THE RENAISSANCE OF NUCLEAR ENERGY

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The Calvert Cliffs nuclear plant in Maryland seen from the Chesapeake Bay.

Nuclear power renewal promises to energize electricity generation worldwide and help address concerns about greenhouse gas emissions, despite remaining challenges. In the long term, nuclear energy could become safer and more economical, proliferation resistant, and sustainable.

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The strong economic and safety performance of nuclear power in the United States, the growing demand for energy, and the increasing awareness of the environmental benefits of clean nuclear power form the foundation for a nuclear energy renaissance that can support U.S. energy security, economic prosperity, and environmental quality goals in the 21st century. However, before such a renaissance can become a reality, policy makers must respond to major challenges in such areas as the relatively high capital costs of new plants, sustainable management of used nuclear fuel, and the risks of proliferation of weapons-grade plutonium from the nuclear power fuel cycle.

Nuclear Power Development in the United States

Nuclear power in the United States was born in the 1950s and 1960s to unreasonable and, as it turned out, unachievable expectations of being so inexpensive that it

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was “too cheap to meter.” As the first nuclear power plants were built and operated, they began to experience difficulties with rising construction costs and with safety performance, culminating in the accident at the Three Mile Island Unit II plant near Middletown, Pennsylvania, in 1979. The subsequent corrective actions put in place by the U.S. Nuclear Regulatory Commission (NRC) to assure safe operations delayed for many years completion of plants under construction during a time of double-digit inflation and caused several of these plants to go bankrupt and be cancelled, thus ending the first era of U.S. nuclear power.

Throughout the 1980s, the nuclear electric utilities completed many of the remaining plants, brought them on line, and devoted their attention to improving cost effectiveness and operations performance, which simultaneously improved safety. By the mid-to-late 1990s, the 103 nuclear power plants in the United States were producing 20 percent of America’s electricity at a cost that made them highly competitive with those fired by coal and other fuels—less than 2 cents per kilowatt-hour. Furthermore, their safety performance has improved by more than a factor of 10, to a point where nuclear power is a leader in industrial safety performance today. By the end of the 1990s, with rising energy prices and major blackouts in California, U.S. business interest in nuclear power turned up. Several large utilities, such as Exelon and Entergy, bought nuclear power assets from smaller, less profitable utilities as the business environment for nuclear power began to improve.

Today, more than half of currently operating U.S. nuclear power plants have sought and received 20-year extensions to their original 40-year licenses. The industry fully expects all U.S. plants to apply for these extensions as their original license periods expire. Such extensions would ensure that these large capital assets continue to produce electricity while Americans continue to enjoy their financial and environmental benefits.

As we close out the second era of nuclear power, the era of financial and safety recovery, nuclear power is poised to contribute even more to U.S. and world energy needs. This recovery will be fueled in part by growing national energy security concerns and the rising costs of imported fossil fuels; substantial demand growth for energy to fuel our economic prosperity; increased attention to eliminating environmental threats associated with burning fossil fuels and substituting emissions-free nuclear power; and an electricity market very favorable to inexpensive nuclear power.

Public trust in the operation of nuclear power plants has steadily improved with better understanding of the economic and environmental benefits and with improved safety performance. Some polls show that 70 percent of Americans favor continued operation of the existing plants, and more than 50 percent support building new plants.

Today, 440 nuclear power plants generate 16 percent of the world’s electricity needs. Aggressive new nuclear plant construction programs have begun, particularly in East Asian countries, Russia, and India. The United States itself is on the verge of resuming construction of new nuclear power plants, a process that has been dormant for more than 25 years. This is the beginning of the third era, the renaissance of nuclear energy.

