ISSUE 12

Is It Time to Revive Nuclear Power?

YES: Michael J. Wallace, from "Nuclear Power 2010 Program," Testimony before the United States Senate Committee on Energy & Natural Resources, Hearing on the Department of Energy's Nuclear Power 2010 Program (April 26, 2005)

NO: Karen Charman, from "Brave Nuclear World? Part II," *World Watch* (July/August 2006)

ISSUE SUMMARY

YES: Michael J. Wallace argues that because the benefits of nuclear power include energy supply and price stability, air pollution control, and greenhouse gas reduction, new nuclear power plant construction—with federal support—is essential.

NO: Karen Charman argues that nuclear power's drawbacks and the promise of clean, lower-cost, less dangerous alternatives greatly weaken the case for nuclear power.

The technology of releasing for human use the energy that holds the atom together got off to an inauspicious start. Its first significant application was military, and the deaths associated with the Hiroshima and Nagasaki explosions have ever since tainted the technology. It did not help that for the ensuing half century, millions of people grew up under the threat of nuclear Armageddon. But almost from the beginning, nuclear physicists and engineers wanted to put nuclear energy to more peaceful uses, largely in the form of power plants. Touted in the 1950s as an astoundingly cheap source of electricity, nuclear power soon proved to be more expensive than conventional sources, largely because safety concerns caused delays in the approval process and prompted elaborate built-in precautions. Many say that safety measures have worked well when needed—Three Mile Island, often cited as a horrific example of what can go wrong with nuclear power, released very little radioactive material to the environment. The Chernobyl disaster occurred when safety measures were ignored. In both cases, human error was more to blame than the technology itself. The related issue of nuclear waste has also raised fears and added expense to the technology.

It is clear that two factors—fear and expense—impede the wide adoption of nuclear power. If both could somehow be alleviated, it might become possible to gain the benefits of the technology. Among those benefits are that nuclear power does not burn oil, coal, nor any other fuel; does not emit air pollution and thus contribute to smog and haze; does not depend on foreign sources of fuel and thus weaken national independence; and does not emit carbon dioxide. The last may be the most important benefit at a time when society is concerned about global warming, and it is the one that prompted James Lovelock, creator of the Gaia Hypothesis and an inspiration to many environmentalists, to say, "If we had nuclear power we wouldn't be in this mess now, and whose fault was it? It was [the antinuclear environmentalists']." See his autobiography, *Homage to Gaia: The Life of an Independent Scientist* (Oxford University Press, 2001). Stewart Brand, "Environmental Heresies," *Technology Review* (May 2005), says that he expects environmentalists to change their minds. The Organisation for Economic Co-operation and Development (OECD's) Nuclear Energy Agency, in "Nuclear Power and Climate Change," (Paris, France, 1998), available at http://www.nea.fr/html/ndd/climate/climate.pdf, found that a greatly expanded deployment of nuclear power to combat global warming was both technically and economically feasible. In 2000 Robert C. Morris published *The Environmental Case for Nuclear Power: Economic, Medical, and Political Considerations* (Paragon House). In August 2000 *USA Today Magazine* published "A Nuclear Solution to Global Warming?" "The time seems right to reconsider the future of nuclear power," say James A. Lake, Ralph G. Bennett, and John F. Kotek, in "Next-Generation Nuclear Power," *Scientific American* (January 2002). See also I. Fells, "Clean and Secure Energy for the Twenty-First Century," *Proceedings of the Institution of Mechanical Engineers, Part A—Power & Energy* (August 1, 2002). David Talbot, "Nuclear Powers Up," *Technology Review* (September 2005), notes that "While the waste problem remains unsolved, current trends favor a nuclear renaissance. Energy needs are growing. Conventional energy sources will eventually dry up. The atmosphere is getting dirtier." Peter Schwartz and Spencer Reiss, "Nuclear Now!" *Wired* (February 2005), argue that nuclear power is the one practical answer to global warming and coming shortages of fossil fuels. Paul Lorenzini, "A Second Look at Nuclear Power," *Issues in Science and Technology* (Spring 2005), says that nuclear power is essential to a sustainable future.

