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The Nuclear Energy Futures Project

The US Nuclear Industry: Current Status and Prospects under the Obama Administration

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Abstract

Expectations of a nuclear energy renaissance are particularly high in the United States, which hasn't had a new reactor order in 30 years. Government programs to jump-start new reactor construction have contributed to the optimism, but these are not likely enough to spark more than a handful of reactors by 2015. Aggressive government support would be needed, including subsidies, a carbon pricing mechanism, and an acceptable waste management solution. This paper discusses the history, current status and prospects for US nuclear power under the Obama administration.

Canadian Centre for Treaty Compliance

CIGI's Nuclear Energy Futures Project is being conducted in partnership with the Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa.

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Letter from the Executive Director

On behalf of The Centre for International Governance Innovation (CIGI), it is my pleasure to introduce the Nuclear Energy Futures Papers Series. CIGI is a non-partisan think tank that addresses international governance challenges and provides informed advice to decision makers on multilateral governance issues. CIGI supports research initiatives by recognized experts and promising academics; forms networks that link world-class minds across disciplines; informs and shapes dialogue among scholars, opinion leaders, key policy makers and the concerned public; and builds capacity by supporting excellence in policy-related scholarship.

CIGI's Nuclear Energy Futures Project is chaired by CIGI distinguished fellow Louise Fréchette and directed by CIGI Senior Fellow Trevor Findlay, Director of the Canadian Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa. The project is researching the scope of the purported nuclear energy revival around the globe over the coming two decades and its implications for nuclear safety, security and nonproliferation. A major report to be published in 2009 will advance recommendations for strengthening global governance in the nuclear field for consideration by Canada and the international community. This series of papers presents research commissioned by the project from experts in nuclear energy or nuclear global governance. The resulting research will be used as intellectual ballast for the project report.

We encourage your analysis and commentary and welcome your thoughts. Please visit us online at www.cigionline.org to learn more about the Nuclear Energy Futures Project and CIGI's other research programs.

John English
Executive Director

List of Acronyms

ABWR	Advanced Boiling Water Reactor
AEA	Atomic Energy Act of 1954 (as amended)
AEC	Atomic Energy Commission
AP-1000	Westinghouse's Gen III+ reactor (pressurized water reactor)
APWR	Advanced Pressurized Water Reactor
ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
COL	Combined Construction and Operating License
DoE	Department of Energy
EPACT	Energy Policy Act of 2005
EPC	Engineering, Procurement and Construction
EPR	European Pressurized Reactor, AREVA design
ERDA	Energy Research and Development Administration
ESBWR	Economic Simplified Boiling Water Reactor, GE design
GE	General Electric
GEN IV	Generation IV reactors
GNEP	Global Nuclear Energy Partnership
GWe	Gigawatt, electric
IGCC	Integrated gasification combined cycle
JSW	Japan Steel Works
MWe	Megawatt, electric
NAS	National Academy of Sciences
NEPDG	National Energy Policy Development Group
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, 1982
O&M	Operation and maintenance
PWR	Pressurized Water Reactor
SWU	Separative Work Unit
USEC	U.S. Enrichment Corporation

Introduction

By many accounts, the United States is primed for a "nuclear renaissance" – a rebirth of nuclear energy. The US once pursued nuclear energy vigorously, building and operating one quarter of the world's nuclear power reactors. Americans promoted the peaceful use of nuclear energy widely overseas, building research and power reactors across the globe as part of the 1953 Atoms for Peace program. Far from meeting Atomic Energy Commission (AEC) Chairman Lewis Strauss' prediction in the 1950s that nuclear power would become "too cheap to meter," nuclear power in the United States suffered a precipitous decline by the mid-1970s. No new power reactors have been ordered in the US in over 30 years.

The common perception that nuclear power declined solely because of the 1979 accident at Three Mile Island is wrong, although public opposition grew significantly thereafter. Years of significant cost overruns in reactor construction, which predated the Three Mile Island accident, and safety concerns were already tempering enthusiasm for nuclear power. The largest municipal debt default in the history of the United States – the US$2.25 billion bond default in Washington State for four new reactors – was complicated by public opposition, but not created by it. The falling price of oil in the 1990s also provided incentives to build new gas-fired capacity instead of nuclear power plants.

Nonetheless, existing nuclear power reactors play an important role in US electricity production. The 104 operating reactors generate 19 percent of the American electricity supply, although they comprise just 14 percent of generation capacity. In other words, nuclear plants have achieved high operating levels. Although the lifetime capacity of American reactors since 1973 averages 76 percent, this rate has been climbing significantly; the average annual operating capacity reached 90.1 percent in 2008. Over their lifetimes, the majority of the US power reactors have produced electricity in the range of 3 to 8 cents per kilowatt-hour (kWh) (Hultman, Koomey and Kammen, 2007). This was possible in part because the costs associated with moving from regulated to deregulated electricity markets could be written off as stranded costs. In other words, many of the expensive capital costs associated with nuclear power were taken off the books of the utilities so they could operate cost-effectively.

Utilities in the United States thus have a strong incentive to keep nuclear power plants operating. With an average age of 29 years, however, many reactors will soon require extensions of their 40-year operating licences (Schneider, 2009). Half of US reactors have received 20-year licence extensions and 19 are under consideration for the same. Licences for virtually all reactors are expected to be extended. A current debate in the industry is whether reactor lives can or should be extended to 80 years.

Future American nuclear reactors, however, are unlikely to be cost-effective until their construction costs can be written off. Cost estimates for new reactors range from 7 cents to 17 cents per kWh, depending on varied assumptions about the cost of capital. Since capital costs explain over 90 percent of variances in total lifetime levelized costs of US nuclear power plants, the uncertainties are magnified. (Hultman, Koomey and Kammen, 2007). Moody's, a private credit-rating service, stated in an October 2007 special report that "the ultimate costs associated with building new nuclear generation do not exist today – and that the current cost estimates represent best estimates, which are subject to change" (Moody's, 2007). In the year following that report, commodity prices escalated considerably and the global financial crisis erupted.

Despite great uncertainty about the cost of nuclear reactors, hope for a nuclear energy revival in the United States persists for several reasons. Streamlined regulations, which require about 90 percent completion of engineering before construction begins, could reduce regulatory delays

Author Biography

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(Hultman and Koomey, 2007). The federal government has implemented programs to help new generations (Generations III+ and IV) of nuclear power plants get underway, including the 2002 Nuclear Power 2010 program and the Advanced Energy Initiative in 2006. Perhaps most important, the 2005 Energy Policy Act contained several incentives for the first six new nuclear power plants, including loan guarantees, delay insurance, production tax credits and limited liability.

Not even industry promoters, however, suggest that it is clear sailing for nuclear energy in the United States. They predict that four to eight new reactors might come online by 2015, given loan guarantees, but the current level of loan guarantees may only support two to three reactors. More than a handful of new nuclear reactors would require additional support, especially a price on carbon that could make nuclear energy more competitive with electricity generation alternatives, including coal and natural gas.

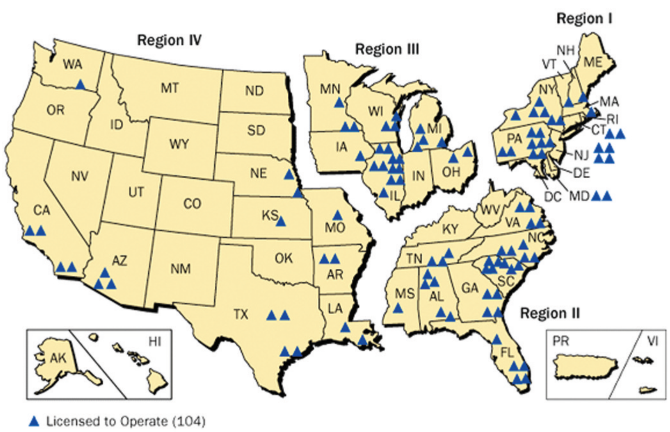
Can stakeholders in this potential next round of nuclear power plant construction overcome the challenges of the past? Will this be a rebirth or merely resuscitation? In part, the outcome depends on whether the vendors, utilities and government (local, state and federal) entities can adjust to new realities, including a short-term tightening of credit markets.

Nuclear Energy in the United States: The Golden Past

Civilian nuclear power in the United States owes its existence to the nuclear weapons program. In the beginning, the two were tightly entwined, particularly because the 1946 AEC had responsibility for both nuclear weapons and promoting and regulating nuclear power. Two military-sponsored power reactors – the US Army's SM-1 reactors and the US Navy's Shippingport reactor – first delivered electricity to a light bulb in 1957, more than a decade after the first successful atomic weapon tests. With the passage of the Atomic Energy Act (AEA) of 1954, tight military control over fissile material and technology began to loosen.

The AEA made commercial nuclear energy possible in the United States. The two major reactor vendors, General Electric (GE) and Westinghouse, leveraged their military nuclear contracts with the US Navy to build civilian nuclear power businesses. But it was not until GE introduced the "turnkey" contract, which entailed fully constructed power plants at a fixed price, that construction began in earnest in the mid-1960s. By 1967, American utilities had ordered more than 50 power reactors and, in the next seven years, they placed an additional 196 orders (IAEA, 2004). By 1973, 40 units were operating. These first and second generation reactors were built primarily by Westinghouse and GE, whose pressurized water (PWR) and boiling water (BWR) designs, respectively, were adopted worldwide. Two-thirds (69) of US reactors are PWRs, and the remaining (35) are BWRs. Figure 1 shows the location of operating nuclear power plants in 2009. Fixed price, turnkey contracts made these reactors competitive, but virtually all turnkey plants lost money for their manufacturers.