To fulfill robust expectations, nuclear power needs to meet four principal challenges:

- First, nuclear power must remain economically competitive in the world energy market; in particular, energy companies must better control capital costs.
- Second, in order to satisfy the public’s expectations of exceptional safety performance, current plants must continue to operate safely and future plants must continuously improve safety in expanding world markets.
- Third, nuclear power and its fuel cycle must be viewed by the public and by national leaders as sustainable; in particular, used nuclear fuel must be managed in a manner that is cost effective and safe for the extended period of time that used fuel remains highly radioactive, and the nuclear fuel supply must be extended for centuries in the face of depleting fossil fuels.
- Fourth, the nuclear materials from the fuel cycle must be protected from proliferation and misuse for non-peaceful purposes.

AP/Wide World Photo

Tests are run on the advanced test nuclear reactor at Idaho National Laboratory.

A New Direction for U.S. Nuclear Power

In 2001, the U.S. government issued a new National Energy Policy (NEP) that set the nation on a course to expand the use of nuclear energy in the near term by making more efficient the processes of obtaining extensions of licenses to operate existing nuclear plants and of obtaining licenses to build new nuclear facilities. The NEP further sought to encourage nuclear energy use through the development, demonstration, and deployment of next-generation nuclear power technologies. Importantly, it aimed at achieving this goal through research and development of advanced fuel cycles that might prove to be cleaner, more efficient, less waste intensive, and more proliferation resistant than a single-use nuclear fuel, which requires geologic disposal of the used fuel.

Several programs were put in place to implement the NEP, including:

- the Nuclear Power 2010 program to encourage the near-term construction of new nuclear power plants;
- the Generation IV program to develop next-generation reactors that are more economical, safer, more sustainable, and more resistant to proliferation of weapons-grade plutonium;
- the Advanced Fuel Cycle Initiative to investigate advanced reprocessing and recycle strategies for used nuclear fuel that extract substantially more energy from uranium resources by burning up long-lived constituents in used nuclear fuel in a manner that does not separate plutonium. Such technologies promise to reduce the amount of used fuel, potentially extending the life of the planned Yucca Mountain geologic repository for spent nuclear fuel and radioactive waste.

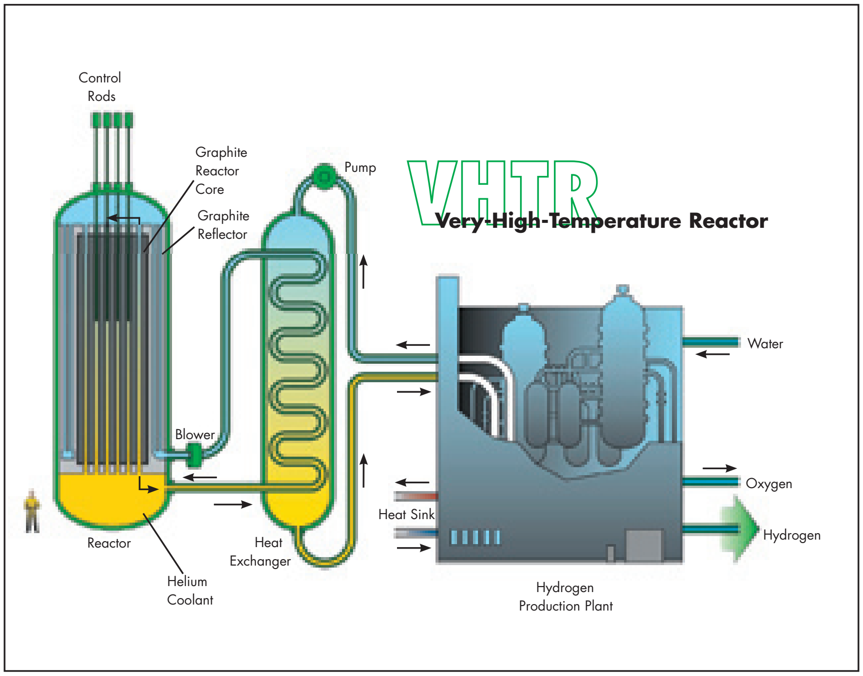
On August 8, 2005, President George W. Bush signed into law the Energy Policy Act of 2005, which authorizes long-term budgets for these programs, including loan guarantees, production tax credits, and protection for private sector investment in the construction of the first few new nuclear power plants. (These plants face risks associated with the new licensing process and with reestablishment of the U.S. design and construction infrastructure.) The act further provides funding authorization for long-term nuclear energy research and development programs, including the Generation IV advanced reactor development program and the Advanced Fuel Cycle Initiative, which together have grown into the Global Nuclear Energy Partnership (GNEP).

