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First of Two Parts

by Karen Charman

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A few miles down an idyllic New England country road dotted with handsome homesteads and gentleman farms in central Connecticut sits the Connecticut Yankee nuclear power plant—or what's left of it. After shutting down in 1996, the 590-megawatt reactor is nearing the end of its decommissioning, a process spokesperson Kelley Smith describes as "construction in reverse."

Most of the buildings, the reactor itself, and its components have been removed. Adjacent to the Connecticut River, the discharge pond, which received the reactor's second-stage cooling water from the internal heat exchanger, is being dredged. The soil, including hot spots near the reactor that were contaminated with strontium-90 from leaking tanks, has been replaced. Forty concrete casks of highly radioactive spent fuel now sit on a fenced and guarded concrete pad surrounded by woods on the company's property about three-quarters of a mile from the reactor site. Soon the spent fuel pool that housed the irradiated fuel assemblies will be drained and dismantled. A twisted spaghetti-like tangle of metal protruding from a partially demolished building will be carted off to a dump site. Stories-high stacks of steel containers packed with mildly radioactive rubble are also waiting to be taken away. One of the final tasks will be to demolish the containment dome, which consists of 35,000 metric tons of steel-reinforced concrete. When decommissioning is completed by the end of the year, over 136,000 metric tons of soil, concrete, metal, and other materials will have been removed from the site at a cost of more than US$400 million to the area's electricity customers.

But for a fluke in timing, Connecticut Yankee might well have remained in operation today. Ten years ago, when the board of directors of the Connecticut Yankee Atomic Power Company decided to close its reactor at Haddam Neck, nuclear power was widely considered, if not a dying industry, then one that was seriously and chronically ill. In the newly deregulated electricity market, the company found it could buy electricity for less than its nuclear power plant could produce it. Connecticut's deregulation of the electricity sector required the company to divest itself of the plant. Company directors didn't think they could sell a single reactor of relatively low capacity, so they decided to shut it down.

Just a few years later, the economic landscape for nuclear power began changing with the emergence of companies like Exelon Corporation (a merger between Chicago-based Commonwealth Edison and Pennsylvania-based PECO) and the Louisiana-based Entergy Corporation, which began buying up reactors. Entergy purchased Vermont Yankee, a 540-megawatt reactor, for US$180 million in 2002. Less than 80 kilometers south of Connecticut Yankee, Dominion Resources spent US$1.3 billion to acquire three reactors (two operating and one shut) at Millstone—a plant with the dubious distinction of landing on the cover of *Time* in 1996 for long-standing, egregious breaches of safety regulations. By 2002, just 10 corporations owned all or part of 70 of the nation's 103 operating reactors.

Fast forward to today. The world has begun to wake up to the very real and growing perils of human-induced, catastrophic climate change. The war in Iraq, increasing tension in the oil-rich Middle East, and memories of both the (market-manipulated) energy fiasco in California in 2001 and the

Bugey Nuclear Power Plant, on the Rhone River near Lyon.

blackout that affected one-third of the United States and Canada in August 2003 have raised awareness and anxiety about unstable, unsustainable energy supplies. These factors, along with a very skillful, multi-pronged public relations and lobbying campaign, have put nuclear power, which is touted as carbon-free, back on the table.

According to the International Atomic Energy Agency (IAEA), nine new nuclear plants—three in Japan, two in Ukraine, and one each in South Korea, India, China, and Russia—have gone online since 2004. In that time, two plants in Canada were restarted after years of not operating, and there is talk of building a new reactor there. Currently 23 nuclear power plants are under construction around the world, including one in Finland, the first in western Europe since the 1986 explosion at Chornobyl in northern Ukraine. France, whose 58 reactors provide approximately 80 percent of that country's electricity, is also considering building another reactor, and British Prime Minister Tony Blair is calling for new reactors to replace Britain's aging fleet of 31 reactors, most of which are due to retire by 2020. In August 2005, U.S. President George W. Bush signed into law an energy bill that contained US$13 billion in public subsidies to help jumpstart a new generation of nuclear reactors.