Figure 1: Operating Nuclear Power Plants in the United States, 2009



Source: Map of the United States Showing Locations of Operating Nuclear Power Reactors United States Nuclear Regulatory Commission, October 2008

Along with construction of nuclear power plants, the AEC also encouraged spent fuel reprocessing, beginning in 1956. In the early years of civilian nuclear power, experts worried about potential scarcity in the supply of uranium. Breeder reactors could be the path to circumvent such scarcity, since they can be configured to produce more plutonium than they burn. In 1959, the Davison Chemical Company (later Nuclear Fuel Services), began discussing commercial reprocessing with the AEC. A few years later, the AEC-sponsored Experimental Breeder Reactor at the Argonne National Laboratory was brought online. In 1966, the AEC granted a licence to Nuclear Fuel Services (NFS) to operate a commercial reprocessing plant at West Valley, New York. The plant reprocessed both defence-related material and commercial spent fuel from 1966 to 1972. A temporary shutdown to expand capacity and retrofit for new regulatory requirements became a four-year shutdown from which the facility never recovered. Eventually, NFS abandoned the plant to the lessor, the

State of New York. Legislation in 1980 committed the federal government to take on 90 percent of the cleanup costs. More than US$2 billion has been spent, but the job is still not complete.

Two other reprocessing plants were under construction at that time: GE's US$64 million commercial reprocessing plant in Morris, Illinois, and Allied-General Nuclear Services' plant in Barnwell, South Carolina. Declared inoperable in 1974, the GE plant eventually stored spent fuel; the Allied-General plant was neither complete nor ready for licensing when the Carter Administration decided in 1977 not to encourage reprocessing and recycling, even domestically, because of proliferation concerns. By the time the Reagan administration reversed that decision in 1981, Allied-General decided the Barnwell project was commercially unviable.

In the early 1970s, both reprocessing and nuclear power reactors came under criticism for safety and cost reasons. Critics of the AEC argued that its regulation was "insufficiently rigorous in several important areas, including radiation protection standards, reactor safety, plant siting, and environmental protection" (NRC, 2009). A few changes helped tighten the regulations. First, the Energy Reorganization Act of 1974 abolished the AEC and split its functions between two agencies: the Energy Research and Development Administration (ERDA, now the Department of Energy) and the Nuclear Regulatory Commission (NRC). ERDA was given responsibility for developing and producing nuclear weapons, promoting nuclear power and other energy-related work. The NRC was assigned responsibility for regulating civilian power and research reactors, with a primary focus on protecting public health and safety by regulating materials, reactor safety and radiation protection.

Second, the growth of environmentalism and public interest groups in the United States focused public attention on the regulatory process. The National Environmental Policy Act was signed into law in 1969, creating the Environmental Protection Agency, the Council on Environmental Quality and new requirements for environmental impact statements. The first Earth Day followed in April 1970. More than half the challenges to almost 100 construction permits for nuclear power plants between 1962 and 1971 came from environmentalists concerned about the impact of waste heat from power plants on the local waterways. Public Citizen founder Ralph Nader created the Critical Mass Energy Program (which reportedly had 200,000 members) in 1974 and lobbied against nuclear power.

The Denouement

The changed licensing environment began to have an effect on new reactor orders by 1975. More than 100 reactor orders were cancelled, including all those ordered after 1973. More importantly, however, cost overruns became more transparent and egregious, sometimes ten times above industry estimates. The most prominent example is the Shoreham, New York plant. Estimated to cost US$350 million in 1967 when construction began, the final cost when it was completed in 1986 was US$5.4 billion. The Shoreham plant never produced electricity.

The Congressional Budget Office's 2008 study on the role of nuclear power in generating electricity compared US utilities' projections of average overnight costs with actual overnight costs (this excludes financing costs) of 75 reactors built between 1966 and 1977. The average overrun was 207 percent.[1] For the 40 plants constructed after Three Mile Island in 1979, cost overruns exceeded 250 percent (Congressional Budget Office, 2008).

Some of the factors contributing to cost overruns for first and second generation nuclear power plants included:

- the need to respond to regulatory changes as safety concerns were uncovered, particularly in the wake of Three Mile Island;
- incomplete designs, released too early to engineering, procurement and construction contracts which then had to be modified during construction;
- slowdowns by utilities because high finance costs and falling demand made it very difficult to borrow money to build plants no longer needed by the original dates; and
- cost-plus construction contracts (Maloney, 2009).[2]

In the early licensing scheme, less than 50 percent of the engineering designs were generally completed before construction, requiring field engineering and backfitting based on operating experience in other plants (Hultman and Koomey, 2007: 5,638). Figure 2 shows the distribution of costs (in 2004 US dollars) for 99 US reactors from 1970 to 2005, using a 6 percent discount rate.

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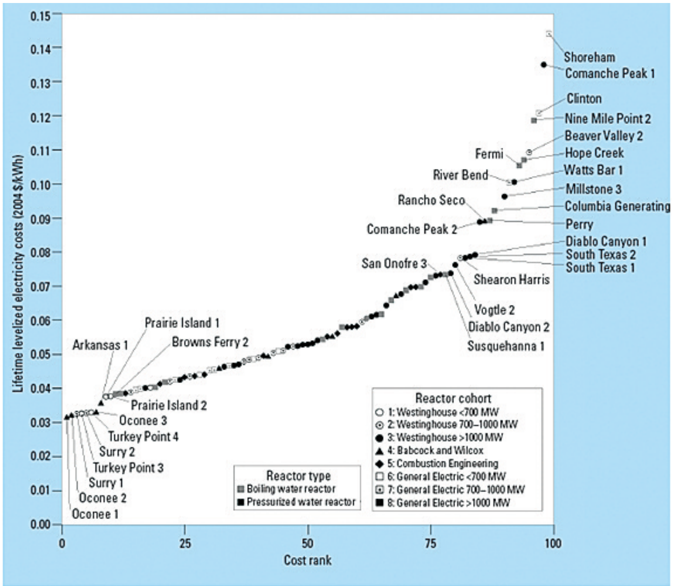
1 Overnight costs are what the reactor construction would cost if it could be done overnight – that is, without escalation of commodity prices (inflation), financing or ownership costs. Overnight plus finance and ownership costs equal what are called "all-in" costs. To get busbar costs, or cost per kilowatt hour of producing electricity, one would add operation and maintenance, fuel, waste disposal and decommissioning costs.

2 A cost-plus construction contract would include the cost of construction plus a fee (which could include profits and overhead).

Figure 2: Distribution of Levelized Costs for 99 US Reactors



Source: Hultman, Koomey and Kammen (2007: 2,090)

The structure of the utilities and electricity markets in the United States also began to shift during this time. The 1978 Public Utilities Regulatory Policies Act initiated the creation of an unregulated, wholesale electricity market. About half of all states have begun deregulating their electricity markets. The Energy Policy Act of 1992 further encouraged competition. Deregulation, or restructuring, affected investors' assurances of rates of returns on investments. By the 1990s, many state public utility commissions provided for recovery of stranded costs – investment costs deemed unrecoverable in a newly competitive market. Many nuclear power plants subsequently benefited from this windfall.

A final facet of the denouement of civilian nuclear power, according to some observers, was the withdrawal of government support in 1976 for closing the nuclear fuel cycle – that is, for spent fuel reprocessing. No US allies interested in pursuing reprocessing and closed fuel cycles, like Japan and France, would do so without significant government support, and many believed the US assured its fall from world nuclear leadership by closing off this option. President Carter announced in early 1977 that the federal government would halt any funding for completing the commercial reprocessing plant at Barnwell, effectively sealing its fate. By 1985, popular magazines such as *Fortune* and *Time* had pronounced the death of nuclear power in the United States; *Forbes magazine* called it "the largest managerial disaster in history." The US$2.25 billion municipal bond default of the Washington Public Power Supply System (WPPSS) plants in 1983 certainly contributed to that popular sentiment, only to be reinforced by the closing of the Shoreham plant – fully constructed, never operated – in 1989 at a cost of more than US$5 billion.

Relaunching Nuclear Energy

In 2001, the National Energy Policy Development Group (NEPDG), chaired by Vice President Dick Cheney, recommended that President Bush "support the expansion of nuclear energy in the United States as a major component of our national energy policy" (NEPDG, 2001). Specifically, the group recommended that the US "reexamine its policies to allow for research, development and deployment of fuel conditioning methods…that reduce waste streams and enhance proliferation resistance. In doing so, the United States will continue to discourage the accumulation of separated plutonium worldwide." The group also recommended that the United States consider technologies in collaboration with international partners.

The Bush administration advocated nuclear energy both for its contributions to energy security and its ability to generate carbon-free electricity. For example, the February 2006 Advanced Energy Initiative advocated safe, clean nuclear energy to help reduce American dependence on foreign sources of energy (National Economic Council, 2006). Its report highlighted nuclear power's "domestic" characteristics and its contribution to energy security (National Economic Council, 2006: 11). Later, the Bush Administration extolled nuclear energy's climate change virtues. In a speech on April 16, 2008, President Bush described the right and wrong ways to approach climate change legislation:

> The wrong way is to jeopardize our energy and economic security by abandoning nuclear power and our nation's huge reserves of coal. The right way is to promote more emission-free nuclear power (Bush, 2008).

