# Nuclear Energy Opening Up, Learning From Experience

*Thomas TerBush and Brian Schimmoller*

Dirt is moving at the construction site for two new nuclear units near Waynesboro, Georgia. Preliminary construction activities are also under way at a new nuclear plant site near Jenkinsville, South Carolina. Similar work may soon begin at locations in Maryland and Texas. It has been three decades since the last major nuclear construction boom in the United States, and while it is too early to call the current activity a "boom," the signs are favorable for a substantial number of new nuclear plants to be built over the next 10–20 years.

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Buoyed by an increased desire for electricity generation sources with minimal carbon dioxide emissions and its decades-long record of safe, reliable, economical electricity production, nuclear is poised for growth. The new reactors being planned in Georgia, South Carolina, and elsewhere are part of a much larger wave. In the last two years, the U.S. Nuclear Regulatory Commission (NRC) has received 17 construction and operating license applications for 26 new reactors. By 2010, the NRC expects 22 license applications from 20 different companies for 33 new reactors. **Exhibit 1** shows the locations and developers of the announced new nuclear plants as of June 2009.

The new reactors being planned in Georgia, South Carolina, and elsewhere are part of a much larger wave.

The optimism is real, but it is important to temper the favorable outlook with the reality that building a new nuclear plant is a multibillion-dollar business decision, and various factors could lead to delays or cancellations. In fact, two of the planned new nuclear projects—one in Texas and one in Missouri—have been put on hold because of financing and cost-recovery concerns.

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## WHY NOW?

Only a few short years ago, nuclear power was widely perceived as a dying, if not dead, industry. While the existing plants were running fairly well, there was little expectation that conditions would change sufficiently to support new nuclear plant construction in the United States. Coal plants were shouldering a large burden of base-load electricity demand, natural gas plants were coming on-line in droves to satisfy emerging peaking capacity requirements, and renewables were beginning to make inroads as a new, green resource.

**Thomas TerBush,** PhD (tterbush@epri.com, [202] 293-2694) is EPRI Market Leader, Nuclear, and **Brian Schimmoller** (bschimmoller@epri.com, [704] 595-2076) is EPRI Communication Leader, Nuclear, for the Electric Power Research Institute.

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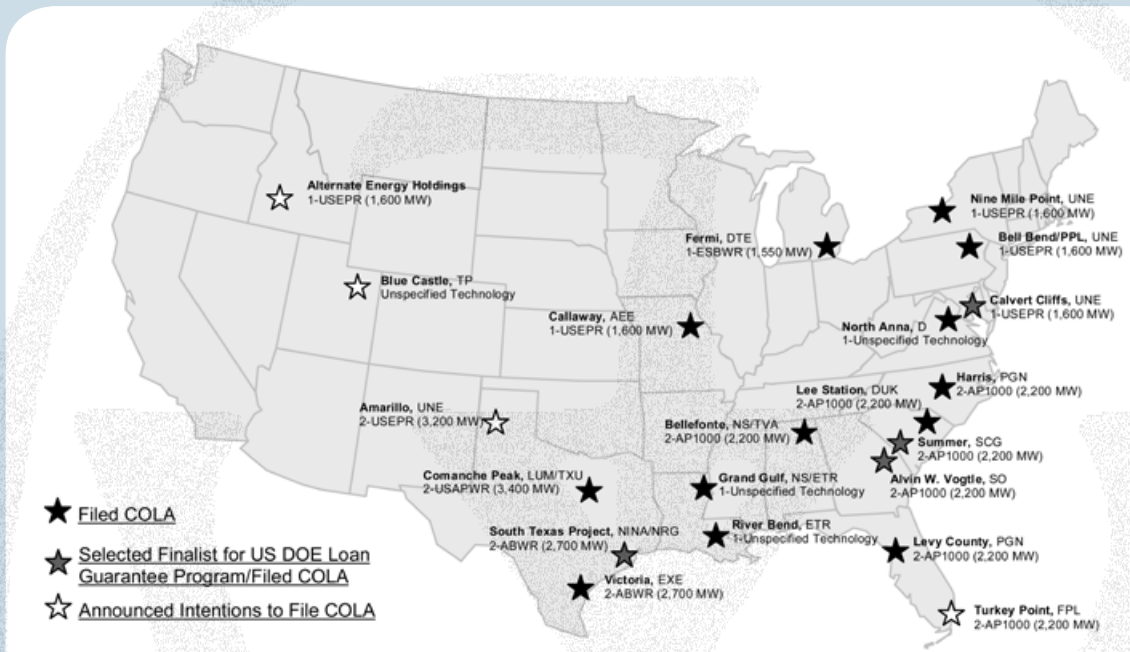
**Exhibit 1.** New Nuclear Plant Announcements