Nuclear Power vs. Global Warming

A growing chorus of nuclear advocates, government officials, international bureaucrats, academics, economists, and journalists is calling for nuclear power to save us from devastating climate change. Nuclear reactors do not emit carbon dioxide (CO_2) and other greenhouse gases when they split atoms to create electricity. But it's inaccurate to say that nuclear power is "carbon-free"—on a cradle-to-grave basis, no currently available energy source is. (Even wind turbines are guilty by association: the aluminum from which they are built is often smelted using coal-fired electricity.) In the case of nuclear power, fossil fuel energy is used in the rest of the nuclear fuel chain—the mining, milling, and enriching of uranium for use as fuel in reactors, the building of nuclear plants (especially the cement), the decommissioning of the plants, the construction of storage facilities, and the transportation and storage of the waste. In fact, the gaseous diffusion uranium enrichment plant at Paducah, Kentucky, is one of the single biggest consumers of dirty coal-fired electricity in the country.

Still, it seems impossible to pin down exactly how carbon-intensive the nuclear fuel chain is, and there is disagreement within the environmental community about nuclear energy's potential contribution to global warming. Tom Cochrane, a nuclear physicist with the Natural Resources Defense Council, says nuclear power is not a large greenhouse gas emitter compared to other conventional sources of energy. But in order for nuclear energy to make a significant dent in greenhouse gas emissions, we would need a huge increase in the number of nuclear power plants now operating worldwide, which he does not support.

Just how huge? A widely quoted 2003 report by Massachusetts Institute of Technology researchers, "The Future of Nuclear Power," calls for the construction worldwide of 1,000–1,500 new 1,000-megawatt reactors by 2050, an expansion that would potentially displace 15–25 percent of the anticipated growth in carbon emissions from electricity generation projected over that time. A 2004 analysis in *Science* by Stephen Pacala and Robert Socolow, co-directors of Princeton University's Carbon Mitigation Initiative, says 700 gigawatts of new nuclear generation—roughly double the number and output of the world's 443 operating reactors—would be needed to achieve just one-seventh of the greenhouse gas emission reductions (at current emission rates) required

Mihama Nuclear Power Plant, near Tokyo.

to stabilize atmospheric carbon concentrations at 500 parts per million (ppm).

The MIT report acknowledges such an expansion would create an enormous nuclear waste challenge requiring a permanent disposal site with the capacity of the proposed repository at Yucca Mountain in Nevada "to be created somewhere in the world every three to four years." If the spent fuel were reprocessed instead, as many nuclear proponents advocate, it would dramatically increase opportunities to spread nuclear material that could be used in making atomic bombs. The MIT report rejects reprocessing as uneconomic and, because of the weapons proliferation dangers, unnecessarily risky. To deal with the waste, it calls for the U.S. Department of Energy to develop "a balanced long-term waste management R&D program" and investigate the possibility of placing the waste in deep geologic boreholes. It also recommends the establishment of a network of centralized facilities in the United States and internationally that can store spent fuel for several decades until better solutions are worked out. Of course, the policy landscape is strewn with technically plausible recommendations that were dead on arrival because they glibly ignored the difficult politics of nuclear energy.

Pacala and Socolow maintain that a range of options is needed to address climate change. They identify 15 technologies or practices now in commercial operation somewhere in the world and say that scaling up any seven of them could stabilize carbon emissions over the next 50 years. These alternatives will be more fully explored in Part II of this series.

Nukonomics

"Nuclear Follies," a February 11, 1985 cover story in *Forbes*, declared the United States' experience with nuclear power "the largest managerial disaster in business history." With US$125 billion invested, the magazine wrote, "only the blind, or the biased, can now think that most of that money has been well spent. It is a defeat for the U.S. consumer and for the competitiveness of U.S. industry, for the utilities that undertook the program and for the private enterprise system that made it possible."

