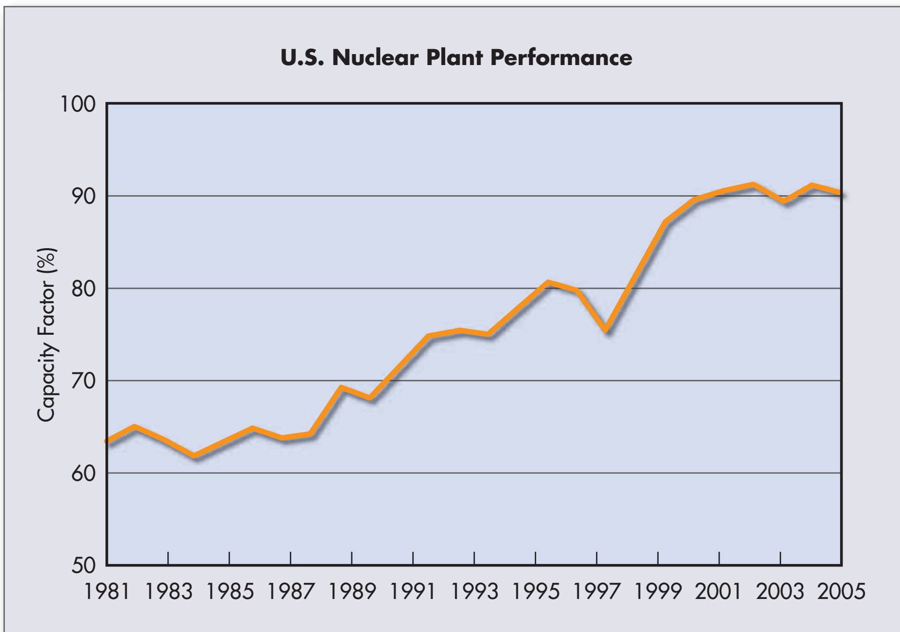
Attention to nuclear safety remains paramount among plant staff as well as the public. Analysis by EPRI—and measurements of specific safety metrics set by the industry and the Nuclear Regulatory Commission (NRC)—confirm the ever-improving safety record of the U.S. nuclear fleet. In addition, EPRI research suggests a link between reliability and safety, indicating that the nuclear fleet is operating not only at high capacity, but with an unprecedented level of safety.

Mulford also points out that nuclear energy is one of the lowest-cost energy sources available today, particularly for baseload power. In the United States, for example, electricity production costs in 2005 for nuclear power were 1.72¢/kWh, according to the Nuclear Energy Institute (NEI), compared with 2.21¢/kWh for coal and 7.51¢/kWh for natural gas. Moreover, nuclear fuel costs are not volatile and account for only a small portion of overall production costs, thus providing excellent overall price stability. Andy White, president and CEO of GE-Hitachi Nuclear Energy, puts it this way: "A 50% increase in fuel costs for a natural-gas-fired plant raises operating costs by about 38%. For a coal-fired plant, operating costs go up by about 20%. For a nuclear plant, a 50% increase in fuel costs increases operating costs by only 3%."

Reliability and efficiency improvements have enabled nuclear plants to boost electricity production at individual sites, and ongoing operational advances could increase output even further. Electricity demand will grow much faster than gains in nuclear plant efficiency, however. The Department of Energy's Energy Information Administration (EIA) projects world electricity demand to increase 85% by 2030, with the strongest growth in emerging economies. In the United States, the EIA expects electricity demand to surge by 45% over the next 25 years. This increase translates into a need for nearly 350,000 MW of new electric generating capacity, much of it baseload—coal-fired and nuclear power plants. About 60,000 MW of new generating capacity will be required in the next 10 years alone, according to the EIA.

Considering this need and the capabilities of today's technologies, it's clear that new nuclear capacity must provide a substantial portion of the coming decades' generation mix. "We're not saying that nuclear energy is the only answer," says Domin-





Renewed interest in nuclear power has been supported by a quarter century of low costs and substantially improved reliability for the existing nuclear fleet. The NRC confirms that safety records have also improved steadily over this period. (source: NEI) ion's Grecheck. "Solar, wind, and other renewables have a role to play, but they're not currently practical on a large scale."

