Extracted from the *EPRI Journal*, Summer 2006 feature: "Generation Technologies for a Carbon-Constrained World."

NUCLEAR POWER
CHALLENGES AND OPPORTUNITIES

As the most widely deployed carbon-free technology, nuclear power will play a critical role in stabilizing atmospheric CO_2 levels. There are currently about 440 nuclear power plants operating in 31 countries, generating about 17% of the world's electricity. More than two dozen additional reactors are under construction around the world. In the United States, 103 reactors are now operational, almost twice the number operating in any other country. The safety, reliability, and economic performance of the fleet have steadily improved over the past 20 years, making these reactors a valuable asset. Given their performance, the lessons learned and applied to new designs, and the need for emission-free generation of electricity, many U.S. utility companies are looking hard at new nuclear plants as part of their future generating mix. EPRI is supporting nuclear industry activities to begin building new nuclear plants in the United States before the end of this decade.

These activities focus on Generation III+ advanced light water reactors (ALWRs) with standardized designs certified by the U.S. Nuclear Regulatory Commission (NRC) and now available for new orders. Plants based on these new designs have already been constructed on schedule in Japan and South Korea. No major technical hurdles stand in the way of ALWR orders in the United States, and passage of the Energy Policy Act of 2005 has gone a long way toward reducing financing uncertainties. Standardization has helped reduce costs significantly since the previous-generation nuclear plants were built, and the new designs incorporate the latest safety and reliability features—some including passive safety measures—which are based on decades of research.

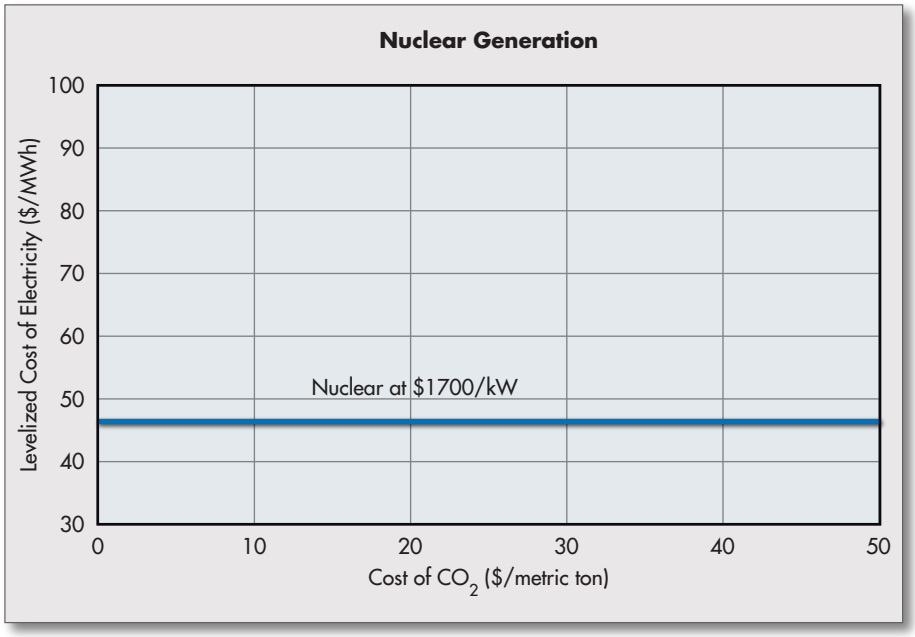
Near-Term Activities

In 2002, to reduce regulatory uncertainty, DOE announced a cost-sharing program —Nuclear Power 2010—to test and demonstrate the new NRC regulatory process, 10CFR Part 52. The new three-part licensing process requires design and siting decisions and other key approvals before construction of a nuclear plant begins. Included in the NP2010 program are projects to complete and submit three Early Site Permit (ESP) applications and a number of combined Construction and Operating License (COL) applications.

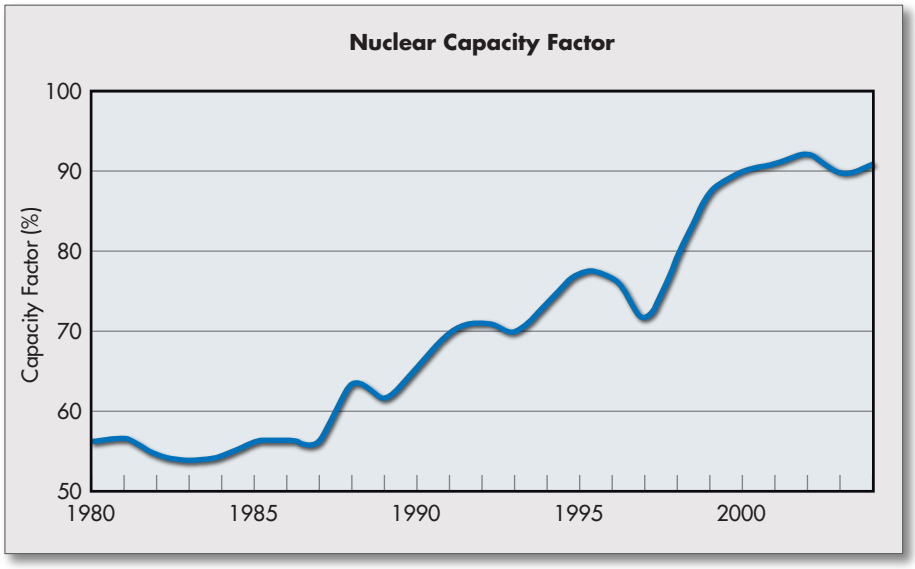
The ESP allows a utility to "bank" an approved site for a 20-year period, and the COL pairs a site with a specific certified design prior to construction. Significant time and cost are associated with application and NRC staff review under this Part 52 process; and the last step—the COL—is unproven and a significant source of uncertainty and business risk.