In the following selections, Michael J. Wallace, executive vice president of a major energy company, argues that because the benefits of nuclear power include energy supply and price stability, air pollution control, and greenhouse gas reduction, new nuclear power plant construction is essential, and there is a clear place for federal support. Karen Charman argues that nuclear power's drawbacks—risk, expense, and waste—and the promise of clean, lower-cost, less dangerous alternatives greatly weaken the case for nuclear power.

YES

Michael J. Wallace

Nuclear Power 2010 Program

. . . Constellation Energy, a Fortune 200 company based in Baltimore, is the nation's leading competitive supplier of electricity to large and industrial customers and the nation's largest wholesale power seller. Constellation Energy also manages fuels and energy services on behalf of energy intensive industries and utilities. The company delivers electricity and natural gas through the Baltimore Gas and Electric Company (BGE), its regulated utility in Maryland. We are the owners of 107 generating units at 35 different locations in 11 states, totaling approximately 12,500 megawatts of generation capacity. In 2004, the combined revenues of the integrated energy company totaled more that $12.5 billion and we are the fastest growing Fortune 500 Company over the past two years.

Our portfolio based on electricity produced is approximately 50 percent nuclear, 35 percent coal-fired, 7 percent gas-fired and 5 percent renewables. We own and operate the Calvert Cliffs nuclear plant in Maryland, and the Nine Mile Point and Ginna nuclear stations in New York State.

Constellation is part of the NuStart consortium that is preparing an application to the NRC for a license that would allow us to build and operate a new nuclear plant. Additionally, in December 2004, we submitted a proposal to the Department of Energy (DOE) for studies that could lead to an application to the Nuclear Regulatory Commission for an Early Site Permit as part of the Nuclear Power 2010 program. So, as you can tell, we have a vested interest in the continued success of Nuclear Power 2010, and we're bullish on the future of nuclear power.

Although I am here testifying today on behalf of Constellation, this testimony is supported by our trade association, the Nuclear Energy Institute (NEI).

My statement this morning will address four major issues:

1. The strategic value of our 103 operating nuclear power plants, and the compelling need to build new nuclear plants to preserve our nation's energy security, meet our environmental goals, and sustain our economic growth.
2. The critical importance of the Department of Energy's Nuclear Power 2010 program as a platform from which to launch the next generation of nuclear power plants in the United States.

United States Senate Committee on Energy & Natural Resources Hearing on the Department of Energy's Nuclear Power 2010 Program, April 26, 2005.

3. The need to recognize that the Nuclear Power 2010 program does not address all of the challenges facing companies interested in building new nuclear power plants, and that additional joint investment initiatives by the federal government and the private sector will be necessary.
4. The urgent need for comprehensive energy legislation that squarely addresses the critical need for additional investment in our electricity and energy infrastructure, including advanced nuclear and coal-fired generating capacity, electric and natural gas transmission, and other areas. Construction of the next nuclear power plants in the United States will require some form of investment stimulus, but I know I speak for the entire electric sector when I say that the need for investment stimulus extends well beyond nuclear power. This sector is starved for investment capital, and new federal government policy initiatives are necessary to reverse that trend and place our economy and our future on a sound foundation.

The Strategic Value of Nuclear Power and the Need for New Nuclear Power Plants

The United States has 103 reactors operating today. Nuclear power represented 20 percent of U.S. electricity supply 10 years ago, and it represents 20 percent of our electricity supply today, even though we have six fewer reactors than a decade ago and even though total U.S. electricity supply has increased by 25 percent in the period.

Nuclear power has maintained its market share thanks to dramatic improvements in reliability, safety, productivity and management of our nuclear plants, which today operate, on average, at 90 percent capacity factors, year in and year out. Improved productivity at our nuclear plants satisfied 20 percent of the growth in electricity demand over the last decade.

Due, in part, to excellent plant performance, we've seen steady growth in public support for nuclear energy. The industry has monitored public opinion closely since the early 1980s and two key trends are clear: First, public favorability to nuclear energy has never been higher; and second, the spread between those who support the use of nuclear energy and those opposed is widening steadily: 80 percent of Americans think nuclear power is important for our energy future and 67 percent favor the use of nuclear energy; 71 percent favor keeping the option to build more nuclear power plants. Six in 10 Americans agree that "we should definitely build more nuclear power plants in the future." Sixty-two percent said it would be acceptable to build new plants next to a nuclear power plant already operating.