Most importantly, however, the Bush administration created several programs to help jump-start the US nuclear industry.

Nuclear Power 2010

The Department of Energy (DoE) initiated a joint government/industry program in 2002 called "Nuclear Power 2010" (NP 2010) to help facilitate the construction of new nuclear reactors in the United States. Under NP 2010, the DoE pays up to half of industry's costs of seeking regulatory approval for new reactor sites, applying for licenses and preparing detailed plant designs. Specifically, this includes obtaining early site permits and design certifications; ensuring complete applications for combined construction and operating licenses; adding specificity to inspection, testing, analysis, and acceptance criteria (ITAAC); and estimating costs and evaluating the business cases for new nuclear reactors. Under NP 2010, DoE and the industry also conducted an infrastructure assessment.

DoE began to award funding in 2004, and the total cost of the program was expected to be about US$550 million. Two consortia have received assistance in preparing combined Construction and Operating Licenses (COLs) under NP 2010: Dominion Resources for the GE Economic Simplified Boiling Water Reactor (ESBWR) at North Anna, and NuStart, which has applied for a COL for two Advanced Pressure Water Reactors (APWR, AP-1000) at Bellefonte and an ESBWR at Grand Gulf (which was suspended in early 2009).

In the 2008 fiscal year (FY), about US$134 million was appropriated and about US$ 280 million more will be spent to wrap up the program through 2010. The anticipated activities for FY2009 included resolving design issues with the NRC related to COLs, Safety Evaluation Reports and Final Environmental Impact Statements; continuing first-of-a-kind engineering details and specifications to enhance standardization of components, accelerating design finalizations so that utilities can issue fabrication contracts, and resolving design issues with the NRC related to the AP-1000 and ESBWR (Black, 2008). A 2008 study of DoE nuclear energy-related research and development (R&D) by the National Academy of Sciences recommended the DoE focus on the short-term objectives of NP 2010, rather than some of the far-reaching objectives of closing the fuel cycle and commercializing fast reactors.

Nuclear Energy Research and Development

The Bush administration tripled the DoE's R&D budget for nuclear energy from 2001 to 2009 (Gallagher, 2008). By contrast, DoE R&D for renewables doubled in that time period, while R&D for fossil fuels declined (Gaffigan, 2008). In FY2008, appropriations in nuclear energy R & D totaled about US$1 billion; the expected request for FY2009 was US$1.4 billion. R&D programs within the DoE to support nuclear energy include the Generation IV (Gen IV) program, the Nuclear Hydrogen Initiative Program (NHI), and the Advanced Fuel Cycle Initiative (AFCI). Gen IV funding increased from US$113 million in FY2008, to US$179 million in the FY2009 Omnibus Appropriations Act (Public Law 111-8, signed March 11, 2009) to US$ 220 million in FY10 appropriations. NHI was funded at US$10 million in FY2008, which declined to US$8 million in FY2009 and was terminated for 2010. AFCI was funded at US$179 million in FY2008, declining to US$145 million in FY2009 and limited to research and development (Congressional Record, 2009: H1953).

The goal behind Gen IV is to lead a global partnership in R&D to develop the next generation of safe, secure, sustainable and economic reactors. From 2002 to 2005, a main focus of Gen IV was the Next Generation Nuclear Plant, which would supply electricity, and produce hydrogen and high-temperature process heat. Beginning with six technologies identified in the Gen IV roadmap in 2002, DoE's focus has narrowed to two: sodium-cooled fast reactors for near-term demonstration of advanced fuel cycles, and the very-high temperature thermal reactors for process heat.[3] A National Academy of Sciences study (National Academy of Sciences, 2008) criticized the choice, stating that the DoE should choose one technology that could accomplish both tasks.

The Advanced Fuel Cycle Initiative began in 2002, but was brought under the rubric of the Global Nuclear Energy Partnership (GNEP) program in 2006. The FY2009 budget request was more than halved by Congress in the omnibus appropriations bill, reflecting disapproval of efforts to move beyond research and development. The House report on energy appropriations from December 2008 was particularly scathing about nuclear fuel cycle activities, calling the GNEP program "rushed, poorly-defined, expansive and expensive," and recommended slashing the program by two thirds (House Report 110-921, 2008: 93)

The final FY2009 budget reflected House priorities, completely eliminating funds for demonstration facilities; grid-appropriate reactors; and GNEP, including developing partnerships with countries.

[3] High temperatures are required for certain industrial processes, including desalination, synthetic and unconventional oil production (including oil from tar sands) and hydrogen production. The steam from nuclear energy can provide heat for such processes.

New Licensing Procedures

The Energy Policy Act of 1992 created a "one-step" licensing procedure for new nuclear reactors. Previously, utilities had to apply for a construction licence and, once construction was complete, an operating licence. This process led to several instances in which the construction, but not the operation, of reactors was licensed. The new process combines those two licences and limits the kinds of interventions that led to delays. It would allow completed plants to operate without delay if construction criteria are met.

Early site permits (ESP) are another innovation of the last five years. ESPs allow reviews of site safety, environmental and emergency planning considerations before specific reactor design reviews. However, most utilities have applied for combined construction and operating licences (COLs) without early site permits. NRC staff have issued three ESPs for the Clinton, Grand Gulf and North Anna sites. These permits are valid for between 10 and 20 years.

Energy Policy Act of 2005

The US Congress has also approved significant subsidies for the American nuclear industry. The Energy Policy Act of 2005 (EPACT) provided a combination of incentives, specifically for the first new nuclear reactors to come online, including production tax credits, energy facility loan guarantees, cost-sharing, limited liability and delay insurance. The production tax credit would provide relief in the form of US1.8 cents/kWh produced at qualifying new nuclear power plants during the first eight years of operation. This credit is significant because the average wholesale price of electricity in 2005 was US5 cents/kWh (Congressional Budget Office, 2007). The overall limit for the credit is US$7.5 billion, which would limit the credit to the first 6,000 MW of capacity, or five plants. To qualify for the production tax credits, the owners of projects needed to apply for a COL by December 2008, begin construction by January 2014, and receive certification by DoE that it is feasible to begin operating before January 2021.

Under US Treasury loan guarantees, discussed in more detail below, lenders would not have to pay in the case of default; loan guarantees are available for 80 percent of the construction costs. The DoE also committed to sharing design and licensing costs for the "first of a kind" reactor, with its share estimated at US$281 million (CBO 2008:10). EPACT also extended Price-Anderson limits on liability through 2025, capping new plants' liability in case of accidents at US$10.6 billion. Finally, delay insurance would apply to the first six new licensed reactors delayed by the regulatory process; some US$500 million would be available for each of the first two reactors and US$250 million for each of the next four reactors. This was intended to compensate for delays in implementing the new combined construction and operating license process by the NRC.

Since the law was enacted, 17 applications for combined construction and operating licenses for nuclear power plants have been filed. Such applications do not necessarily indicate that the power plants will be built. Since the cost of applying for a licence is estimated at about US $100 million, however, it is not necessarily a decision taken lightly by utilities.

Public Debate

Nuclear energy has not been debated seriously in the United States for decades. Thirty years ago, most public attention on nuclear power was focused on safety and waste. Today, it is directed more generally at concerns about rising energy prices and dependence on foreign sources of energy. A February 2008 Pew on-line survey indicated that a majority of Americans believe

> "developing new sources of energy, rather than protecting the environment, is the more important priority for the country. However, when asked specifically about energy policy priorities, 55% favour more conservation and regulation of energy, compared with 35% who support expanded energy exploration." (Pew, 2008)

According to the Pew survey, about 48 percent of Americans oppose promoting more nuclear power, while 44 percent favour doing so. Among Republicans, 59 percent favour more nuclear power, along with 46 percent of independents and 34 percent of Democrats. Fewer women (31 percent) than men (58 percent) support such investments. A UPI/Zogby International Poll in June 2008 showed 67 percent of those polled online support nuclear power, and 23 percent oppose building new nuclear power plants (Zogby International, 2008). Breaking those numbers down, new nuclear power plants attracted strong support from Republicans (85 percent vs. 49 percent of Democrats) and political independents (70 percent), older Americans (78 percent of Americans 65 years or older) and men (82 percent vs. 52 percent of women).

Advocates of nuclear energy have embarked on strong marketing campaigns. For example, the Nuclear Energy Institute (NEI) has run advertisements describing nuclear energy as "clean air" energy. The Clean and Safe Energy Coalition, co-run by former EPA administrator Christine

Todd Whitman and former Greenpeace activist Patrick Moore, has been funded by the nuclear industry. One industry slogan is "Know new nukes." The slogan appears over a field of yellow soybean flowers. "Clean" energy appears to be a euphemism for renewables plus nuclear power, which is why anti-nuclear advocates were heartened by President Obama's February address to Congress in which he spoke only of renewable energy, rather than clean energy (Wasserman, 2009).

Opponents of nuclear energy generally have less money to spend on media campaigns, and their message is less pithy. They stress that nuclear power is not the solution to climate change and that it is dangerous, polluting, unsafe, and expensive. Only a few planned nuclear plants are in states that do not already have power plants, such as Utah, Missouri and Idaho. Most of the expected plants will be constructed on existing reactor sites, which make them more acceptable to the local public.