Cost and Risk

Most nuclear utilities and vendors identify the same challenges to building new nuclear plants, and not surprisingly, the overriding issues come down to cost and investment risk. Given the U.S. industry's experience in the 1970s and 1980s, when licensing and construction delays led to escalating costs, building new nuclear plants is a tremendous risk management exercise, notes Richard Myers, vice president of policy development at NEI. "Numerous nuclear utilities are preparing license applications for new plants, but no company will make a commitment to build a new plant unless it has a high level of confidence in the cost and schedule. We are trying to identify all the project risks and make sure they're mitigated and managed and properly hedged," he says.

One key challenge is the need to confirm competitive capital costs for new nuclear plants. "Vendors need to provide firm costs to their customers," says Buzz Miller, senior vice president for nuclear development at Southern Nuclear. "Most new plants will be built in regulated states in the southeastern United States. We need pricing at a level of certainty that will be acceptable to our public utility commissions." Southern is preparing a license application for two new AP1000 units at the Plant Vogtle site, and it needs to convince the Georgia Public Service Commission (PSC) that these units will be cost-competitive with other generating sources, including coal and natural gas. Southern is working with Westinghouse, the AP1000 vendor, and expects to have the figures it needs to support a submittal to the PSC in mid-2008, which would result in PSC certification around December 2008. Vendors recognize that most of their customers are regulated, says Ed Cummins, vice president of licensing and standardization for Westinghouse. "We are trying to provide a degree of firmness in price that would permit them to interact with their public utility regulators."

Similarly, Dominion is working with GE Energy on pricing for the Economic Simplified Boiling Water Reactor (ESBWR), while Constellation expects to have 70–75% of Areva Inc.'s U.S. Evolutionary Power Reactor (EPR) at a fixed price, excluding labor, by late 2009 and early 2010. TXU, which has selected Mitsubishi's U.S. Advanced Pressurized Water Reactor, expects production costs based on the US-APWR to be competitive in Texas's deregulated market within the next year or two.

GE Energy's White admits that the company is working with estimates at present, but he expects to have "locked down the engineering-procurement-construction (EPC) contracts" by the end of 2008. "One question is where commodity prices will be during a 2010–2015 construction timeframe," he says. Areva is closer to pricing certainty than it was a year ago, says Ronald Affolter, vice president for EPR deployment. Ongoing construction of an EPR plant in Finland has helped the company better understand the potential costs of a U.S. plant.

Advanced modeling tools can provide insight into nuclear project costs. In a program sponsored by EPRI, Westinghouse developed a virtual reality construction model of the AP1000 reactor design to assess the impact of two drivers of plant construction costs—the cost of financing during construction and the substantial skilled craft labor needed on-site during construction. The virtual reality model identified opportunities for reducing both cost drivers by establishing parallel construction paths using modules and integrating construction sequence review into the design process. According to EPRI, the model should reduce construction times for advanced reactors by 10%.

Standardization

Many of the risk factors that nuclear companies must deal with are beyond their control. One issue that is clearly within the industry's control is standardization: standardization of design requirements, standardization of resulting advanced designs, and standardization of operations. The industry has devoted significant time and resources to this issue over the past few decades. In the 1980s and 1990s, EPRI led efforts to create a standardization framework that would guide new plant development and deployment. The Utility Requirements Document (URD) captured user requirements for advanced reactor designs that utilities reached consensus on and that the reactor designers and the NRC could accept. The nuclear industry's *Strategic Plan to Build New Nuclear Power Plants,* an annual report updated each year through the 1990s, laid the foundation for efforts of both reactor vendors and utility consortia to maintain cost-effective standardization in new plant projects under development today.

The URD is a living document, with periodic revisions to reflect technology advances and lessons learned from operating plants. EPRI, through its technology transfer capabilities, is sharing information from R&D activities in a number of areas, including radioactive waste, materials, water chemistry, systems engineering and design, human factors engineering, instrumentation and control, electrical cabling, equipment qualification, and seismic design. Updates in these areas are being shared continually with utilities and vendors and will be documented in a subsequent URD revision.