The operating nuclear plants are such valuable electric generating assets that virtually all companies are planning to renew the operating licenses for these plants, as allowed by law and Nuclear Regulatory Commission regulations, and operate for an additional 20 years beyond their initial 40-year license terms. Sixty-eight U.S. reactors have now renewed their licenses, filed their formal applications, or indicated to the Nuclear Regulatory Commission that they intend to do so. The remaining 35 reactors have not yet declared because most of them are not yet old enough to do so. We believe that virtually all U.S. nuclear plants will renew their licenses and operate for an additional 20 years. At Constellation, we are proud that our Calvert Cliffs station was the first U.S. nuclear plant to renew its license. At the time, the license renewal process was a novel concept. Today, thanks to efficient management of the process by the Nuclear Regulatory Commission, it is a stable and predictable licensing action. Ten years from now, we hope and believe that the issuance of combined construction/operating licenses for new nuclear plants—a novel concept today—will be similarly efficient and predictable.

Although it has not yet started to build new nuclear plants, the industry continues to achieve small but steady increases in generating capability—either through power uprates or the restart of shutdown nuclear capacity. The Tennessee Valley Authority is restarting Unit 1 at its Browns Ferry site in northern Alabama. This is a very complex project—fully as challenging as building a new nuclear plant—and it is on schedule and within budget at the midpoint of the project.

However, despite the impressive gains in reliability and output, there are obviously limits to how much capacity we can derive from our existing nuclear power plants. The time has come to create the business conditions under which we can build new nuclear power plants in the United States. We believe there are compelling public policy reasons for new nuclear generating capacity.

First, new nuclear power plants will continue to contribute to the fuel and technology diversity that is the core strength of the U.S. electric supply system. This diversity is at risk because today's business environment and market conditions in the electric sector make investment in large, new capital-intensive technologies difficult, particularly the advanced nuclear power plants and advanced coal-fired power plants best suited to supply baseload electricity. More than 90 percent of all new electric generating capacity added over the past five years is fueled with natural gas. Natural gas has many desirable characteristics and should be part of our fuel mix, but over-reliance on any one fuel source leaves consumers vulnerable to price spikes and supply disruptions.

Second, new nuclear power plants provide future price stability that is not available from electric generating plants fueled with natural gas. Intense volatility in natural gas prices over the last several years is likely to continue, thanks partly to unsustainable demand for natural gas from the electric sector, and subjects the U.S. economy to potential damage. Although nuclear plants are capital-intensive to build, the operating costs of nuclear power plants are stable and can dampen volatility of consumer costs in the electricity market.

Third, new nuclear plants will reduce the price and supply volatility of natural gas, thereby relieving cost pressures on other users of natural gas that have no alternative fuel source.

And finally, new nuclear power plants will play a strategic role in meeting U.S. clean air goals and the nation's goal of reducing greenhouse gas emissions. New nuclear power plants produce electricity that otherwise would be supplied by oil-, gas- or coal-fired generating capacity, and thus avoid the emissions associated with that fossil-fueled capacity.

In summary, nuclear energy represents a unique value proposition: new nuclear power plants would provide large volumes of electricity—cleanly, reliably, safely and affordably. They would provide future price stability and serve as a hedge against price and supply volatility. New nuclear plants also have valuable environmental attributes. These characteristics demonstrate why new nuclear plant construction is such an imperative in the United States.

The Critical Value of the Nuclear Power 2010 Program

As I said earlier, the Department of Energy's Nuclear Power 2010 program is an essential foundation in the joint government/industry partnership to build new nuclear power plants. This committee and, in particular, you, Mr. Chairman, deserve great credit for your leadership in ensuring adequate funding for this program in the 2005 Fiscal Year.

Nuclear Power 2010 is designed to demonstrate the various components of the new licensing system for nuclear power plants, including the process of obtaining early site permits (ESPs) and combined construction/operating licenses (COLs), sharing the cost of the detailed design and engineering work necessary to prepare COLs, and resolving generic licensing issues. This work is an essential risk-management exercise because it allows industry and the NRC staff to identify and resolve scores of technical and regulatory issues that must be settled before companies can undertake high-risk, capital-intensive construction projects like new nuclear plant construction.