Loan Guarantees

The single most important spur to build new reactors in the United States is loan guarantees. In fact, industry sources indicate they are so critical that new plants may not be built without them. These guarantees are attractive to the US Congress because they offer a way to influence markets and incentivize specific projects, and because they are "scored" as a lower liability for the taxpayer than the actual amount. Thus, a potential US$50 billion in loan guarantees could be scored by the Congressional Budget Office as only costing the taxpayer US$500 million. As originally proposed in the Energy Policy Act (EPACT) of 2005, loan guarantees would only have applied to nuclear power, but this was broadened to apply to a wide range of "innovative energy technologies," including renewable energy technologies, which further extends their attractiveness within Congress.

The loan guarantees can cover up to 80 percent of a project's cost, and 100 percent of the loan is guaranteed, provided that the loan is issued by a federal financing bank. The program also allows for appropriations by Congress of direct subsidy costs, but these are less attractive because they are considered "real" money. There are significant reasons why the loan guarantees are important to utilities and vendors: they transfer the risk of cost overruns due to lengthier construction times from the utilities or vendors to the taxpayer. The market capitalization of utilities is insufficient to allow them to increase the equity ratio of funding, which would be another way to reduce the high cost of loans.

The Consolidated Appropriations Act of 2008 provided US$40.5 billion for nuclear energy loan guarantees and was extended for an indefinite period in the FY2009 omnibus appropriations bill. The nuclear portion of the plan includes US$2 billion for front-end nuclear power facilities – that is, enrichment – and US$18.5 billion for nuclear power facilities. This is an increase from an initial US$4 billion appropriated in FY2007 (which has not expired), but far less than utilities were hoping for. By the December 2008 deadline for submissions, DoE received two applications for front-end facilities (from the US Enrichment Corporation (USEC) and French firm AREVA) and 17 applications for 21 reactors, totaling US$122 billion in requests. Since then, the number of applicants has been whittled down, either through attrition or active discouragement. As of February 2009, there were 15 submissions for 10 specific projects for nuclear power facilities. Industry sources suggest DoE will be able to support no more than 2-4 reactors, given costs of US$5 billion to US$12 billion per reactor. According to one inside source, DoE is hoping to encourage diversity in designs, picking "winners" from the utilities furthest along in their COL applications. Of course, the Department's choice is complicated by the fact that the Loan Guarantee Program "cannot enter into loan guarantee agreements relative to any of the projects until the Nuclear Regulatory Commission has issued the Construction and Operating Licenses (COL) which are expected to begin being issued in 2011" (Frantz, 2009). This is further complicated by the fact that not a single COL application, according to NRC Chairman Jaczko, was complete in its submission (Jaczko, 2009).

Loan incentives have prompted utilities to focus on designs with the highest probability of getting COLs, which means those designs that have already been licensed or are operating elsewhere. In testimony before the Senate Committee on Energy and Natural Resources on March 18, 2009, Dr. Thomas Cochran and Christopher Paine of the Natural Resources Defense Council criticized this approach:

> To avoid serious and lasting distortion of the US energy marketplace and an economically inefficient decarbonization effort, nuclear loan guarantees should be limited to the lead units of new nuclear plant designs, not previously deployed in the United States or in similar markets abroad with comparable regulatory requirements. These designs must incorporate substantial design innovations promising improved safety, increased operating efficiencies, significantly reduced capital costs, and lower environmental impacts.

In our view, few if any of the Gen III+ reactors being proposed today plausibly meet this description, but if any of them do, it could only be the lead units of new passive safety, smaller footprint, less capital intensive designs that have not yet been deployed elsewhere. Fitting that description currently are the AP-1000 and the Economic Simplified Boiling Water Reactors (ESBWR) and possibly later the Very High-Temperature Gas-Cooled Reactor, now in the early stages of development by the Department of Energy (Cochran and Paine, 2009: 2).

The Prospects for Carbon Pricing

Loan guarantees may be necessary, but they are likely not sufficient. Some US industry executives, such as Jeffrey Immelt of General Electric, have suggested that only "five to ten US nuclear power projects would go ahead unless there was a carbon-pricing framework to create incentives for utilities to build more" (Crooks and Guerrera, 2007). In other words, building other electricity-generating plants would continue to be more cost-effective than new nuclear power plants, absent carbon pricing.

Just how high would that carbon tax need to be? Estimates vary from US$30/ton of carbon dioxide to US$100/ton (Williams, 2006). According to calculations in the Massachusetts Institute of Technology's (MIT) 2003 study, *The Future of Nuclear Power,* nuclear generation begins to become competitive with coal when carbon dioxide is priced at US$100/ton (assuming 85 percent capacity and a 40-year time frame). Yet prices in carbon trading in Europe in the first three years varied from about €30/mt to less than €0.02/mt; in the second round of trading, allowances have been hovering in the low €20/mt (equivalent to US$50/mt) range (Ryan, 2008:3). A stable, long-term price for carbon is far from assured.

Estimates by the Congressional Research Service in 2008 suggest that lowering the cost of capital through loan guarantees or imposing carbon costs could make nuclear energy significantly more competitive in the United States. Table 1 summarizes three of the cases estimated by CRS – a base case that includes just production tax credits, a government incentives case that includes loan guarantees, and a carbon pricing case.

Figure 3: CRS 2008 Estimated Annualized Cost of Power, (cents/kWh; 2008 dollars)

Technology	Base Case	Incentives Case	Carbon Pricing Case*
Coal: Pulverized	6.3	6.0	10
Coal: IGCC	8.2	7.3	11.4
Natural Gas: Combined Cycle	6.1	6.1	7.7
Nuclear	8.3	6.3	8.3
Wind	8.0	7.2	8.0
Geothermal	5.9	5.9	5.9
Solar: Thermal	10	10	10
Solar: Photovoltaic	25.5	25.5	25.5

Source: Kaplan (2008: 39, 44, 55.)

*The cost of adding carbon capture & storage to the coal technologies adds about one cent/kWh while adding CCS to natural gas would add 1.7 cents/kWh. See CRS Report for more details.

As Figure 3 shows, electricity generation using nuclear energy with only a production tax credit is more expensive than all alternatives except solar energy (base case). Adding loan guarantees makes nuclear energy competitive with natural gas and pulverized coal. Imposing CO2 allowances pushes up the price of coal-fired electricity significantly above nuclear energy, although natural gas would remain less expensive.

Foreign Financing

American utilities may be able to secure foreign financing for new nuclear reactors in the United States. In late 2008, the Japanese government created the Japan Finance Corporation, which would provide Japanese government-backed loan guarantees for US reactors, provided the reactors have Japanese private investment. Export credit assurances are another vehicle for foreign support for US reactors. The French may also provide subsidies to US reactors; in late 2008, Electricite de France bought a 50 percent share in Constellation, which hopes to build the next reactor in Calvert Cliffs, Maryland. NRG is reportedly seeking export credit assistance from Japan, while Toshiba has taken a 12 percent interest in the new Nuclear Innovation North America Company (a NRG-Toshiba partnership). Toshiba will contribute US$150 million toward the development costs of NRG's proposed South Texas plants and another US$150 million for the development costs of another four units.

Spent Fuel Recycling

As noted above, the Bush administration sought to close the nuclear fuel cycle in the United States by promoting the development of fast reactors to burn up plutonium and "recycling" waste for that purpose. The basic idea was to reduce the volume of nuclear waste by reusing the fuel in fast reactors, which can burn more of the material.[4] GNEP, AFCI, and other related programs have all contributed to that goal. These plans essentially overturned a 30-year policy of discouraging the use of plutonium in the US civilian nuclear fuel cycle for proliferation reasons. Thus far, the US Congress has taken a "go slow" approach, delaying demonstrations of advanced recycling technologies until more research can be completed (United States Senate, 2007). A National Academy of Sciences report in 2008, which reviewed DoE's nuclear energy R&D, suggested that DoE reconsider reactor technologies under the Gen IV program that would support both advanced fuel cycles and the production of process heat, instead of pursuing two reactor technologies – very high temperature reactors and sodium-cooled fast reactors – for those tasks. It also recommended that DoE continue research on advanced recycling techniques, rather than move toward a technology demonstration plant.

Current State of Play

New Technologies and Designs

Dale Klein, chairman of the Nuclear Regulatory Commission, has joked that the French have 100 different types of cheese and one type of nuclear reactor, and the United States has one kind of cheese and 100 different types of reactors (Grunwald, 2008). While the hope is that standardization will lead to reductions in cost, five technologies are now under consideration for this round of nuclear power plants:

- GE/Hitachi/Toshiba's Advanced Boiling Water Reactor (ABWR);
- Westinghouse's AP-1000;
- AREVA's European Pressurized Water Reactor (EPR);
- Mitsubishi's Advanced Pressure Water Reactor (APWR); and
- GE/Hitachi's Economic Simplified Boiling Water Reactor (ESBWR)

[4] The 104 power reactors in the United States are so-called "thermal" power reactors. These reactors use low-enriched uranium as fuel and water to slow down, or moderate, the speed of neutrons to a "thermal" level" so that more fissioning can occur. In so-called "fast reactors," different kinds of fuel are used with no attempt to slow down the speed of neutrons. Fast reactors operate at higher temperatures and have a wider spectrum across which fissioning can occur, allowing a broader menu of actinides to be fissioned and therefore "burned up." The resulting actinides are shorter-lived radionuclides, which are much more radioactive, but decay much more quickly.