Standardization implies industrywide resolution of common issues. "The utilities that are expected to submit combined construction and operating license applications to the NRC are basing their applications on several different reactor designs," says EPRI's Mulford. "While these reactors have a host of specific design differences, there remain a number of issues that are generic to more than one design, such as seismic issues and digital instrumentation and control. Addressing these issues in a collaborative fashion ensures continuity with the URD and enables lessons learned

Snapshot of Advanced Reactors

Unlike today's nuclear plants, the reactors proposed for new plants have standardized designs with innovative safety features. Two reactors being considered for construction—the Westinghouse AP1000 and General Electric's Economic Simplified Boiling Water Reactor (ESBWR)—are advanced, "passive safety" designs that rely on natural forces such as gravity for plant safety, rather than on pumps or fans. Both employ a modular design. Three other reactors under consideration—Areva's Evolutionary Power Reactor (EPR), General Electric's Advanced Boiling Water Reactor (ABWR), and Mitsubishi's U.S. Advanced Pressurized Water Reactor (US-APWR)—are evolutionary designs. Although based on current plants, these reactors have enhanced safety features.

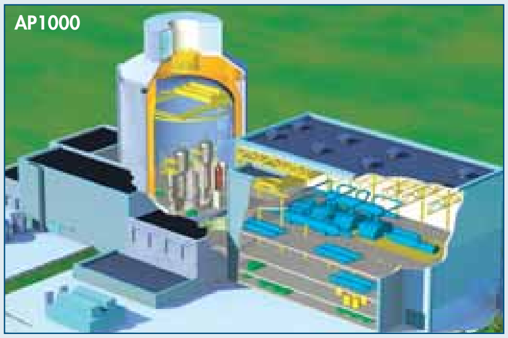
The Westinghouse AP1000, a 1000-MW pressurized water reactor (PWR), has significantly fewer components than today's PWRs. It has 50% fewer valves, 35% fewer pumps, 83% less pipework, and 87% less control cable. In addition, the design reduces by 45% the amount of building materials required. The reactor's safety system uses gravity, natural circulation, and compressed gas to ensure emergency core cooling and employs no pumps, fans, diesels, chillers, or other rotating machines in safety applications that could malfunction or lose power in an emergency.

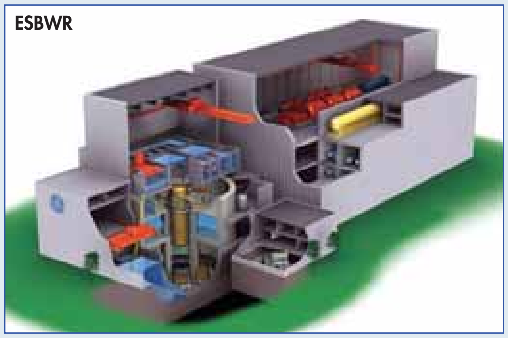
General Electric's ESBWR, a 1500-MW boiling water reactor (BWR), has reduced the number of systems by 25% and contains 25% fewer pumps and valves and 25% less piping and cabling than conventional designs. Its natural circulation and passive safety features eliminate the need for safety system pumps and safety diesel generators. For example, the ESBWR has a gravity-driven cooling system for the reactor and a passive containment cooling system that removes heat by means of four low-pressure natural circulation loops, each with a heat exchanger.

Areva's EPR, an evolutionary PWR designed by Framatome ANP, incorporates simplified safety systems that improve accident prevention and protection against external hazards. It features a robust containment structure consisting of two cylindrical walls—an inner prestressed wall with a steel liner and an outer reinforced-concrete wall, each with a separate dome. The EPR being deployed in the U.S. market has been designed to use 7% less uranium fuel per kilowatthour, reducing the cost of electricity generation. The first EPR is under construction in Finland; construction of a second EPR will begin in France by the end of 2007.

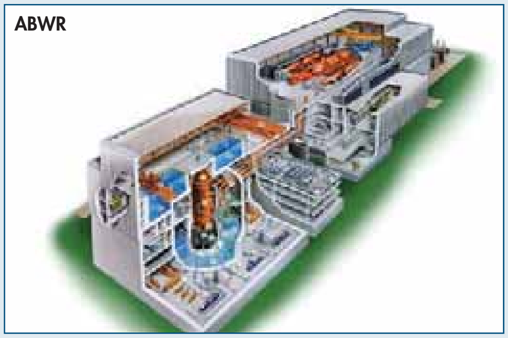
General Electric's ABWR employs a more compact design than the current BWR, increasing safety and reducing construction costs. All major equipment and components have been engineered for improved reliability and ease of maintenance—including such features as vessel-mounted reactor internal pumps and fine-motion control rod drives. This design was certified by the NRC in 1997. The first two ABWRs went into commercial operation in Japan in 1996 and 1997 at the Kashiwazaki-Kariwa site. Two ABWRs are under construction in Taiwan at the Lungmen site.