The Nuclear Power 2010 program is the springboard that launched a tangible and visible industry commitment to new plant construction. The industry's commitment to Nuclear Power 2010 includes a planned investment of $650 million over the next several years on design, engineering, and licensing work, which will create a business foundation for decisions to build. Three companies have applications for early site permits under review at NRC. In addition to these three, Constellation and possibly one other company are also considering ESP applications. The industry is developing at least three applications for construction/operating licenses; the first will be filed in 2007, the second and third in 2008.

As you know, the administration has proposed $56 million for the Nuclear Power 2010 program in the 2006 fiscal year. The $56 million funding proposed for 2006 is sufficient for the ESP and COL demonstration projects already underway. It is not adequate, however, to cover more recent expressions of interest from Constellation and others, and additional resources will be needed to ensure this program is viable into the future.

It is also important to recognize that Nuclear Power 2010 is a multi-year undertaking. Certainty of future funding and program stability are a big concern for industry. However, our biggest frustration with the Nuclear Power 2010 program involves the time it has taken the DOE to award the grants. In the case of NuStart, we submitted our application in April 2004 and we were not notified that we received the grant until November 2004. As for Constellation's ESP application, we submitted it almost four months ago and have yet to hear from DOE.

To support the ESP and COL demonstration projects currently underway and future projects, we anticipate that the Department of Energy will need to significantly increase funding for Nuclear Power 2010 over FY 2006 levels.

The process of developing the first COL applications, certifying new designs and completing NRC review of the first ESP and COL applications will take some time. We are looking for ways to accelerate that process, and the Congress may be able to help there—by ensuring sufficient funding for Nuclear Power 2010 and even accelerating that funding; and by providing NRC sufficient resources to ensure that the commission has adequate manpower to conduct licensing reviews and meet aggressive but realistic schedules.

The Nuclear Power 2010 Program Does Not Address All the Challenges Facing New Nuclear Plant Construction

The Department of Energy's Nuclear Power 2010 program is a necessary, but not sufficient, step toward new nuclear plant construction. We must address other challenges as well.

Our industry is not yet at the point where we can announce specific decisions to build. We are not yet at the point where we can take a $1.5 billion to $2 billion investment decision to our boards of directors. We do yet not have fully certified designs that are competitive, for example. We do not know the licensing process will work as intended: That is why we are working systematically through the ESP and COL processes. We must identify and contain the risks to make sure that nothing untoward occurs after we start building. We cannot make a $1.5–$2 billion investment decision and end up spending twice that because the licensing process failed us.

The industry believes federal investment is necessary and appropriate to offset some of the risks I've mentioned. We recommend that the federal government's investment include the incentives identified by the Secretary of Energy Advisory Board's Nuclear Energy Task Force in its recent report. That investment stimulus includes:

1. secured loans and loan guarantees;
2. transferable investment tax credits that can be taken as money is expended during construction;
3. transferable production tax credits;
4. accelerated depreciation.

This portfolio of incentives is necessary because it's clear that no single financial incentive is appropriate for all companies, because of differences in company-specific business attributes or differences in the marketplace—namely, whether the markets they serve are open to competition or are in a regulated rate structure.

The next nuclear plants might be built as unregulated merchant plants, or as regulated rate-base projects. The next nuclear plants could be built by single entities, or by consortia of companies. Business environment and project structure have a major impact on which financial [illegible] companies prefer tax-related incentives. Others expect that construction loans or loan guarantees will enable them to finance the next nuclear plants.

It is important to preserve both approaches. We must maintain as much flexibility as possible.

It's important to understand why federal investment stimulus and investment protection is necessary and appropriate.

Federal investment stimulus is necessary to offset the higher first-time costs associated with the first few nuclear plants built.

Federal investment protection is necessary to manage and contain the one type of risk that we cannot manage, and that's the risk of some kind of regulatory failure (including court challenges) that delays construction or commercial operation.

The new licensing process codified in the 1992 Energy Policy Act is conceptually sound. It allows for public participation in the process at the time when that participation is most effective—before designs and sites are approved and construction begins. The new process is designed to remove the uncertainties inherent in the Part 50 process that was used to license the nuclear plants operating today. In principle, the new licensing process is intended to reduce the risk of delay in construction and commercial operation and thus the risk of unanticipated cost increases. The goal is to provide certainty before companies begin construction and place significant investment at risk.