Yet nuclear power is now widely promoted as one of the most economical sources of electricity, with a production cost of 1.68 cents per kilowatthour (kWh), compared to 1.9 cents/kWh for coal, 5.87 cents/kWh for natural gas, 2.48 cents/kWh for solar, 0.2 cents/kWh for wind, and 0.5 cents/kWh for hydroelectric, according to the Electric Utility Cost Group, a data group within the nuclear industry that draws its information from plant surveys, and Global Energy Decisions, a private energy data consulting firm. Those figures measure the operating cost of fuel, labor, materials, and services to produce one kWh of electricity. But like most sources of energy, nuclear power benefits from substantial government subsidies. Including nuclear's subsidies, collateral costs, and externalities leads to a different economic assessment.*

Although a full nuclear revival with a new generation of reactors to replace the existing fleet could not take place—at least in the United States—without the participation of the private sector, commercial nuclear power has never had to compete in a true free market. From the beginning, nuclear

* Although no comprehensive and integrated study comparing the collateral and external costs of energy sources globally has been done, all currently available energy sources have them. Large hydroelectric dams dramatically alter ecosystems, threaten species, and displace and impoverish people whose lands are flooded. Burning coal—the single largest source of air pollution in the U.S.—causes global warming, acid rain, soot, smog, and other toxic air emissions and generates waste ash, sludge, and toxic chemicals. Landscapes and ecosystems are completely destroyed by mountaintop removal mining, while underground mining imposes high fatality, injury, and sickness rates. Even wind energy kills birds, can be noisy, and, some people complain, blights landscapes.

Energy and other markets are usually shaped by politics. See Groundwork, p. 14.

Michael Dalder/REUTERS ©2002

Grafenrheinfeld Nuclear Power Plant, in northern Bavaria.

power worldwide has always required government patronage. In the United States, the industry was launched in 1946 with the passage of legislation creating the Atomic Energy Commission (the predecessor to the Nuclear Regulatory Commission, or the NRC), which was charged with developing both civilian nuclear power and nuclear weapons. In 1954 the government brought the private sector in, and under President Dwight D. Eisenhower's "Atoms for Peace" initiative continued to encourage the development and commercialization of nuclear power.

Although nuclear power currently provides about 20 percent of U.S. electricity (and about 16 percent of the world's), between 1950 and 1993 the U.S. nuclear power industry received nearly 50 percent of the total federal spending on energy research and development—some US$51 billion—according to energy economist Doug Koplow. Substantial government assistance appears to be the status quo for the nuclear industry around the world, he adds, though specific data from many countries is unavailable. Nuclear power continues to get favored treatment, with government assistance covering virtually all segments of the nuclear fuel chain to one degree or another.

Uranium mining companies operating in the United States, for example, get a "percentage depletion allowance" of 22 percent (the highest rate of all depletion allowances for minerals), which gives them a tax write-off for the market value of what they have extracted—a significant subsidy since the write-off is typically much greater than their actual investment. The manufacture of the reactor fuel has also been heavily subsidized. Until 1998, the government owned the country's two uranium enrichment plants. When they were privatized into the U.S. Enrichment Corporation, the government retained liability for the waste clean-up associated with the operation of the facilities, an ongoing endeavor with a price tag in the billions.

During construction of the reactors, utilities were able to pass on the interest costs of the loans to their electricity customers, utilizing the "Allowance for Funds Used During Construction." While this was available to all types of power plants, Koplow says it mainly benefited owners of nuclear plants, because costs on the already expensive plants ran out of control with construction delays. Nuclear plant owners also took advantage of highly accelerated depreciation and investment tax credits in the early 1980s. Koplow says these three accounting mechanisms significantly reduced the capital costs of the reactors. Even so, after states began deregulating electricity markets in the 1990s, utilities with nuclear plants found they needed to charge much more than the going rate for electricity to pay off their remaining debt, or "stranded costs," and stay competitive with other electricity sources. State after state changed the rules to allow utilities to pass on these stranded costs to ratepayers as a surcharge on their electric bills, a gift to the nuclear industry that by 1997 was worth some US$98 billion.

The ratepaying public also bears the cost of dealing with the spent fuel—estimated at US$60–100 billion for the existing fleet of reactors—as well as for decommissioning the plants. And if there is another serious accident, the 1957 Price-Anderson Act shields nuclear plant owners from the lion's share of the cost by capping their liability. According to Koplow, the utility responsible for the accident would pay US$300 million in primary liability plus US$95.8 million that it and the nation's other nuclear utilities would contribute per reactor (paid in US$15-million annual installments over six years) to an insurance pool. With 103 operating U.S. reactors, the size of the insurance pool is approximately US$10 billion. By comparison, some estimates put the cost of the Chornobyl accident at over US$350 billion, and the Union of Concerned Scientists estimates that a serious accident at New York's Indian Point plant 56 kilometers north of New York City would be in the trillions—costs mainly left to individuals because of the standard nuclear exclusion clause in home insurance policies. Without this particular liability mitigator in the United States and similar instruments in other countries, commercial nuclear power probably would not exist.