Mitsubishi's US-APWR, an evolutionary design with active safety features, is a 1700-MW reactor. Twenty-three versions of the basic Mitsubishi design are now operating in Japan.


AP1000

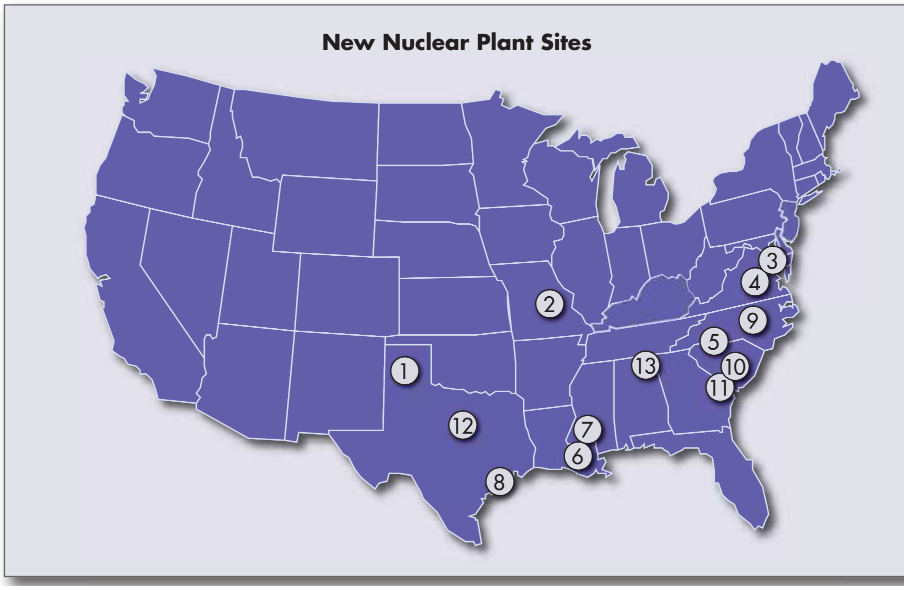

ESBWR


EPR


ABWR


US-APWR

A new licensing process established by the NRC in 1989 will help utilities avoid the expensive delays and redesigns that plagued nuclear plant construction in the 1970s. Applications for combined construction and operating licenses (COLs) are expected to be submitted for over a dozen new U.S. nuclear plants by the end of 2008. (source: NEI)



	Company	Site	Design	Number of Units
1	Amarillo Power	Amarillo, TX	EPR	1
2	AmerenUE	Callaway, MO	EPR	1
3	Constellation (UniStar consortium)	Calvert Cliffs, MD, plus two other sites	EPR	3
4	Dominion	North Anna, VA	ESBWR	1
5	Duke	Cherokee County, SC	AP1000	2
6	Entergy	River Bend, LA	ESBWR	1
7	Entergy (NuStart consortium)	Grand Gulf, MS	ESBWR	1
8	NRG Energy/STPNOC	Bay City, TX	ABWR	2
9	Progress Energy	Harris, NC	AP1000	2
10	South Carolina Electric & Gas	Summer, SC	AP1000	2
11	Southern Company	Vogtle, GA	AP1000	2
12	Texas Utilities	Comanche Peak, TX	US-APWR	2
13	TVA (NuStart consortium)	Bellefonte, AL	AP1000	2

from the existing fleet to be reflected in new plant designs, minimizing risks in critical areas such as materials and equipment reliability."

Financing and Loan Guarantees

As multi-billion-dollar investments, nuclear power plants present a formidable financing challenge. In a number of countries, government support, government ownership, and/or high electricity prices can make the large investment more palatable, but the hefty price tag invariably raises the level of scrutiny.

In the United States and other countries with deregulated wholesale markets, private development, ownership, and operation further accentuate the investment challenge. A new nuclear plant would represent an extremely significant part of a company's total value, according to Dominion's Eugene Grecheck: "We're at the critical stage, and companies need to work on financing packages right now." Mike Wallace, president of Constellation Energy's generation group, agrees, adding: "We can't get past this barrier without loan guarantees. We haven't begun construction of a nuclear plant for 25 years, when there were more than a few financial problems; the risks of putting up a new plant with a new design in today's business environment can't be adequately described or costed out. If banks are going to underwrite the debt for such a plant, they're going to require that somebody guarantee the loan."