In practice, until the process is demonstrated, the industry and the financial community cannot be assured that licensing will proceed in a disciplined manner, without unfounded intervention and delay. Only the successful licensing and commissioning of several new nuclear plants (such as proposed by the NuStart and Dominion-led consortia) can demonstrate that the licensing issues discussed above have been adequately resolved. Industry and investor concern over these potential regulatory impediments may require techniques like the standby default coverage and standby interest coverage contained in S. 887, introduced by Senators Hagel, Craig and others.

Let me also be clear on two other important issues:

1. The industry is not seeking a totally risk-free business environment. It is seeking government assistance in containing those risks that are beyond the private sector's control. The goal is to ensure that the level of risk associated with the next nuclear plants built in the U.S. generally approaches what the electric industry would consider normal commercial risks. The industry is fully prepared to accept construction management risks and operational risks that are properly within the private sector's control.
2. The industry's financing challenges apply largely to the first few plants in any series of new nuclear reactors. As capital costs decline to the "nth-of-a-kind" range, as investors gain confidence that the licensing process operates as intended and does not represent a source of unpredictable risk, follow-on plants can be financed more conventionally, without the support necessary for the first few projects. What is needed [is] limited federal investment in a limited

number of new plants for a limited period of time to overcome the financial and economic hurdles facing the first few plants built.

In summary, we believe the industry and the federal government should work together to finance the first-of-a-kind design and engineering work and to develop an integrated package of financial incentives to stimulate construction of new nuclear power plants. Any such package must address a number of factors, including the licensing/regulatory risks; the investment risks; and the other business issues that make it difficult for companies to undertake capital-intensive projects. Such a cooperative industry/government financing program is a necessary and appropriate investment in U.S. energy security.

I hope this Committee can find a place for this type of investment stimulus in the comprehensive energy legislation now being developed.

In addition, I would be remiss if I did not thank the Chairman for his support for three additional programs/provisions that will assist in the construction of new nuclear power plants in the United States:

1. Sustained progress with the Yucca Mountain project is essential. This includes the funding necessary to maintain the schedule, ensure timely filing of the license application, and access to the full receipts of the Nuclear Waste Fund.
2. Renewal of the Price-Anderson Act, which provides the framework for the industry's self-funded liability insurance. I am pleased to note that this is included in the recently House-passed energy bill.
3. Updated tax treatment of decommissioning funds that would provide comparable treatment for unregulated merchant generating companies and regulated companies. This provision, included in the energy tax legislation passed recently by the House, would allow all companies to establish qualified decommissioning funds and ensure that annual contributions to those funds are treated appropriately as a deductible business expense.

The U.S. electricity business and our nation are paying the price today for our inability to strike an appropriate balance between what was expedient and easy in the short-term, and what was prudent and more difficult in the long-term. We are paying the price today for 10 to 15 years of neglect of longer-term imperatives and the oversupply of base-load generation in the 1990s.

The United States faces a critical need for investment in energy infrastructure, including the capital-intensive, long-lead-time advanced nuclear and coal-fired power plants that represent the backbone of the U.S. electricity supply system.

While some may not realize it, the United States faces an imminent energy crisis today.

Electric power sales represent three to four percent of our gross domestic product. But the other 96 to 97 percent of our $11-trillion-a-year economy depends on that three to four percent. We cannot afford to gamble with something as fundamental as energy supply, and the biggest problem we face with nuclear energy is not having enough of it.

Karen Charman

NO

Brave Nuclear World?

This year marks the 20th anniversary of the world's most notorious nuclear disaster. At 1:23 a.m. on April 26, 1986, the Number Four reactor at the Chornobyl* nuclear plant in northern Ukraine exploded and burned uncontrolled for 10 days, releasing over 100 times more radiation into the atmosphere than the Hiroshima and Nagasaki bombs combined. At least 19 million hectares were heavily contaminated in Belarus, Ukraine, and Russia. Prevailing winds and rain sent radioactive fallout over much of Europe, and it was measured as far away as Alaska. Approximately 7 million people lived in the contaminated zones in the former Soviet Union at the time of the accident (over 5 million still do). More than 350,000 were evacuated, and 2,000 villages were demolished. Radioactive foodstuffs from Belarus and Ukraine continue to show up in the markets of Moscow, and farmers on 375 properties in Wales, Scotland, and England still must grapple with restrictions due to radioactive contamination from Chornobyl.