*Source:* NRC Expected New Nuclear Power Plant Applications.

What has changed? The biggest driver for new nuclear plant development is the likelihood of restrictions on carbon dioxide ($CO_2$) emissions from electricity production plants. Because nuclear power generation emits no carbon dioxide, its role in a low-carbon future could be significant.

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President Obama has called for reducing $CO_2$ emissions to 1990 levels by 2020, with a further 80 percent reduction by 2050. The Waxman-Markey energy bill that passed the U.S. House of Representatives on June 26 includes similar carbon-reduction targets.

Federal climate and energy legislation is also expected to contain renewable electricity production targets, and many states already have aggressive renewal portfolio standards. Although wind and solar will meet a portion of the demand for emission-free electricity, these fuel sources are variable and cannot provide power around the clock. Nuclear is currently the only low-carbon-emitting technology that can provide large blocks of base-load power—operating 24/7 to deliver reliable quantities of dispatchable, economical electricity to help drive economic growth.

Reaching aggressive $CO_2$ reduction goals will not be easy and will require contributions from all sectors of the energy economy. Energy efficiency, renewables, and advanced fossil generation will have a role, but so will nuclear power. In a series of analyses the Electric Power Research Institute (EPRI) conducted evaluating how the U.S. generation mix might change in response to carbon-emission-reduction goals under various technology availability conditions, nuclear maintained a significant or growing share of total electricity production.

Just as important, nuclear power remains an economical power-generation resource. Despite its high capital costs, over the life of the plant, electricity production costs are projected to be among the lowest of all generation sources. **Exhibit 2** shows the levelized cost of electricity in the 2015–2020 period for several generation sources, as a function of the price of carbon—assuming legislation is enacted imposing a price on the cost of a ton of $CO_2$. For carbon prices


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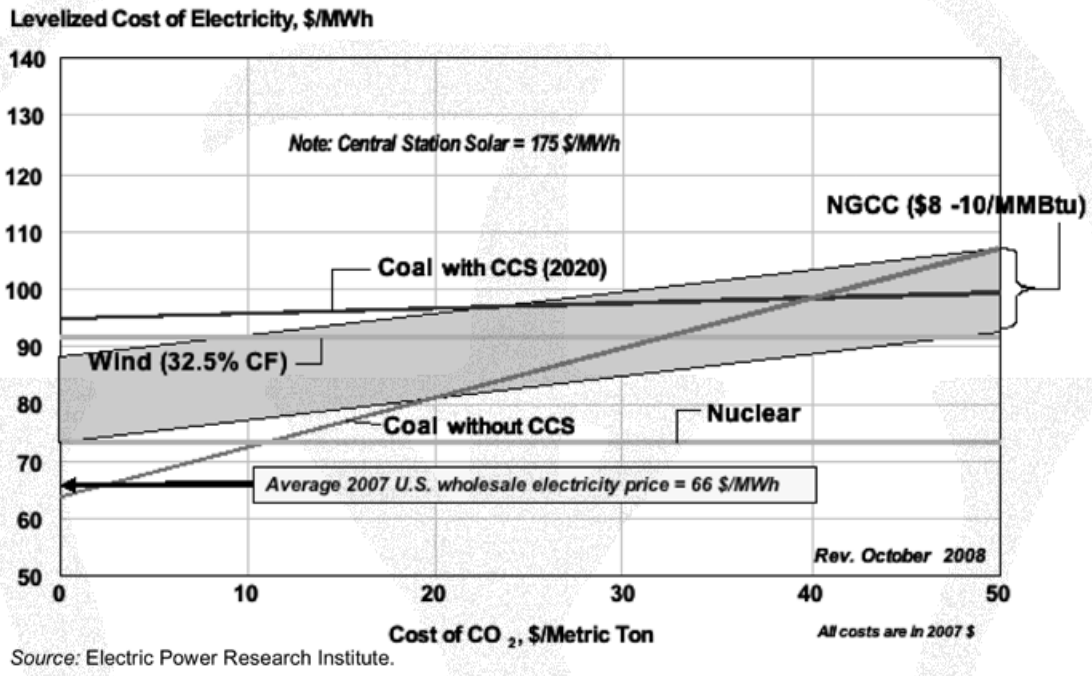
**Exhibit 2.** Comparative Levelized Costs of Electricity, 2015–20