In addition, NP2010 will fund the first-of-a-kind engineering necessary to reduce the cost premium usually expected in initial construction of plants with new designs. EPRI is providing the industry with R&D support related to detailed engineering and construction of the proposed reactors and is working with the Nuclear Energy Institute on resolving technical issues and standardizing the form and content of licensing submittals.

Meanwhile, renewal of licenses for existing plants continues to make steady progress. In addition to 42 applications completed and 9 under review, the commission has received letters of intent for 27 additional renewal applications to be submitted from July 2006 to early 2015. The total is 78. Consequently, EPRI—working closely with other industry organizations—is currently focused on helping utilities meet the inspection and surveillance commitments required for the granting of 20-year license renewals from the NRC.



Because nuclear generation produces no carbon emissions, its power production costs are not affected by carbon constraints. But no new U.S. nuclear plants have been ordered in over 30 years, and deploying a new fleet of advanced plants carries a number of uncertainties. If the next generation of nuclear plants can be built for $1700–$1800/kW, they will be very cost-competitive.



Nuclear plant performance has improved dramatically since the 1980s, with annual capacity factors for the last five years averaging about 90%. Such operational excellence has made nuclear a low-cost leader in power production.

Mid-Range Concerns

Beyond consideration of new plant construction, a variety of mid-range concerns will have to be resolved if nuclear power is to take its place among the primary non-emitting electricity generation options for the long term. Perhaps foremost among these is resolution of the U.S. high-level nuclear waste issues. Although an operational spent-fuel repository is not a requirement for new plant construction, state and federal governments—as well as potential investors in new reactors—need confidence that a workable and sustainable spent-fuel management scheme can be put in place. Current efforts by DOE and industry leaders are converging on such a sustainable approach, which includes a centralized interim storage of spent fuel in the very near term, continued progress toward licensing and construction of a permanent spent-fuel repository at Yucca Mountain, Nevada, and ultimate deployment of a proliferation-resistant closed fuel cycle. The first step, centralized interim storage, while not a condition of new plant construction, would clearly erase a major impediment.

A major financial concern had been renewal of the Price-Anderson Act, which provides for the nuclear industry's self-funded liability insurance. The provisions of this legislation are considered by many executives to be a prerequisite for new nuclear plant orders. The recent passage and signing of the Energy Policy Act of 2005 provided for continuation of these critical self-insurance provisions.

Because of the long gap in nuclear plant construction in the United States, domestic component fabrication and manufacturing capability has declined. In addition, competition will be stiff among construction industries for qualified workers to build new plants, particularly nuclear-qualified welders and inspectors. The addition of significant nuclear capacity will also create demand for more reactor operators and maintenance staff, as well as for nuclear engineers, particularly since many experienced personnel currently in the workforce will be retiring in the next few years. To prepare for these needs, utilities, vendors, industry associations, and the government have focused in recent years on replacement staff education and training, for both engineers and technicians, and progress is evident.

Assuming that these and more immediate licensing concerns can be adequately addressed, COL applications are likely to come in the 2007–2008 timeframe, with actual plant orders following in 2008–2010. Currently there are four new reactor designs certified by the NRC: the Westinghouse System 80+, the General Electric Advanced Boiling Water Reactor, the Westinghouse AP600, and—most recently certified—the Westinghouse AP1000. Two others—General Electric's Economic Simplified Boiling Water Reactor (ESBWR) and Areva's U.S. Evolutionary Pressurized Water Reactor (USEPR)—are now undergoing the certification process. All six of the ALWR designs currently certified or in the certification process already meet or are addressing the comprehensive set of design specifications that are put forth in the EPRI Utility Requirements Document.

Long-Term Opportunities

The nuclear industry is working to add significant new capacity in the United States by about 2020; a recent EPRI study concludes that this will be possible if gas prices remain above about $4.75/MMBtu or if the capital costs of new nuclear plants can be reduced by 10%. Most of the new capacity is expected to come from Generation III+ reactors, especially from ALWR designs optimized to offer enhanced economics for near-term deployment. For the longer term, however, a new group of nuclear technologies, Generation IV, is being pursued by government entities with hopes of addressing new missions and long-term sustainability. Generation IV technology would be deployed between 2020 and 2030.

Development of this next generation of nuclear systems is being approached through an international R&D program involving ten individual countries plus the European Atomic Energy Community. Work so far has identified a number of promising technologies, and research continues through DOE, U.S. national laboratories, and private companies. One technology of particular interest is the very-high-temperature reactor (VHTR)—a helium-cooled reactor that would operate at around 900–1000°C and would have the ability to produce hydrogen.