The operating crew and the 600 men in the plant's fire service who first responded to the disaster received the highest doses of radiation, between 0.7 and 13 Sieverts (Sv). According to chernobyl.info, a United Nations Internet-based information clearinghouse, this is 700 to 13,000 times more radiation in just a few hours than the maximum dose of 1 millisievert that the European Union says people living near a nuclear power plant should be exposed to in one year. Thirty-one of those first on the scene died within three months. A total of 800,000 "liquidators"—mainly military conscripts from all over the former Soviet Union—were involved in the cleanup until 1989, and government agencies in Belarus, Ukraine, and Russia have reported that 25,000 have since died.

By any measure, Chornobyl was a horrific catastrophe and has become the icon of nuclear power's satanic side. Yet controversy has dogged the environmental and health impacts of Chornobyl from the beginning. The Soviet leadership first hoped nobody would notice the accident and then did their best to conceal and minimize the damage. As a result, a full and accurate assessment of the consequences has proved impossible. Historian and Chornobyl expert David

* In this article we use the Ukrainian spelling of "Chornobyl." The word may appear as "Chernobyl" in the formal names of organizations.

From *World Watch Magazine*, July/August 2006, pp. 12–18.

Marples wrote that authorities in the former Soviet Union classified all medical information related to the accident while denying that illnesses among cleanup workers resulted from their radiation exposure. Independent researchers have had difficulty locating significant numbers of evacuees and those who worked on the cleanup, and they have had to piece together their conclusions from interviews with medical providers, citizens, officials in the contaminated areas, others involved, and those cleanup workers they could find.

In September 2005, a report on the health impacts of Chornobyl by the UN Chernobyl Forum (seven UN agencies plus the World Bank and officials from Belarus, Ukraine, and Russia) said only 50 deaths could be attributed to Chornobyl and ultimately 4,000 will die as a result of the accident. The Chernobyl Forum report acknowledges that nine children died from thyroid cancer and that 4,000 children contracted the disease, but puts the survival rate at 99 percent. It denies any link with fertility problems and says that the most significant health problems are due to poverty, lifestyle (e.g., smoking, poor diet), and emotional problems, especially among evacuees. Marples notes that the overall assessment of the Chernobyl Forum is "a reassuring message."

The reality on the ground offers a different picture. In Gomel, a city of 700,000 in Belarus less than 80 kilometers from the destroyed reactor and one of the most severely contaminated areas, the documentary film *Chernobyl Heart* reports the incidence of thyroid cancer is 10,000 times higher than before the accident and by 1990 had increased 30-fold throughout Belarus, which received most of the radioactive fallout. Chernobyl.info states that congenital birth defects in Gomel have jumped 250 percent since the accident, and infant mortality is 300 percent higher than in the rest of Europe. A doctor interviewed in *Chernobyl Heart* says just 15 to 20 percent of the babies born at the Gomel Maternity Hospital are healthy. Chernobyl Children's Project International executive director Adi Roche says it's impossible to prove that Chornobyl caused the problems: "All we can say is the defects are increasing, the illnesses are increasing, the genetic damage is increasing." Referring to a facility for abandoned children, she adds, "places like this didn't exist before Chornobyl, so it speaks for itself." Marples, who has made numerous trips to the Chornobyl region over the past 20 years, reports the health crisis in Belarus today is so serious that there are open discussions of a "demographic doomsday."

The long-lived nature of the radionuclides and the fact that they are migrating through the contaminated regions' ecosystems into the groundwater and food chain further complicate the task of predicting the full impact of the disaster. But as the global campaign to build new reactors gains momentum, it bears asking whether a Chornobyl could happen elsewhere.