In the United States, the Energy Policy Act of 2005 provides several incentives for new nuclear plants, including loan guarantees. Under the legislation, the Department of Energy guarantees up to 80% of the project cost to support the development of innovative energy technologies that avoid, reduce, or sequester air pollutants or greenhouse gases. Uncertainties have recently arisen, both about congressional appropriations for the guarantees and about the DOE guidelines that define how the policy act incentives will be administered; while these issues are currently unresolved, industry experts remain confident that government-backed loan guarantees will be available for new nuclear plants.

The financial community understands the business case for new nuclear, says Caren Byrd, executive director of Morgan Stanley's Global Utility and Power Group. "We see the need for new capacity and understand how companies have been hurt by the volatility of natural gas, which has been difficult on investors. Also, more investors are environmentally sensitive and want to invest in environmentally friendly projects. But the most important factor is economics. The financial community is waiting to be convinced on that."

Plant Licensing

Most U.S. nuclear power plants were licensed during the 1960s and 1970s. Plants were issued a construction permit based

Challenges for Existing Plants

While most plans for dealing with climate change include substantial increases in new nuclear power, addressing the climate issue will also require continued operation of existing nuclear plants around the globe. Sustained contributions to CO_2 reductions are projected to call for operating lifetimes of at least 60 years for the world's nuclear fleet.

This vote of confidence is reassuring to nuclear power proponents, but it is not a guarantee that nuclear's future is secure. "To ensure safe, cost-effective operation for 60 or more years, nuclear plants must address a number of challenges associated with the plants' physical integrity and staffing," says Ken Huffman, EPRI technical director, plant technology. "In particular, plants must continue to resolve materials degradation issues, ensure sustained equipment reliability, address equipment obsolescence and supply chain issues, and provide a trained workforce to replace retiring employees and maintain plant performance at the high levels necessary for economic operation."

The industry's ability to recognize and react to emerging materials issues has been clearly demonstrated. For example, much has been learned about the performance of materials in the primary systems of existing nuclear power plants, especially in relation to BWR recirculation piping, PWR steam generator tubing, and PWR vessel head penetrations. Nevertheless, as plants enter their fourth, fifth, and sixth decades of operation, new materials-aging issues can be expected that will require rapid response. This response will depend on the availability of robust and sensitive detection technology and on a workforce attuned to subtle indications and with a detailed awareness of system and materials performance under various operating conditions.

The cross-cutting nature of these challenges—spanning technical, operational, and management concerns—calls for optimization strategies that encompass the total nuclear plant asset. Scenario-based studies performed by EPRI highlight several societal and environmental benefits that would accrue from optimization strategies at existing nuclear plants: significant economic benefits from higher plant capacity factors and extended plant life, greater CO_2 reductions compared with other proven large-scale generation sources, and provision of a bridge between the current nuclear fleet and the startup of significant nuclear "new build" plants.

"The incremental value of increased nuclear plant performance and output—in comparison with initial performance—is estimated to be on the order of two trillion dollars in the United States alone," says Huffman. Extending these benefits to plants around the world would substantially amplify the economic value while sustaining nuclear power's ability to reduce global CO_2 emissions.

on a preliminary design, but safety issues were not fully resolved until the plant was essentially complete—a process flaw that led to a "design as you go" construction process with substantial rework that had major financial implications. The other critical flaw in the old process was the fact that the public did not have access to the details of the design or an opportunity to comment until construction was almost finished. To address this problem in the United States, the NRC established a new licensing process in 1989, which was affirmed and strengthened by Congress as part of the 1992 Energy Policy Act.

The new process has three components: approval of standard reactor designs, early site permits (ESPs), and combined construction and operating licenses (COLs). The ESP enables nuclear utilities to obtain public input and NRC approval for a nuclear plant site before committing to build a plant. The use of approved, standardized designs is intended to eliminate the ad hoc redesigns and construction delays that plagued projects in the 1970s. The process also gives the public an opportunity to comment on the design before it is approved. The public is given another opportunity for comment at the COL stage, when a particular certified design is matched to a preapproved site. When the NRC grants a COL, it signifies resolution of all safety issues associated with both the site and the plant.

While these improvements are encouraging, the nuclear and financial communities are awaiting clear signs that the NRC's new process will be effective and efficient. As Morgan Stanley's Byrd points out, "On paper, the process makes sense, but it hasn't been tested."