It would be easy to assume that utilities applying for combined construction and operating licences would choose proven and certified reactor designs. However, this is not the case. In fact, the design certification and COL application process for several of these reactors are running simultaneously.

The designs for both the AP-1000 and the ABWR have been certified by the NRC, although planned changes will require additional certification. In addition, the ABWR design certification will expire in 2012 and must be resubmitted (Winn, 2009). The design certification applications for the other reactors were submitted several years ago: the EPR and APWR in December 2007 and the ESBWR in 2005. Of all of these, only the ABWR has been built abroad; 4 units have been operating in Japan since 1996. Two units of the EPR and of the AP-1000 will commence operations in China soon, as will two APWRs in Japan. In addition, EPRs are under construction in Finland (Olkiluoto) and France (Flammanville). Both sites have had construction difficulties and delays.

The purpose of evolutionary, improved designs – so-called Generation III+ reactors – is to enhance safety and decrease costs. Of the five designs, two utilize passive safety design features: the AP-1000 and the ESBWR. Only one includes aircraft hazard protection in the original design: AREVA's double containment design for the EPR. Passive safety systems use natural processes like gravity, condensation and evaporation in addition to features such as battery-powered valves. Given expected lower failure rates, they should also require less redundancy, leading to lower capital, operation and maintenance costs.

Modular construction has been touted as another way to reduce costs, by allowing construction off-site, thereby limiting the required on-site skilled craft labour. Japanese plants have successfully employed modular construction. All the designs currently being considered, except for the EPR, employ modular construction methods. Another way to decrease costs is to simplify designs and use less steel and concrete. Apart from the EPR, the requirements for steel and concrete are estimated to be lower than those of first and second generation reactors. Figure 4, adapted from Standard & Poor's, summarizes some of the differences among these technologies.

Figure 4: Comparison of reactor designs currently under consideration in the US

	Pressurized Water Reactors			Boiling Water Reactors	
	EPR	AP 1000	APWR	ABWR	ESBWR
Design certification status with NRC	Submitted December 2007	Modifications will require NRC certification	Submitted December 2007 require NRC certification	Yes but modifications will require NRC certification	Submitted August 2005
Design (net) MWe	1,600	1,117	1,700	1,370	1,520
Capital costs	High	Low	Medium	Low	Low
Reactor coolant system	Four-loop	Two-loop	Four-loop	N.A.	N.A.
Active/passive safety systems	Active	Passive	Active	Active	Passive
Reactor coolant pumps (safety trains)	Four trains	Two trains	Four trains	Three trains	Two trains
O&M costs per kW	Medium	Medium	Medium	High	Low
Fuel efficiency	High	Medium	Medium	Low	High
Core damage frequency/year	5.8x 10 -7	5 x 10 -7	N.A.	1.6 x 10 -7	3 x 10 -7
Aircraft hazard protection	Yes	No	No	No	No
Construction track record	2 plants being built (Finland, France.) 2 in China soon to commence	None, but 2 in China soon to commence	None, but 2 in Japan soon to commence	4 Japanese units in operation, first since 1996	None
Modular construction?	No	Yes	Yes	Yes	Yes
Steel, concrete,	High	Low	Medium	Low	Low

Source: This table was abbreviated from one that appeared in Venkataraman and Prabhu, 2009

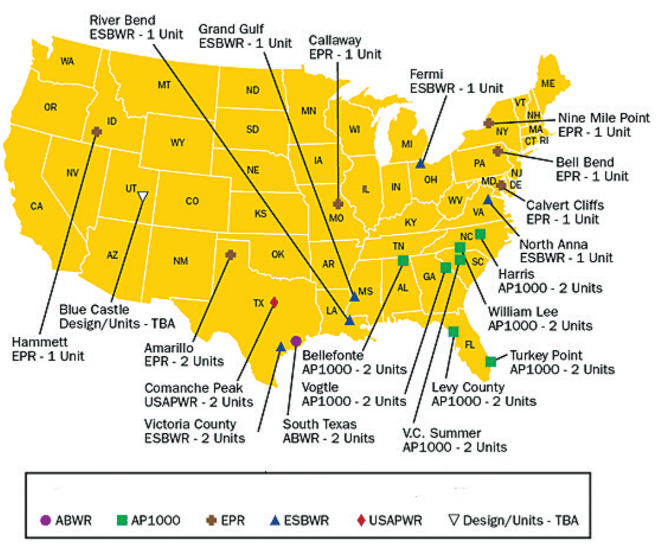
In general, the attractiveness of these reactors for utilities varies. Four considerations play a role: capital cost, time to market, evolutionary versus revolutionary technologies, and active versus passive safety design features. For the most part, unregulated electricity generators – such as Constellation Energy Group, NRG Energy Inc. and PPL Corp. – have chosen active safety designs, presumably because they rely on the market for cost recovery and therefore want the most proven technologies. Regulated utilities have so far valued the lower life-cycle costs of passive designs, choosing the AP-1000 and ESBWR. The exception is Exelon Corp., which operates in unregulated markets and still chose the ESBWR. But even Exelon, which has the largest fleet of plants and therefore may be able to weather shorter-term costs associated with a first-of-a-kind plant, may be changing its mind based on concerns about its eligibility for loan guarantees.

New Licence Applications

By early February 2009, 17 licences for constructing and operating 26 new reactors were filed with the NRC. According to the director of the Office of New Reactors, the NRC is "well underway in conducting reviews," having completed less than half of the safety and environmental reviews. By type of reactor, these include: six AP-1000 (Westinghouse-Toshiba); five ESBWR (GE-Hitachi); four EPR (AREVA); one ABWR (GE-Hitachi); and one US-APWR (Mitsubishi). Three additional applications have been filed since January 2009, including Florida Power & Light's application for two AP-1000 units at Turkey Point; Amarillo Power's application for two EPRs near Amarillo; and Alternate Energy Holding's application for one EPR near Hammett, Idaho.

As of January 2009, three ESBWR projects appear to be in question. Entergy has requested the NRC halt licensing activities for the ESBWR project in River Bend, as well as the NUSTART project in Grand Gulf (World Nuclear News, 2009a). Dominion has not halted the licensing process for the North Anna site but may be considering

Figure 5: Location of Projected New Nuclear Reactors



Source: United States Nuclear Regulatory Commission, May 2008a.

*Note that this map does not reflect Exelon's choice of ABWRs for Victoria County, or the suspension of license applications for ESBWRs in River Bend or Grand Gulf

Figure 6: Current Nuclear Plant Applications

Expected New Nuclear Power Plant Applications Updated July 2, 2009						
Company*	**Date of Application**	**Design**	**Date Accepted**	**Site Under Consideration**	**State**	**Existing Operating Plant**
Calendar Year (CY) 2007 Applications						
NRG Energy (52-012/013)***	09/20/2007	ABWR	11/29/2007	South Texas Project (2 units)	TX	Y
NuStart Energy (52-014/015)***	10/30/2007	AP1000	01/18/2008	Bellefonte (2 units)	AL	N
UNISTAR (52-016)***	07/13/2007 (Envir.) 03/13/2008 (Safety)	EPR	01/25/2008 06/03/2008	Calvert Cliffs (1 unit)	MD	Y
Dominion (52-017)***	11/27/2007	ESBWR	01/28/2008	North Anna (1 unit)	VA	Y
Duke (52-018/019)***	12/13/2007	AP1000	02/25/2008	William Lee Nuclear Station (2 units)	SC	N
2007 TOTAL NUMBER OF APPLICATIONS = 5 TOTAL NUMBER OF UNITS = 8						
Calendar Year (CY) 2008 Applications						
Progress Energy (52-022/023)***	02/19/2008	AP1000	04/17/2008	Harris (2 units)	NC	Y
NuStart Energy (52-024)***	02/27/2008	ESBWR	04/17/2008	Grand Gulf (1 units)	MS	Y
Southern Nuclear Operating Co. (52-025/026)***	03/31/2008	AP1000	05/30/2008	Vogtle (2 units)	GA	Y
South Carolina Electric & Gas (52-027/028)***	03/31/2008	AP1000	07/31/2008	Summer (2 units)	SC	Y
Progress Energy (52-029/030) ***	07/30/2008	AP1000	10/06/2008	Levy County (2 units)	FL	N
Exelon (52-031/032)***	09/03/2008	ESWBR	10/30/2008	Victoria County (2 units)	TX	N
Detroit Edison (52-033)***	09/18/2008	ESBWR	11/25/2008	Fermi (1 unit)	MI	Y
Luminant Power (52-034/035)***	09/19/2008	USAPWR	12/2/2008	Comanche Peak (2 units)	TX	Y
Entergy (52-036)***	09/25/2008	ESBWR	12/4/2008	River Bend (1 unit)	LA	Y
AmerenUE (52-037)***	07/24/2008	EPR	12/12/2008	Callaway (1 unit)	MO	Y
UNISTAR (52-038)***	09/30/2008	EPR	12/12/2008	Nine Mile Point (1 unit)	NY	Y
PPL Generation (52-039)***	10/10/2008	EPR	12/19/2008	Bell Bend (1 unit)	PA	Y
2008 TOTAL NUMBER OF APPLICATIONS = 12 TOTAL NUMBER OF UNITS = 18						
Calendar Year (CY) 2009 Applications						
Florida Power and Light (763)	6/30/2009	AP1000		Turkey Point (2 units)	FL	Y
Amarillo Power (752)		EPR		Vicinity of Amarillo (2 units)	TX	UNK
Alternate Energy Holdings (765)		EPR		Hammett (1 unit)	ID	N
2009 TOTAL NUMBER OF APPLICATIONS = 3 TOTAL NUMBER OF UNITS = 5						
Calendar Year (CY) 2010 Applications						
Blue Castle Project		TBD		Utah	UT	N
Unannounced		TBD		TBD	TBD	UNK
2010 TOTAL NUMBER OF APPLICATIONS = 2 TOTAL NUMBER OF UNITS = 2						
Calendar Year (CY) 2011 Applications						
No Letters of Intent have been received from applicants expressing their plans to submit new COL applications in CY 2011.						
2007 – 2011 Total Number of Applications = 22 Total Number of Units = 33						