Nuclear Power 2010: The focus of the Nuclear Power 2010 program is on testing and validating a new NRC licensing process based on certification of the safety of the reactor system design, issuing a permint for the proposed reactor site, and issuing a combined license for construction and operation of a certified reactor design on a permitted power plant site.

Four advanced reactor designs developed by Westinghouse and General Electric have already received NRC certification, and another six are still in review, with at least two of these expected to be certified by 2008 to 2010. Early site permit applications were submitted by three groups for at least six potential new plant sites and are under review. Finally, 12 utilities have notified the NRC of their plans to seek construction and operating licenses for as many as 23 new reactors. It is expected that the first formal nuclear power plant orders will be placed by late 2007 or early 2008.

Generation IV and the next-generation nuclear plant: The Generation IV advanced reactor roadmap was developed by more than 100 international nuclear experts to evaluate and prioritize six next-generation reactor technologies that have strong potential to be more economical, safer, more sustainable, and more proliferation resistant than existing technologies. The very-high-temperature gas-cooled reactor and the sodium-cooled fast reactor have emerged as the priority technologies for international development and demonstration.

The next-generation nuclear plant is based on a gas-cooled technology that can operate at temperatures of 850 to 950 degrees Celsius with greatly improved thermal efficiency for electricity production, but notably in a tem-



Courtesy of Idaho National Laboratory

Diagram of a very-high-temperature reactor.

perature range that may enable high-efficiency production of hydrogen. High-efficiency, emissions-free production of hydrogen is a critical element of President Bush's efforts to displace increasingly expensive imported oil with hydrogen as a domestic transportation fuel—initially to enrich heavy domestic crude oil, but subsequently to produce synthetic transportation fuels, and, ultimately, to power fuel cell vehicles. It is important, therefore, that the next-generation nuclear plant can not only generate electricity but also produce hydrogen for the transportation sector and heat for industrial processes, the areas in which the heavy U.S. dependence on imported oil is a threat to our economic prosperity.

The Advanced Fuel Cycle Initiative and the GNEP: The GNEP was announced by President Bush in early 2006. It is intended to substantially accelerate the U.S. advanced-fuel-cycle and fast-reactor technology development efforts. The goals of the program are these:

- to reduce the burden related to geologic disposal of used nuclear fuel in terms of waste volume, heat load (as the radioactive fuel decays, it gives off huge amounts of thermal energy), radiotoxicity (levels of radiation that become toxic to living cells or tissue), and number of repositories that will be needed in the 21st century;
- to recover the substantial energy value contained in used nuclear fuel;
- to increase the proliferation resistance of used nuclear fuel recycle processes.

In order to meet these goals, three technologies will be developed and demonstrated. They are (1) the transmutation of the materials in used nuclear fuel in a new generation of sodium-cooled fast-spectrum advanced burner reactors to extract their energy value and to render the ultimate nuclear wastes more manageable with a single repository; (2) the separation of the elements of used nuclear fuel coming from the fleet of water-cooled reactors into uranium, reusable fuel components, and fission product wastes using a uranium extraction process called UREX+ that does not separate weapons-usable plutonium; and (3) the development and demonstration of fuel-recycle and fuel-fabrication technologies for the advanced burner reactors.