*Source:* Electric Power Research Institute.

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## LEARNING FROM THE PAST

To get a better understanding for what has changed to promote nuclear power, it is useful to examine what led to the halt in new construction 30 years ago. In the 1970s and 1980s, 50 to 60 reactors were being built each decade, and 30 to 60 reactors were under construction at any given time.

This development pace came to a screeching halt in early 1980s, and at least three factors have typically been identified as being responsible for the sudden stop.

- ***Slower load growth:*** Between 1946 and 1973, U.S. electricity demand grew at 2 to 3 percent per year, and utilities ordered many nuclear plants expecting that the trend would continue. It didn't. Since the mid-1970s, electricity demand has grown about half as fast, which meant that dozens of nuclear and coal plants that were planned in the 1970s were no longer needed.

  *What is different today?* While the U.S. Department of Energy's Energy Information Administration projects electricity consumption to rise at only a 1 percent average annual rate through 2030, reaching aggressive carbon-reduction goals will require contributions from across the electric utility value chain. Carbon-free or low-carbon sources of electricity such as nuclear, wind, solar, and natural gas will be in greater demand.

  It is also important to recognize the numerical significance of 1 percent growth. In the United States, 1 percent annual growth in electricity demand corresponds to about 41.6 billion kilowatt-hours, the equivalent of about five large nuclear plants per year or more than 5,000 large wind turbines per year.
- ***Three Mile Island:*** In 1979, the accident at the Three Mile Island plant in Pennsylvania slowed down existing construction activities and also complicated new construction plans, as public opposition to nuclear power increased in many quarters and oversight of

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the nuclear industry dramatically escalated. In the post–Three Mile Island atmosphere, corporate America's stomach for new nuclear development projects waned, and the industry began focusing its efforts on completing ongoing construction projects and achieving operational excellence at the existing units.

*What is different today?* As unfortunate as Three Mile Island was, it set the industry on a path toward excellence that over the past 30 years has resulted in a remarkable safety and performance record. In the intervening decades, there have been no repeats of the accident, and risk-related measures of safety have improved dramatically.