*Project Numbers/Docket Numbers **Yellow – Acceptance Review Ongoing ***Blue – Accepted/Docketed

another technology. Both Entergy and Dominion apparently began some contracts, but could not agree with GE-Hitachi on engineering, procurement and construction (EPC) contracts. In late 2008, Exelon announced the ESBWR would not be its preferred design choice for the Victoria site in Texas, because the company reportedly wanted to improve its eligibility for federal loan guarantees (World Nuclear News, 2008). Although expected to submit an application for ABWRs at the Victoria site, Excelon chose instead to apply for an early site permit, stating it was not "leaving the Victoria site." Figure 5 shows the location of sites for new COLs.

NRC Commissioner Greg Jaczko told an industry audience in mid-February 2009 that all the licence applications submitted had defects, ranging from incompleteness to unresolved technical, contracting and permitting issues.

Nonetheless, a few vendors have already signed EPC contracts. Such contracts are a positive sign of intention, but do not necessarily indicate a decision to build, since the utilities must have COLs before construction can begin. However, EPC contracts lock in prices and schedules, which are key to controlling costs. In January 2009, for example, Progress Energy signed a US$7.65 billion contract with Westinghouse and Stone and Webster for two AP-1000s at the Levy County site in Florida. Before construction can begin, Progress Energy will also need a site certification from the Florida Department of Environmental Protection. Florida has already determined that it needs new electric generating capacity and the Public Service Commission has approved cost recovery for the pre-construction phase of US$357 million. Other EPC contracts signed so far have been for the two AP-1000s at the Vogtle site in Georgia (2008) and two AP-1000s at the Summer site in South Carolina.

Prospects for Litigation

The US nuclear industry is realistic about potential public controversy over building new nuclear plants. At an industry conference in February 2009, one speaker flatly said "There will be litigation on new plants." However, there was optimism that such litigation could be minimized or halted. Local or regional groups requested interventions in eight of the nine applications due by February 2009. The remaining eight, for which the deadline for intervention is still open, could also be subject to legal challenges. While the new licensing process limits interventions to a greater extent than the old process, amendments by applicants can apparently provide opportunities for public intervention. Water issues and other environmental concerns will continue to be a key focus of litigators.

Enrichment Plants

In the United States, no fewer than four new enrichment plants are either under construction or awaiting licenses to begin construction. Until 15 years ago, the Department of Energy owned and operated gaseous diffusion uranium enrichment plants at Paducah, Kentucky, and Portsmouth, Ohio. The 1992 Energy Policy Act privatized DoE's enrichment capabilities, creating the United States Enrichment Corporation (USEC). The remaining USEC plant at Paducah enriches uranium for domestic use and for export. US utilities have relied on downblended Russian highly enriched uranium (HEU) for about half of their low-enriched uranium (LEU) fuel since 1992. The plant at Paducah, which is scheduled to shut down in the next few years (between 2010 and 2015), will be replaced by a six million separative work unit (SWU) capacity plant in New Mexico (the Louisiana Enrichment Site) and the Advanced Centrifuge Project, a gas centrifuge plant expected to produce about 3.8 million SWU per year using American technology (Donelson, 2009). The figure below shows the new capabilities:

Figure 7: Enrichment Projects in the United States

Consortium	Location	Technology	Capacity (SWU)	Date
AREVA	Eagle Rock, ID	gas centrifuge	6.6 million	2014-19
LES	New Mexico	gas centrifuge	5.9 million	2009-15
USEC	Paducah, Kentucky	gas centrifuge	3.8 million	2010-12
GE-Hitachi	Wilmington, SC	laser enrichment	3.5 million	2013-16

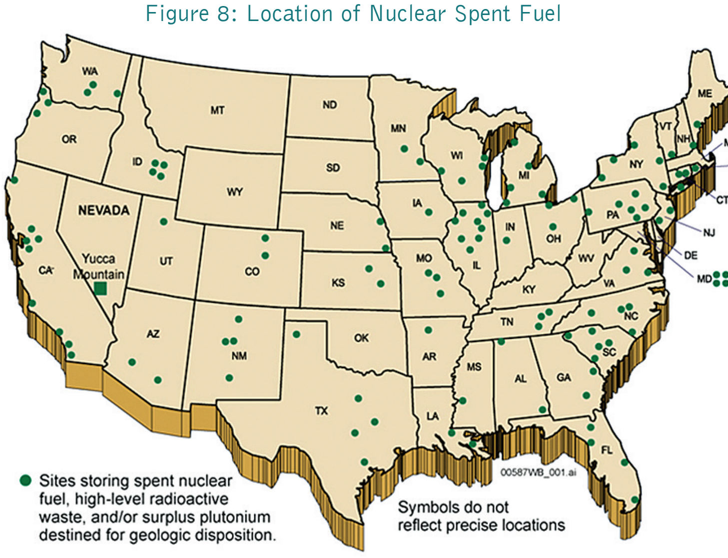
Source: *Increasing Enrichment Capacity for a Growing Nuclear Industry.* Presentation by John M.A. Donelson, February 13, 2009

The Louisiana Enrichment Services (so called because Louisiana was the original proposed site) plant and the American Centrifuge Plant are under construction, while the licence for the AREVA facility at Eagle Rock is pending. GE-Hitachi has submitted a licence application for a proposed laser enrichment plant in South Carolina. The ACEP facility is estimated to cost about US$3.5 billion. According to USEC, it expects to have all funding in place by November 2009. It began cascade testing in January 2009 and expects to begin limited operations in February 2010, and to reach one million SWU capacity in 2011. USEC has until the end of 2009 to finalize its loan guarantee application; although the DOE initially declined the application, it then gave USEC another 6 months to make progress (World Nuclear News, 2009b). ACEP is expected to reach its full operational capacity in 2012. Other projects have similar construction costs; the LES plant is estimated at about US$3 billion, while the AREVA plant is expected to cost US$4 billion.

Waste Management

In 1956, a National Academy of Sciences study group concluded that a deep geologic repository was the best solution to dispose of high-level waste from nuclear reactors. Nuclear power reactors in the United States generate about 2,000 metric tons of fuel each year. So far, the United States has accumulated about 57,700 metric tons of spent fuel, which is stored in spent fuel ponds and in dry storage casks at 121 sites in 39 states (Holt, 2009). According to the 1982 Nuclear Waste Policy Act (NWPA), nuclear power plant operators are required to pay into the Nuclear Waste Fund (now estimated at US$20 billion) in return for DoE waste disposal services – that is, eventual disposal in a geologic waste repository. That repository, designated as the Yucca Mountain site in 1987, was supposed to have opened in 1998. Beginning in 1997, nuclear

Figure 8: Location of Nuclear Spent Fuel



Source: Nuclear Regulatory Commission (2009) power plant operators filed 56 lawsuits against the DoE for costs incurred in the absence of shipments to Yucca Mountain. DoE estimates that its liabilities under the current law will total US$11 billion if shipments begin by 2020, and a lot more if they do not. The NWPA did not provide for another method of disposing waste, such as reprocessing, and the Nuclear Waste Fund may not be used for anything other than legislated purposes.

Further delays are ahead, since the Obama administration decided to cancel construction funds for the Yucca Mountain program in early 2009, while continuing the licensing process at the NRC. This raises the question of whether the funding decision could be reversed in the future. If so, advocates of Yucca Mountain would still need to address storage capacity and geology issues. The NWPA set an arbitrary limit of 70,000 tons for Yucca Mountain, but it presupposed a second waste site would be authorized. By 2020, the level of waste is expected to reach 81,000 metric tons. Including defence waste and shipments by US reactors through 2066, the expected accumulated waste is estimated to reach 122,100 metric tons (Holt, 2009).

The suitability of Yucca Mountain's geology is still debated. Critics have maintained that fractures in the volcanic tuff can transport water and therefore possibly radioactive waste. Also, the discovery in 2007 that the Bow Ridge fault line runs underneath a facility, rather than a few hundred feet away, raised additional concerns. These concerns likely form part of the basis for the Obama administration's decision to examine alternative disposal solutions.