The NRC's ability to handle the new plant licensing workload will certainly need to be demonstrated. But another key point for utilities will be the COL application itself—essentially the need to understand what review criteria and implementation measures the NRC will use in assessing COL applications. Some companies have begun preparing applications without knowing "what they need to look like," but the majority are awaiting the official release of the regulatory guide for the application contents, expected this summer.

NEI's Adrian Heymer, senior director for new plant development, says that the NRC is doing the right things to encourage an efficient process, with emphasis on standardization of submittals and reviews. In addition to encouraging all applications for a specific design to be as standardized as possible, the NRC is promoting standard processes and technical issue resolutions across different designs. The NRC also has advocated the creation of designcentered working groups among utility applicants, with corresponding NRC staff organizational teams, each responsible for reviewing all applications for a given design. "Once the NRC has reviewed and approved the reference plant submitted by the working group," Heymer says, "it is our understanding that the NRC will then check the next application for the same design and focus on site-specific differences. It should be possible to achieve significant efficiencies and improvements in the schedule after the reference plant review."

Because the end-to-end permitting and approval process is untested, disciplined navigation will be essential. Tools developed from past and current activities can guide the way. To help utilities select a suitable site for a new nuclear plant, EPRI developed a siting guide and an early site permit model program plan. The guide describes a four-step process that addresses the full range of issues important to siting, while the ESP model program plan identifies the tasks needed to prepare an ESP application. EPRI also has developed a combined construction and operating license model program plan, which identifies the activities needed to supply the information required for a COL application. The program plan describes the interfaces between the vendor, the ESP holder, the architect-engineer, and other entities involved in preparing a COL application.

Getting the Plants Built

Although modest nuclear plant construction has continued around the world for much of the past 25 years, the population of manufacturers capable of supplying nuclear equipment has diminished because of the limited number of projects. The decades-long hiatus in North American plant orders has had a withering effect on what was once a vibrant nuclear manufacturing base in the United States. As a result, the first batch of new plants is likely to face bottlenecks in availability of key components. Increased demand will eventually lead to greater manufacturing capacity, but not surprisingly, vendors see the supply chain as a major challenge.

At present, only one company in the world—Japan Steel Works (JSW)—manufactures the ultraheavy forgings needed for nuclear plants. "JSW currently has the capacity to produce about 42 ultralarge forgings a year; each new plant will require between two and nine of these forgings, depending on the design," says NEI's Heymer. According to Entergy Nuclear's Hutchinson, a reactor pressure vessel has a lead time of 48 months from the placing of the order to the shipment of the vessel. "JSW's throughput is six to eight pressure vessels a year, maximum, so for the first plant orders, this will be a pinch point." For this reason, vendors are already talking with JSW about their future needs. GE Energy has entered into a reservation agreement with JSW, securing a specific number of forging allocations for the next few years. Westinghouse and Areva are also in the JSW queue.

GE Energy's White says that JSW is planning to expand its manufacturing capacity to serve the larger expected demand, but he believes that in the longer term, multiple suppliers will enter the market. Currently, says Westinghouse's Cummins, "it's a chicken-and-egg situation. If suppliers are assured of a market, they will assess capacity and expand to meet the demand; if they are not assured, they will wait to make an investment. There will be shortages or constraints in the supply chain as we build the initial plants, but they will disappear over time. I think there will be alternatives to JSW."

Pressure vessels are not the only concern. To identify choke points, vendors are systematically looking across the entire supply chain, noting the numbers and types of components needed and looking at what is available. Components that are especially critical to reactor safety must be manufactured under a special process of rigorous quality assurance to achieve the designation "nuclear grade." As NRC Chairman Dale Klein told the House Appropriations Subcommittee on Energy and Water Development in March 2007, "The NRC is working with regulators in other countries to ensure the legitimacy and quality of components manufactured internationally."

A limited workforce of both craft workers and construction managers could lead to additional bottlenecks in new plant construction, particularly in Europe and the United States. There are shortages of skilled pipe fitters, welders, journeymen, sheet-metal workers, carpenters, and technicians. "Having seasoned project managers and experienced people to oversee the craft workers will be critical to building plants on time," says NEI's Heymer. The U.S. nuclear industry is working with several federal agencies, as well as community colleges, to ensure the availability of a skilled workforce. "We'll have to train people, and we'll have to import people," says Westinghouse's Cummins. Some utility executives see a similar shortage in their own organizations and expect at least some of the experienced project managers to come from other countries.