Moreover, it seems that Price-Anderson is not the only mechanism available to nuclear utilities to protect themselves from full liability if something goes wrong. According to a 2002 report by Synapse Energy Economics, Inc., since the restructuring of the U.S. nuclear industry began as states started deregulating their electric utility industries in the mid-1990s,

a few large corporations such as Exelon Corp., Entergy Corp., Duke Energy, and Dominion Resources, Inc. increasingly own and operate nuclear power plants through multi-tiered holding companies. The individual plants are often set up as limited liability companies (LLCs), a legal invention that restricts liability to the assets directly owned by the LLC. "The limited liability structures being utilized are effective mechanisms for transferring profits to the parent/owner while avoiding tax payments," the report notes. "They also provide a financial shield for the parent/owner if an accident, equipment failure, safety upgrade, or unusual maintenance need at one particular plant creates a large, unanticipated cost. The parent/owner can walk away by declaring bankruptcy for that separate entity without jeopardizing its other nuclear and non-nuclear investments."

This arrangement is especially valuable under deregulation. Before deregulation, nuclear reactors typically were built by investor-owned utilities and operated under the shelter of a "cost-of-service regulation." This enabled the utilities to enjoy stable rates based on their actual costs rather than on electricity sales at market prices, which can fluctuate. With those stable rates stripped away, the usual risks of operating nuclear plants—unexpected shutdowns for nonscheduled maintenance, for instance, or even accidents—became more severe. The use of LLCs allowed much of that risk to be avoided. Yet, according to former NRC commissioner Peter Bradford, the agency failed to develop a comprehensive policy to ensure that the transfer of reactor ownership into these new corporate structures would not endanger the public. "In the absence of any such requirement, public protection has depended on the acumen of a Nuclear Regulatory Commission unversed in financial matters and of economic regulators unversed in health and safety issues. As has happened in financial and in utility restructuring circles, fundamental safeguards have been circumvented," he writes in the forward to the Synapse report. The consequences, he adds, remain to play out.

The NRC rejects both Synapse's and Bradford's allegations. In a written statement, the agency said it believes its regulations "provide reasonable assurance that a licensee will have sufficient resources to operate, maintain, and decommission nuclear power reactors. The NRC fully considered the issues raised in the 2002 Synapse report and believed then—and continues to believe—that our regulations adequately address LLCs or other corporate arrangements." The agency maintains that regardless of the new business arrangements, it continues to ensure that reactor owners meet their obligations, adding that most reactors also operate under regulation by state public utility commissions, which provide significant financial oversight.

"Their general platitudes don't convince me that we were wrong on any issue," says David Schlissel, lead author on the Synapse report. In addition, he says NRC is incorrect that state public utility commissions continue to oversee reactors in states where electricity markets have been deregulated. "The 19 plants owned by Exelon, they are all deregulated," he says, "as are many nuclear plants in the Northeast and Midwest."

Try, Try Again

On Valentine's Day in 2002, the U.S. Department of Energy unveiled its Nuclear Power 2010 program for sharing costs with industry to "identify sites for new nuclear power plants, develop and bring to market advanced nuclear plant technologies, evaluate the business case for building new nuclear power plants, and demonstrate untested regulatory processes leading to an industry decision in the next few years to seek NRC approval to build and operate at least one new advanced nuclear power plant in the United States." Currently three consortia, an 11-company group called NuStart Energy Development and smaller ones led by the Tennessee Valley Authority and Dominion Resources, have been formed to investigate building new reactors. Despite consortia members' combined revenues of US$447 billion during 2003—which, Koplow points out, rivals the Russian Federation and exceeds the combined GDP of 104 countries—the U.S. government is now offering the nuclear industry additional incentives worth more than US$13 billion as seed money for new nuclear plant construction. According to an analysis released last year by the non-profit group Public Citizen, the Energy Policy Act of 2005 includes US$2.9 billion for R&D, at least US$3.5 billion worth of construction subsidies, more than US$5.7 billion for operating subsidies, and US$1.3 billion for shutdown subsidies.