Assessing the Potential for Growth

Forecasts of growth in nuclear power typically rely on economic models with a few tweaks. Starting with an assumption of GDP growth, demand for electricity is projected and, very often, models are based on the assumption that various types of generation generally retain their market shares. Sensitivity analyses of fuel prices also weigh in. According to an industry source, a 1.5 percent rise in electricity demand each year in the United States, assuming all generation sources maintain their current market shares, would require the following new plants by 2025: 50 new nuclear power plants; 261 coal-fired plants, 279 natural-gas fired plants and 73 renewable projects (Reilly, 2008). Given that only four to eight new nuclear plants might begin operating by 2015, 42-48 such plants would need to be brought online between 2015 and 2025. While not impossible, such expansion is unlikely.

The Energy Information Administration's (EIA) reference cases project significantly fewer new builds. In its *Annual Energy Outlook* 2007, net nuclear capacity was projected to rise from 100 GWe in 2005 to 112.6 GWe by 2030, including: expansions of capacities at existing plants (2.7 GWe), 12.5 GWe new capacity and 2.6 GWe retirements. In that scenario, nuclear energy's share of electricity generation would drop from 19 percent to 15 percent by 2030. The reference case assumed that the production tax credit of 1.8 cents/kWh provided by the 2005 Energy Policy Act (EPACT) would be implemented and that there would be an annual 1.1 percent rise in electricity growth.

EIA's reference case in the *Annual Energy Outlook* 2009 paints a slightly different picture. Electricity growth is estimated at just 1 percent annually because of the continuing decline of energy intensity in the US economy, the result of higher energy prices, greater efficiency and conservation, and policy choices. Coal plants are assumed to be much more difficult to build, even without a carbon pricing scheme. From 100.5 GWe in 2007, nuclear capacity is expected to rise to 112.2 GWe by 2030, which includes 12.7 GWe of new capacity, 3.7 GWe in upratings and 4.4 GWe in retirements.

Nuclear Energy and its Competitors

Coal is still king in the United States, accounting for 59 percent of electricity production. With abundant coal and lower facility construction costs, coal is cost-effective, particularly in deregulated markets. However, utilities may find new coal plants increasingly difficult to build. For example, Governor Jennifer Granholm of Michigan called for a near moratorium on new coal-fired power plants in her February 2009 state of the state address. This would affect eight new coal plants now in the approval process (Hornbeck, Cain and Heinlein, 2009). Perhaps the greatest challenge to new nuclear builds in the United States comes from natural gas, the generation costs of which have fallen recently with the price of oil. Natural gas plants are quicker and cheaper to build, although more subject to the vagaries of fuel prices. In some states, for example Florida, the desire for nuclear power is driven by the need to counteract overwhelming dependence on natural gas. Jeffrey Lyash of Progress Energy Florida has predicted that Florida will depend on natural gas for 55 percent of its electricity generation by 2017. Florida has built only natural gas plants since 1984, which are not considered to be optimal baseload electricity generators because their fuel costs fluctuate significantly (Lyash, 2009).

Figure 9: Range of Cost Estimates for New Nuclear Power Reactors in the United States (2008 dollars; overnight costs are dollars per kilowatt)

Study/Estimate	Date	Low Overnight	High Overnight	Low All-in	High All-in	Cents/kWh
MIT	2002	$1,177	$2,354 (mid)			7
Keystone Center	2007	$3,024	$3,024			8
S&P	2007	$3,000	$5,000			9-10
Moody’s	2007			$5,000	$6,000	
Florida Power & Light (Turkey Pt)	2007	$3,186	$4,540	$5,700	$8,020	
CBO	2008	$2,478 (mid)				
Synapse	2008			$5,500	$8,100	
Constellation	2008	$5,900 (mid)				
South Texas Project	2008	$2,937	$3,596			
Lazard	2008	$3,750	$5,250	$5,750	$7,550	
Harding	2007	$5,535 (mid)	$9,235	$7,550	$7,800	
Duke	2008	$4,900 (mid)		$6,400 (mid)		
CRS (base case)	2008	$3,900 (mid)				8.3
Progress Energy (Levy County)	2008	$4,260		$6,400 (2009)	$7,600 (2009)	
Moody’s	2008	$6,250 (mid)		$7,500 (mid)		

Sources: Kaplan, 2008; Harding, 2007; Harding, 2008; Hempstead, 2007. Mark Cooper calculated the 2008 US dollar values, which are used with his permission

Cost and Financing Challenges[5]

The characteristics of nuclear power that set it apart from other electricity generation sources are low fuel costs, long construction periods and high construction costs, and the scale of projects. Because it is not often helpful to compare smaller generation capacities with larger nuclear power plants, most analysts consider “levelized costs,” or, the cost of electricity generation per kilowatt-hour. As many studies have noted (e.g., MIT’s 2003 Future of Nuclear Power, 2007 Keystone Center Report), new nuclear projects in the United States would require either significant subsidies or significant improvements in construction and management to lower costs relative to other electricity generation options (see also Figure 3 from CRS).

In the United States, Moody’s estimated in October 2007 that the all-in cost of a new nuclear power plant could range from US $5,000 and US $6,000/kW, which translates into US $5-6 billion for a 1,000 MWe plant (Hempstead, 2007:11). Such an estimate includes all the costs incurred during construction, including financing costs, which can add anywhere from 25 to 80 percent. Vendor estimates (minus financing costs) have varied between a low of US $2,865/kW for the South Texas Project Units 3 and 4 (this was their low estimate in March 2008 versus a mid-range estimate of US $3,200/kW) to US $5,746/kW for Calvert Cliffs 3 in Maryland (Kaplan, 2008b).[6] Figure 9 below shows a range of cost estimates.

Since there is no recent construction experience for nuclear power plants in the United States, it is difficult to get an accurate estimate of costs. However, it is very clear that costs are rising. One estimate is that the cost of constructing power plants rose 131 percent between 2000 and 2008, and increased 69 percent in the just the last three years (Kaplan, 2008). Rising cost estimates can be attributed to many factors, including the cost of capital and rising commodity prices. According to one of its authors, the 2007 Keystone Center Report estimated a four percent increase in costs from 2002 to 2007 in assessing construction costs for new reactors and found after publication that the rise was more likely to be 14 percent. The impact of such cost increases is significant for large projects. Whereas the estimate for Turkey Point units 6 and 7 in Florida would remain at US $4,050/kW (medium overnight costs), or 10.7 cents/kWh, with no real cost increases, it could rise to: US $5,400/kW (four percent increase); US $7,100/kW (8 percent increase); or US $9,050/kW (14 percent increase). At 14 percent, the cost doubles – from 10.7 cents/kWh to 20.7 cents/kWh – which is equivalent to the most expensive electricity generation option, photovoltaic power (Harding, 2009).

As indicated above, financing can add 25 to 80 percent to total costs of new nuclear power plants. It can take two to three times as long to build nuclear power plants as it takes to build coal or natural gas plants. Finance charges are accrued all the while. In the United States, partial deregulation of electricity generation has made highly intensive capital projects even less attractive to investors (DoE, 2005b). Financial analysts suggested before the current financial crisis that there would be enough venture capital

[5] For an excellent background paper on the economics of nuclear power, see *Nuclear Energy Futures Paper # 1* by David McLellan.

[6] These costs are overnight costs – that is, they do not include the financing costs (Kaplan, 2008b).

available to finance a major expansion, but balked when asked about the level of risk. A telling indicator of how the private capital market feels about new nuclear power plants is the suggestion by financial market analysts in early 2008 that US utilities seeking to build new nuclear power plants could see their excellent credit ratings drop to a single "B" rating (Hempstead, 2008). In the current climate, it is unlikely many analysts or investors will consider nuclear power plant projects "shovel-ready."

Infrastructure Challenges

The chief operating officer of Exelon told participants at a nuclear industry conference in early 2008 that the lack of recent US nuclear construction experience; the atrophy of US nuclear manufacturing infrastructure; production bottlenecks created by an increase in worldwide demand; and an aging labour force could all constrain major expansion (Crane, 2008). Of these, the lack of construction experience probably has the largest impact on the costs of new nuclear builds. Mainly, it is a question of efficiently managing the average eight million labour hours needed to build a nuclear power plant, but the supply of critical components also comes into play.

In 2005, DoE conducted an infrastructure assessment as part of the NP 2010 program. Its report concluded that most of the major equipment for the next four to eight reactors will need to be procured from foreign manufacturers because American vendors and manufacturers can only produce a portion of it. One indicator of this gap is the number of nuclear-certified component and parts makers in the United States. As of 2005, there were 49 ASME N-stamp holders (American Society of Mechanical Engineers certification for nuclear components) and 63 ASME NPT-stamp holders (certification for nuclear parts). This compares with the 1980s, when the United States had 400 nuclear suppliers and 900 holders of N-stamp certificates. DoE also estimated that the NRC itself would have to spend an additional US$30-40 million dollars beginning in FY2009 and add about 150 additional personnel by 2012.

In part, the US manufacturing base may benefit from foreign ownership of US reactor vendors – GE-Hitachi and Westinghouse-Toshiba – as well as from AREVA's interest in selling EPRs in the US. In late 2008, AREVA announced a partnership with Northrop Grumman to build a manufacturing plant near Newport News, Virginia that will cast and forge reactor components for the EPR. Construction will begin in 2009 and be completed by 2012. AREVA is also working with Lehigh Heavy Forge in Bethlehem, Pennsylvania, to forge components for the EPR (The News and Advance, 2008).