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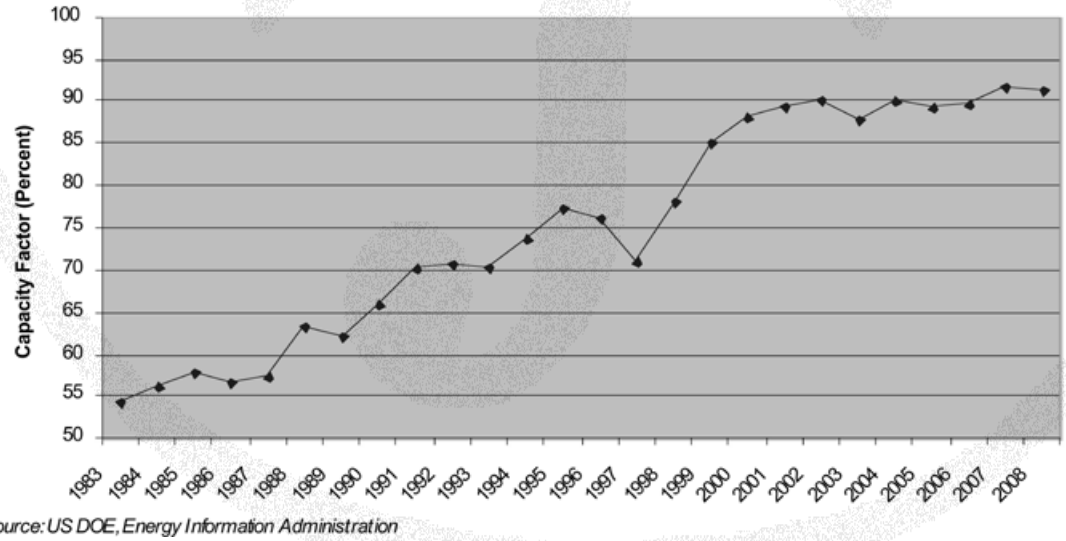
Performance is equally impressive. The nation's 104 nuclear reactors currently operate at an average capacity factor of 92 percent **(Exhibit 3)**, a significant improvement over the 1983 industry average of 54 percent. This increase in performance is equivalent to adding 27 new nuclear plants to the system and has allowed nuclear energy to maintain its 20 percent share of electricity production over the last 20 years, with roughly the same number of reactors operating and despite a 52 percent increase in electricity production during this time.

- ***High interest rates:*** The slowdown in construction partially triggered by Three Mile Island happened at a particularly unfortunate time for utilities that were borrowing hundreds of millions of dollars to construct new plants. As the timelines for plant operation (and cash flow) were pushed back, utilities were stuck borrowing at very high interest rates. This significantly increased overall construction costs for the plants, contributing to cost overruns that were subsequently passed on to ratepayers.

  *What is different today?* Nuclear plants are indisputably high-dollar investments. Single-unit capital costs of $6 to $8 billion are commonly referenced, rivaling the market capitalizations of many of the companies developing these projects.

  However, a number of activities are under way that are designed to more effectively reduce the financial risks during this round of nuclear development. These include a revised regulatory process for new plants, standard-

**Exhibit 3.** U.S. Nuclear Capacity Factors, 1983–2008




Source: US DOE, Energy Information Administration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ized plant designs, and financial provisions such as loan guarantees and production tax credits. To a large degree, it is these factors that have increased the industry's confidence that the problems encountered in the 1980s will not be repeated.

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## REGULATORY PROCESS

In the late 1970s and 1980s, one of the factors often cited as contributing to the cost overruns of the nuclear construction activities was the regulatory process that was then in place for licensing a new nuclear reactor.

At that time, separate regulatory approvals were needed to *build* the reactor and subsequently *operate* it. Conceivably, therefore, one could build a reactor only to be denied a license to operate the reactor. Delays in obtaining operating licenses led to significant cost increases in many cases.

Moreover, the regulatory agency typically issued the construction permit based on a preliminary design. Safety issues were not fully resolved until the plant was essentially complete, a process flaw that had substantial financial implications.

In 1989, recognizing the complications imposed by this approach, the NRC enacted a new approach that combined the construction and operating of a new nuclear plant into a single license. By issuing a combined construction and operating license (COL), the NRC authorizes the licensee to construct and (with specified conditions) operate a nuclear power plant at a specific site, in accordance with established laws and regulations. A COL is valid for 40 years and can be renewed for an additional 20 years.

The COL must be granted before reactor-related construction activities, including excavation and foundation work, can begin. However, provided certain conditions are met, some limited construction work can begin before a full construction and operating license is granted. This type of work is what is currently under way at the sites in Georgia and South Carolina.