Outlook

We stand at the verge of a renaissance of nuclear energy, founded in the continued safe and economical operation of America's 103 nuclear power plants and signaled by the expected near-term announcements of several orders for new nuclear power plants to be constructed and operated in the next 10 years. In the longer term, our national laboratories are working with the nation's universities, U.S. industry, and the international community to develop the next generation of advanced nuclear power systems, which will be even more economical, safer, and sustainable with a closed fuel cycle that burns up substantially more of the nuclear fuel to extract much more of its energy potential while minimizing the quantities of nuclear waste. Nuclear power has an important place in America's energy future, safely providing electricity and transportation fuel products that are economical, clean, and sustainable. ■

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CONDITIONS SHIFT IN FAVOR OF NUCLEAR POWER

Andrew Paterson

The dramatic recovery of interest in nuclear energy is likely to lead, in 10 years or so, to construction of the first nuclear power units in the United States in 25 years. Expectations for the economic viability of new nuclear power projects are rising due to several factors.

Competitive production costs and reliability: In the United States, nuclear power production costs at existing plants are a bit below those of coal-fired plants and roughly one-third of gas-fired plants, according to the Utility Data Institute private directories and data bases. However, this is because the capital equipment costs for the 103 U.S. reactors are now fully recovered by their owners. Uranium fuel prices—below half a cent a kilowatt-hour (kWh)—though rising recently, have been more stable and much lower than gas prices. Moreover, uranium fuel comes from stable allies Canada and Australia, not volatile supply sources in the Middle East. And recycling Russian warhead material from the Cold War actually provides half our fuel. Lastly, nuclear plants run continuously, regardless of weather, making them the most reliable source of large-scale electricity.

Potential for lowering construction costs: Nuclear power plants have the highest construction costs in the large-scale power generation sector. In recent years, however, an international market for nuclear reactors has emerged. U.S. plant owners are developing alliances to provide a string of orders on standardized designs certified by the U.S. Nuclear Regulatory Commission (NRC) that should bring down single-unit prices. By teaming up, utilities provide reactor vendors and engineering firms with a 20-year sales curve, allowing them to efficiently staff up and order large components. With multiple orders, the capital costs of new units can be brought down to around $1,200 to $1,500 per kilowatt-electric (kWe) from roughly $2,000 to $2,300 per kWe for first units. By comparison, capital costs for coal-fired plants are around $1,300 to $1,500 per kWe (depending on whether they combust or gasify the coal), and those of gas-fired plants are around $600 per kWe.

Predictable licensing: The NRC has redefined the licensing process for nuclear power plants—perceived by the industry as a "showstopper"—making it more predictable without compromising on safety. The NRC reforms will be tested in the near future with government help, under the Energy Department's Nuclear Power 2010 program. Unlike the "greenfield" plants of the 1970s, however, the first new reactors will be added to current nuclear sites where infrastructure is already in place and communities support them, primarily in the Southeast.

Advanced plant design and experience: Instead of varying designs, the NRC is now certifying only a few reactor designs. And, more important, plant design and production are now much more advanced than they were 25 to 30 years ago, when the last U.S. reactors were ordered—before automated computer-aided design/computer-aided manufacturing (CAD/CAM) was available. Thousands more hours of experience worldwide since 1980 have strengthened the design and engineering process.

Government financing: Government support for the first few new reactors—in the form of loan guarantees, production tax credits, and federal risk insurance for commissioning delays—monetizes the emissions savings of nuclear power and will help the industry address regulatory uncertainties beyond their control. Interest rates are also significantly lower than in the late 1970s (a prime rate at 5 to 6 percent now versus 15 percent then). More reactors were cancelled because of high interest rates than as a result of the accident at Three Mile Island in March 1979.

Nuclear vs. natural gas: In the 1990s, after passage of the Clean Air Act, relatively cheap natural gas emerged as the most popular clean alternative. The capital costs of nuclear power—which can be three times higher than those of gas plants—and other factors, such as the four- to six-year construction cycle, made nuclear power unattractive to investors and utilities. But gas prices have risen dramatically since then and remain volatile. A 2001 study by the Electric Power Research Institute projected that new nuclear capacity could be economically viable if natural gas prices stayed above $5 per million British thermal units (BTU). In fact, prices are trading between $8 and $12 per million BTU for December 2006 delivery. ■

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