Reliance on foreign components for American nuclear reactors may introduce some delays into the process, but the US, unlike other countries, is unlikely to import construction labour and personnel to either regulate or run its nuclear reactors. Labour is another critical area where shortfalls are expected. Aging workforces at nuclear power plants present a particular problem. For example, at Florida Power and Light Company, 40 percent of current nuclear power plant workers are eligible to retire in the next five years.[7] This is slightly higher than the national average of 35 percent (or 19,600 workers) eligible to retire. The Nuclear Regulatory Commission confronts a similar challenge. The industry has initiated some programs at community colleges and universities to address this issue.

In addition to competing with other electricity projects, nuclear power construction competes with other large investment projects for labour and resources, particularly oil infrastructure. Big construction projects in Texas and efforts to rebuild the infrastructure damaged by Hurricane Katrina will continue to place pressure on labour forces. A Bechtel executive stated in 2008 that the US will face a skilled labour shortage of 5.3 million workers in 2010, which could rise to a shortage of 14 million by 2020. Adding to this is the retirement of baby boomers, and much slower growth in the number of college graduates (Reilly, 2008). Building a nuclear power plant in the United States requires 1,400 to 2,300 construction workers for four or more years. The permanent labour force of a nuclear power plant numbers between 400 and 500.

While it is likely that vendors will prefer to build power reactors in the United States because it is an established market, the possibilities of new nuclear builds elsewhere may create competition for resources. According to one estimate (Burgundy Nuclear Partnership), "a single order for a third generation nuclear plant represents 20-40 percent of a component manufacturer's capacity (McCracken, 2009). The decline in construction since the 1980s has shrunk industrial capacity worldwide. Apart from Russia, there are five large nuclear engineering companies; six companies fabricating steam generators and reactor vessels; a few ultra-heavy forging firms (Japan Steel Works (JSW), Sfarsteel-Creusot Forge and now Doosan) and only three steam generation tubing firms (Valinox Nucleaire,

[7] Comments by Art Stall, quoted in Sneider and Froggatt, 2008.

Sumitomo and Sandvik). AREVA owns Sfarsteel-Creusot Forge and has bought a share of JSW, ensuring its orders for ultra-heavy forgings through 2016. JSW, which will expand its capacity to produce such forgings to eight per year in 2010, has announced plans to further expand to 12 sets of forgings per year by 2011. In the meantime, the waiting list for ultra-heavy forgings at JSW has grown longer.

Policy Directions

The Obama administration is less likely to strongly support subsidies for the US nuclear industry than its predecessor. However, with some key administration positions still unfilled, it remains to be seen whether strong advocates will emerge. Secretary of Energy Steven Chu, in his confirmation hearing, pledged to expedite the release of existing loan guarantees, authority which is expected to lapse at the end of the fiscal year (October 2009) (Mufson, 2009). Secretary Chu stated in the hearing that "I'm supportive of the fact that the nuclear industry should have to be part of energy mix in this century. And recycling [nuclear waste] in the long term can be part of the solution" (Chu, 2009). In interviews several years ago, Chu suggested that new nuclear power plants would require reprocessing, since demands on Yucca Mountain would soon exceed its capacity. Without recycling, however, and an uncertain fate for Yucca Mountain, it is not clear how strong his support for new nuclear power plants will be.

Apart from his support for Yucca Mountain, Secretary Chu's views so far do not seem to stray far from what President Obama has expressed in the last year. During the campaign, Obama similarly supported nuclear energy as an option not to be dismissed, but expressed some reservations in a television interview with Tim Russert in mid-2008:

> I think we do have to look at nuclear, and what we've got to figure out is can we store the material properly? Can we make sure that they're secure? Can we deal with the expense? Because the problem is, is that a lot of our nuclear industry, it reinvents the wheel. Each nuclear power plant that is proposed has a new design, has – it, it has all kinds of changes, there are all sorts of cost overruns. So it has not been an effective option. That doesn't mean that it can't be an effective option, but we're going to have to figure out storage and safety issues. And my attitude when it comes to energy is there's no silver bullet. We've…got to look at every possible option (Obama, 2008).

Loan Guarantees

In his confirmation hearing, Secretary Chu stated he favoured implementing loan guarantees. In his statement before the Senate Energy and Natural Resources Committee, DoE's David Frantz told members that the loan guarantee program is an "urgent priority for Secretary Chu," that Chu is personally reviewing the program, and that Chu directed DoE staff to "accelerate the process significantly while maintaining appropriate evaluation and due diligence to protect taxpayer interests" (Frantz, 2009). Although Secretary Chu has reportedly worked to ensure existing loan guarantees are implemented, he told a Global Energy Summit audience in June 2009 that the Obama administration wants to support development of new nuclear plants, but not at the expense of energy efficiency or renewables (O'Grady, 2009). New loan guarantees for new nuclear power plants were not contained in the new FY2010 DoE budget, but Congress could insert them in other bills.

Waste Management

In its 2010 budget submission, the Obama administration eliminated a third of planned funds for Yucca Mountain (from US$288 million to US$197 million), keeping funds related to licensing, but eliminating those for construction. Specifically, the Department of Energy explained that:

> All funding for development of the Yucca Mountain facility has been eliminated, such as further land acquisition, transportation access, and additional engineering. The budget request includes the minimal funding needed to explore alternatives for nuclear waste disposal…and to continue participation in the Nuclear Regulatory Commission (NRC) license application process, consistent with the provisions of the Nuclear Waste Policy Act. The Administration intends to convene a "blue-ribbon" panel of experts to evaluate alternative approaches for meeting the federal responsibility to manage and ultimately dispose of spent nuclear fuel and high-level radioactive waste from both commercial and defense activities (DoE, 2009).

The same budget contains more funds for fuel cycle R&D (US$192 million), particularly waste management while zeroing out fuel cycle research and facilities funds (DoE, 2009). In Congress, conferees further reduced nuclear waste spending to about US$98 million.

Potential Impact on New Nuclear Reactor Construction

Industry advocates worry that the lack of a permanent waste repository will affect new nuclear reactor construction. In 1977, the NRC adopted a policy that it "would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely" (NARA, 1977). By 1984, as a result of Waste Confidence proceedings, the NRC established a 2007-2009 deadline for a nuclear waste repository. It revised its findings in 1990 to reflect a deadline of the "first-quarter of the 21st Century." The NRC is now proposing a revised finding that a nuclear waste repository be available 50 to 60 years after the reactor's lifetime and that spent fuel can be stored safely for 60 years following a reactor's life (Holt, 2009: 8)

Several states – California, Connecticut, Kentucky, New Jersey, West Virginia and Wisconsin – have specific laws that link new reactor approvals to waste disposal. These have, in effect, resulted in a moratorium on building new nuclear power plants in those states. Kentucky has been considering legislation to overturn its moratorium. In 1983, the Supreme Court ruled (in Pacific Gas & Electric Co. v. State Energy Resources Conservation and Development Commission) that federal responsibility for licensing cannot trump states' authority over reactor approvals related to economic considerations (in contrast to approvals related to safety, which is within the established purview of the NRC). This decision has not been challenged, since no new reactors have been approved since the 1970s.

Conclusions

Some new nuclear power plants are likely to be built in the United States in the next ten years but it is difficult to say whether a handful of plants will spark major growth for US nuclear energy. Climate change legislation could make nuclear power more competitive with natural gas and nuclear energy advocates could push for expanded loan guarantees. The smooth functioning of new NRC regulations will also be critical to keeping costs down. Some states have already decided to offer incentives for new nuclear builds by authorizing cost recovery schemes while construction is in place, and others have offered tax incentives for siting nuclear-related manufacturing plants in their jurisdictions.

Yet the reason for any interest in new nuclear power plants in the US is the implementation of wide-ranging subsidies championed by the Bush administration over the last eight years. From government programs to jump-start new nuclear construction to new policies and funding for nuclear energy research and development, the Bush administration sought to promote nuclear power as a solution to climate change and energy security.

It is unlikely the Obama administration will be such a strong champion of domestic or foreign nuclear energy, yet it is not clear whether it will overturn some of the programs already underway. Congress also has a crucial role in funding initiatives that could support nuclear energy, whether intentional or not. For example, loan guarantees typically apply to a wide variety of technologies, including those using coal and oil. There is significant potential for the nuclear industry to secure funding as a "clean" energy technology.

One wild card is how the debate over waste disposal will play out. Nuclear power opponents have strongly advocated against government subsidies and Yucca Mountain. But if loan guarantees go forward and new nuclear power plants are built, what happens to the waste? Can the Department of Energy remain liable for disposal of spent nuclear fuel? If so, will there be a push to authorize interim storage?

The nuclear industry in the United States has always been characterized by remarkable (some say unfounded) optimism about growth. Efforts to standardize and modularize construction, along with foreign financing, might help the prospects for growth, but the real key to a nuclear rebirth would be aggressive government support. Even then, the challenges are formidable; just to maintain its share of the electricity market, the nuclear industry would need to build 50 reactors in the next 20 years. Given that only four new reactors might be operational by 2015, significant growth could require build rates of more than four per year. Greater government subsidies and a carbon pricing mechanism are not likely enough to achieve such rates of construction. The best outcome for the US nuclear industry over the next five years, particularly under an administration that will probably offer mild rather than aggressive support, will be to demonstrate that it can manage each stage of the licensing, construction and operating processes of the first reactors competently and efficiently. In sum, the industry needs to demonstrate that it has overcome the problems of the past.

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