Nuclear plant developers have filed 17 applications for 26 reactors with the NRC, and five more applications for an additional seven reactors are expected by 2010. It is expected that the first combined construction and operations license will be issued by the NRC in 2011.

Once a license is issued, construction is expected to take four to five years. To drive schedule reductions and ensure that best construction practices are incorporated, the nuclear industry is evaluating nuclear building programs outside the United States, where construction has continued over the past 30 years. Korea, for example, has built five reactors in the last decade and has another five currently under construction. Using standardized designs and improved construction processes, new nuclear plants are now built in less than four years, with a goal to reduce construction length to as little as three years.

## SIMPLER, STANDARD PLANT DESIGNS

As noted above, the previous round of nuclear construction relied on preliminary plant designs in many cases, and most of the existing nuclear plants were custom-designed and custom-built. This one-of-a-kind approach contributed to the high costs and schedule overruns of the previous build-out. To remedy this deficiency, the nuclear industry worked with the NRC and Department of Energy to establish a more stable foundation for new reactor designs.

The NRC is now able to certify a given nuclear plant design, independent of an application to construct or operate a plant. A design certification is valid for 15 years from the date of issuance but can be renewed for an additional 10 to 15 years. To date, the NRC has certified two designs and is currently reviewing three others.

New nuclear plant designs employ advanced technologies that build upon the operating experience of the existing nuclear fleet. Further, the new designs were developed with a strong emphasis on simplification, aimed at expediting licensing and avoiding the cost and construction overruns that plagued the industry in the late 1970s and 1980s.

Simplification takes advantage of the fact that operational and performance issues will be reduced if there are fewer processes and pieces of equipment to maintain. Some of the newer nuclear plant designs have dramatically reduced the numbers of components and subcomponents included in the design. For example, the Westinghouse AP1000 plant is being designed

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with 50 percent fewer safety-related valves, 80 percent less safety-related piping, 85 percent less control cable, 35 percent fewer pumps, and 45 percent less seismic building volume.

## LOAN GUARANTEES

The large price tags associated with new nuclear plant deployment have raised concerns about the ability of the developers to raise the capital necessary for successful project execution. The extended time gap since the last wave of nuclear construction in the United States, coupled with uncertainty about public acceptance and nuclear waste disposal issues, compel banks and other lending institutions to carefully scrutinize investments in nuclear power plants. The end result is that interest rates on borrowed capital may be higher than they otherwise would be.

To moderate the financial risks and uncertainties involved with building nuclear plants based on new designs, the Energy Policy Act of 2005 authorized two nuclear-related provisions addressing loan guarantees and production tax credits. The loan guarantee provision provides for a federal guarantee on debt that covers up to 80 percent of construction costs.

Currently, only $18.5 billion is authorized for loan guarantees, and they can only be used for any given new design three times. Fifteen companies submitted requests for loan guarantees totaling $93 billion covering 16 reactors. DOE has selected four of these applicants to receive loan guarantees.

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The production tax credit provision authorizes qualified companies to claim an $18 per megawatt-hour tax credit for advanced nuclear plants for the first eight years of operation. The production tax credit has an overall limit of $7.5 billion, which means that only the first five or six units could receive the full benefit; more than that would dilute the value for each plant.

In states where capital cost recovery is determined by public utility commissions and built into electricity rates, some companies already have or are expected to request full recovery, with recovery starting during the construction phase in some cases. In other states, plants will operate as "merchants" and sell their electricity through long-term or even short-term contracts.

## LONG-TERM OPERATIONS

The wave of new nuclear plants will be built on the figurative shoulders of the existing nuclear plants. In other words, new nuclear plants will be successful only to the extent that existing nuclear plants continue running safely and reliably. While the record of these existing plants over the past 30 years has been exemplary, sustained diligence is a must.

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The continued operation of existing nuclear plants also amplifies the value of nuclear energy as a non-carbon-emitting electricity source. Nuclear power plants worldwide represent more than 370 gigawatts of $CO_2$-free generating capacity. Simply replacing an existing nuclear plant with a new nuclear plant will have minimal impact on overall $CO_2$ emissions; to take full advantage of nuclear's contribution to emissions reductions, both new and existing nuclear plants are needed. Therefore, it is in the public interest to ensure that existing plants keep running for a long time.