Some of the package's more notable elements include US$2 billion for risk insurance, which allows builders of the first six reactors to collect for any delays in construction or licensing, including challenges by the public on safety grounds (e.g., if a whistleblower reported faulty construction and a citizen group sued). It includes production tax credits of 1.8 cents per kilowatthour for eight years, an estimated US$5.7–7.0 billion that would otherwise go to the U.S. Treasury. There are also provisions for taxpayer-backed loan guarantees for up to 80 percent of the cost of a reactor. These loan guarantees are particularly handy, considering that billions of dollars were lost during the first round of nuclear plant construction when more reactors were cancelled than were built, many after hundreds of millions of dollars had already been spent.

That's a big handout, but it remains to be seen whether it's enough to kick-start a new generation of reactors in the United States, which industry observers say is necessary for a viable economic future for nuclear power. Thomas Capps, the recently retired CEO of Dominion Resources, head of one of the consortia seeking a license for a new reactor, told the *New York Times* last April that if his company announced it was actually going to build a nuclear plant, debt-rating agencies Standard & Poor's and Moody's "would have a heart attack, and my chief financial officer would, too." Peter Wells, general manager of marketing for General Electric's nuclear energy division, is cautiously optimistic but not yet convinced a new generation of reactors will be built. He says it

Sellafield Nuclear Power Plant, on the shore of the Irish Sea.

will depend on friendly government policy and positive experience with the first of the new reactors coming in within budget and on schedule.

Bush Administration policy is increasingly agreeable to the nuclear industry, but whether reactors can be built for their advertised costs is another question. At US$1,500 per kilowatt, the new "advanced" Generation III+ reactors are said to be much cheaper than those in the existing fleet. According to a 2001 Congressional Research Service (CRS) report on the prospects for new commercial nuclear reactors, total construction costs exceeded US$3,000/kw for reactors that were started after 1974, and those completed since the mid-1980s averaged US$3,600/kw. Anyone familiar with Pentagon procurement gaffes knows that chronic overruns and miscalculation of costs has been a longtime problem with large engineering projects, and the nuclear power industry is no exception. According to an analysis by the Energy Information Administration, plants that began construction between 1966 and 1977 underestimated their actual costs by roughly 14 percent, even when plants were 90 percent complete.

So far, only two reactors of new design, both of them GE Advanced Boiling Water Reactors, have been built (in Japan, for the Tokyo Electric Power Company). However, despite GE's estimate that the cost would be US$1,528/kw, CRS reports the first came in at US$3,236/kw and the second at around US$2,800/kw. Wells says the price of those plants was inflated because they were "gold-plate plants with marble floors and the like" that otherwise would have cost much less.

Peter Bradford says that despite the passage of the Energy Policy Act, nothing has fundamentally changed that would improve the economics enough to see a new generation of nuclear reactors. "With US$13 billion in new subsidies, if the government wants to prove that if it spends enough it can build nuclear plants, it can do that. The Chinese prove that for us a couple times a year," he said. "But that's not the same as saying it makes economic sense to do it." Still, Bradford acknowledges, "the stars have not been so favorably aligned for the industry since Atoms for Peace."

In a dramatic turnaround from nuclear's dog days in the 1980s and '90s, excitement is building on Wall Street. Steven Taub, director of emerging technologies at Cambridge Energy Research Associates, is confident new plants will be built, though he says the exact number will depend on how the various government incentives are distributed. Unlike the current fleet of nuclear reactors—nearly all of which were custom built—the next generation will be much more standardized to take advantage of economies of scale.

The government subsidies for new reactors are intended to offset the higher "first-of-a-kind" costs for the first few plants. If all goes without a hitch, the thinking is that lenders and utility shareholders will regain confidence that new nuclear plants can be competitive enough to finance without these subsidies. External factors will also determine the competitiveness and economic viability of nuclear power, Taub says. These variables include the price of natural gas, whether a carbon tax or other price-raising measures will be imposed on coal and other fossil fuels, and whether carbon sequestration technology for coal-fired power plants can be proven and widely adopted. "These are questions that nobody knows the answer to," he says.

Part II of this series will look at the waste problem, the proliferation and other security risks stemming from nuclear power, and at the strength of arguments for nuclear power in the context of other options.

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