Labor availability concerns highlight the importance of effective training—equipping employees with the requisite knowledge and skill to successfully perform in a cross-discipline environment. As new personnel enter the nuclear workforce, training must accelerate the learning process without compromising the demonstrated proficiency levels required for nuclear workers.

The availability of skilled craft workers in the United States will not be a big issue when only two or three plants are under construction, says GE-Hitachi's White. "But if 6, 10, 12 plants are being built simultaneously, it will be difficult to get craft labor." One factor that may ease the demand for skilled craft workers is the use of modular construction. Building modules in a controlled environment—a factory or a shipyard—could raise productivity, says White. "It also could avoid sucking up all the labor supply in the area of the plant site."

Task proficiency evaluation (TPE), a

Spent Fuel Storage: A Showstopper?

In 1987, Congress directed the U.S. Department of Energy to study Yucca Mountain, Nevada—a remote desert location—as the site for a potential repository for geologic disposal of used nuclear fuel and high-level radioactive waste. DOE's study of the site was delayed until 1992, in part because of the refusal of Nevada to issue the environmental permits needed for surface-disturbing work. After a decade of scientific study, the site was approved by Congress in 2002.

Construction of the repository, originally scheduled to open in 1998, has been repeatedly delayed because of funding constraints and DOE management issues. Opposition from the Nevada congressional delegation has played a role in DOE budget cuts for the project. DOE was to begin accepting used fuel from the nation's nuclear power plants in 1998 but failed to do so. This failure led to numerous lawsuits by the industry against the federal government for breach of contracts that DOE had signed with electric utilities. DOE now plans to submit a license application to the Nuclear Regulatory Commission in 2008 to build the repository, which is not likely to open before 2021. Used nuclear fuel is now safely stored at nuclear plant sites. Although the NRC has determined that used fuel could be stored safely at plant sites for 100 years, on-site storage was never intended as anything other than a temporary solution.

Is used fuel an obstacle to new plant construction? Most nuclear utilities and vendors do not think so. "We don't see the management of used fuel as a showstopper to moving forward," says Duke Energy's Bryan Dolan. Adds Southern Nuclear's Buzz Miller, "It's not a safety issue. It's a political issue, a contractual issue." To this point, EPRI commissioned studies in 2003 and 2004 to assess the risk of moving used fuel from the fuel pool into on-site dry storage. The results indicated that the annual risk of a cancer fatality to an individual living within 100 to 300 meters of a plant's loading, on-site transfer, and dry storage operations is essentially zero.

Some in the industry do think that disposal of used fuel is an issue, says Ed Cummins from Westinghouse. He says that could affect the number of new plants built. Opponents to new nuclear plant construction often point to the legislative limit on used fuel to be stored at Yucca Mountain. A 2006 EPRI study, however, demonstrates that the technical capacity of Yucca Mountain as a repository is actually four to nine times the legislative limit. This additional capacity would enable two to four times the existing U.S. nuclear installed capacity to operate for 60 years, with all used fuel stored at Yucca Mountain.

workforce approach advanced by EPRI in conjunction with utilities, trade unions, and labor suppliers, defines the key knowledge and skills required to perform specific tasks. In developing the TPE program, EPRI has created a bank of written and practical skill assessment tests for many of the defined tasks given to craft personnel. To further streamline personnel use and productivity on multiple projects, the program is also working to share information on individuals who have successfully demonstrated specific task skills.

Looking Ahead

Superior plant designs, streamlined licensing approaches, and strong coordination among utilities, vendors, suppliers, industry associations, and regulators are key ingredients to a resurgent nuclear industry, regardless of where the plant is being built. The interdependent nature of nuclear plant operation creates a community in which lessons learned and collaboration continuously guide process improvements. As more nuclear plants proceed from design certification through licensing, procurement, construction, and preservice inspection and testing to operation, capitalizing on these global strengths will be paramount. Sustaining this engagement over the lives of the plants will ensure that nuclear power can remain a reliable non-emitting electricity source.

Although the nuclear industry has gained significant momentum over the past few years, the nuclear renaissance is still in its earliest stages. The full scope and success of the renaissance will be realized only over time, as operating licenses are issued in many more countries around the world, as financing is secured, as foundations are being poured, and as a new generation of nuclear power plant personnel begin delivering emission-free electricity to the grid—from Mississippi to Mumbai. Building on the opportunities embedded in the climate change issue, and appreciating the sobering responsibility associated with nuclear power generation, the industry is poised to move the renaissance from abstraction to reality.

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