While many of the nuclear plants in the United States are nearly 40 years old, there is no technical rationale for ceasing operations. In fact, more than half of the operating U.S. plants have demonstrated the technical justification for plant operation beyond initial licensing periods and have received regulatory approval to extend their operating licenses from 40 to 60 years. The rest are expected to pursue license renewal to 60 years as well.

Efforts are currently under way to determine whether these assets can operate even longer, perhaps to 80 years or more. An EPRI survey of senior executives from 23 of the 26 U.S. nuclear operating companies revealed that more than 95 percent of those interviewed had given some or a lot of thought to extended plant operation beyond 60 years, and more than 85 percent felt operation past 60 years was somewhat or very likely. They cited both the solid economics and low-carbon footprint of existing nuclear plants as key factors impacting their responses.


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Decisions for license renewal will go hand-in-hand with capital project decisions for life extension. Decisions must address life-limiting challenges, asset management of critical equipment, and modernization opportunities. Technical barriers include issues such as materials aging, while modernization opportunities include items such as advanced diagnostics that can support continued high-performance operation of nuclear plants worldwide. EPRI and the U.S. Department of Energy have begun conducting the research and development necessary to identify and overcome key technical barriers and to deploy cost-effective cost-modernization approaches that will enable plant owners to establish a sound technical basis for operation beyond 60 years.

## ADDITIONAL CHALLENGES

A few other challenges warrant brief discussion concerning the deployment of new nuclear plants in the United States.

The manufacturing base to support new nuclear plant development and construction will undoubtedly be much more global in scope than was the case with the original wave of nuclear construction in the 1960s, 1970s, and 1980s. Many of the U.S. companies that supplied the equipment and components for existing nuclear plants have exited the nuclear business. The cause is lack of demand. While a number of U.S. companies are pursuing reengagement, the fraction of foreign-supplied components in new nuclear plants will be significant.

While a number of U.S. companies are pursuing reengagement, the fraction of foreign-supplied components in new nuclear plants will be significant. For example, Japan Steel Works is currently the only manufacturer of the ultra-large forgings that are required to construct nuclear plants. So far, nine companies have ordered large-component forgings that require long lead times.

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The increasingly global supply base will demand increased attention to quality control and logistics management. Nuclear plant developers, along with the nuclear steam supply system vendors and the engineering/procurement/construction contractors, will have to implement rigorous procedures to ensure quality is maintained throughout the supply chain, all the way down to the subcomponent level.

Retirement and attrition will create the need to essentially restaff the existing fleet over the next 10 years.

Another challenge concerns human capital. The nuclear workforce is aging. The average age of employees in the industry is about 50 years, and retirement and attrition will create the need to essentially restaff the existing fleet over the next 10 years. While efforts to encourage interest in nuclear-related engineering and craft careers have been initially successful, replacing the knowledge and work experience accumulated by the existing workforce is not an overnight task. Significant effort will be needed to capture institutional knowledge and transfer it to the new generation of workers.

Optimism related to building a new wave of nuclear plants is increasingly justified.

## LEVEL OF CONFIDENCE HIGH

The future is looking brighter for nuclear. Optimism related to building a new wave of nuclear plants is increasingly justified as companies move forward with development plans, while many if not most of the 104 existing nuclear plants in the United States will probably operate well past 60 years due to economic reasons and carbon constraints.

Whether dozens or even hundreds more are built over the next 20 to 30 years will ultimately depend on the construction cost and timeliness of the first several plants.

Given the carbon restrictions in pending climate legislation and the incentives in the 2005 Energy Act, it is increasingly likely that several new nuclear plants will be constructed by 2020. Whether dozens or even hundreds more are built over the next 20 to 30 years will ultimately depend on the construction cost and timeliness of the first several plants and how soon high levels of performance are achieved.

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