It Can't Happen Here

Nobody wants any more Chornobyls. The question is, can that outcome be ensured without phasing out nuclear power altogether? The Nuclear Energy Institute (NEI), the trade association and lobbying arm of the American nuclear power industry, says a Chornobyl-type accident is highly unlikely in the United States because of "key differences in U.S. reactor design, regulation, and emergency preparedness." Safety is assured, NEI says, by the strategy of "defense in depth," which relies on a combination of multiple, redundant, independently operating safety systems; physical barriers such as the steel reactor vessel and the typically three- to four-foot steel-reinforced concrete containment dome that would stop radiation from escaping; ongoing preventive and corrective maintenance; ongoing training of technical staff; and extensive government oversight. A key argument for nuclear power these days is the claim that nuclear reactors are safe and reliable.

The U.S. nuclear fleet has substantially increased its "capacity factor" (for a given period, the output of a generating unit as a percentage of total possible output if run at full power) since 1980. However, David Lochbaum, director of the Nuclear Safety Project at the Union of Concerned Scientists (UCS), points out that since the Three Mile Island accident in central Pennsylvania in 1979, 45 reactors (out of 104 operating U.S. units) have been shut down longer than one year to restore safety margins. A nuclear engineer by training, Lochbaum left the industry after 17 years when he and a co-worker were unable to get their employer or the Nuclear Regulatory Commission (NRC) to address safety issues at the Susquehanna plant in northeastern Pennsylvania. (The problem at that plant and others across the country was corrected after they testified before Congress.) For the last 10 years Lochbaum has been at UCS monitoring the safety of the nation's nuclear power plants and raising concerns with the NRC. He does not share the industry's confidence in the safety of the current fleet.

Nuclear power plants are incredibly complex systems that perform a relatively simple task: heating water to create steam that spins a turbine and generates electricity. Lochbaum explains that nuclear plant safety problems tend to follow a bathtub curve; the greatest number come at the beginning of a reactor's life, then after a few years when the plant is "broken in" and staff are familiar with its specific needs, problems drop and level off until the plant begins to age.

Most of the current U.S. fleet is either in or entering its twilight years, and since the late 1990s the NRC has allowed reactors to increase the amount of electricity they generate by up to 20 percent, which exceeds what the plants were designed to handle. Such "power uprates" push greater volumes of cooling water through the plant, causing more wear and tear on pipes and other equipment. The agency has also granted 20-year license extensions to 39 reactors, and most of the rest are expected to apply before their initial 40-year licenses expire. At the same time, Lochbaum says, the NRC is cutting back on the amount and frequency of safety tests and inspections. Tests that were carried out quarterly are now performed annually, and once-annual tests are now done when reactors are shut down for refueling, about every two years.

The NRC maintains that it is providing adequate oversight to keep the public safe and prevent serious reactor accidents. Gary Holahan, an official in the NRC's Office of Nuclear Reactor Regulation, explains that extended power uprates, which raise the power output of a reactor between 7 and 20 percent, require modifications to the plant that involve upgrading or replacing equipment like high pressure turbines, pumps, motors, main generators, and transformers. Before a power uprate is granted, he says, the NRC must make a finding that it complies with federal regulations and that there's "a reasonable assurance" that the health and safety of the public will not be endangered.

Lochbaum says the NRC's handling of the large power uprates illustrates the problems with its oversight. In an issue brief entitled "Snap, Crackle, & Pop: The BWR Power Uprate Experiment," he says the Quad Cities Unit 2 reactor in Illinois "literally began shaking itself apart at the higher power level" after operating for nearly 30 years at its originally licensed power level. After the uprate was approved, the steam dryer developed a 2.7 meter crack, and the component was replaced in May 2005. In early April of this year, he says Quad Cities staff found a 1.5 meter crack in the new steam dryer, and they still don't know exactly what is causing the problem. After the problem was first reported, manufacturer General Electric (GE) surveyed 15 of its other boiling water reactors around the world that had been granted 20-percent power uprates and reported problems—all vibration related—in 13.

Despite objections from the Vermont Public Service Board and one of its own commissioners, the NRC recently granted a 20-percent power uprate to the 33-year-old Vermont Yankee reactor. Stuart Richards, deputy director of the NRC's Division of Inspection, says the commission approved the power uprate after a first-time pilot engineering inspection that included an 11,000-manhour technical review failed to find any significant safety issues. "It's not the age of the plant but the physical condition of the components and how well the facility maintains the plant" that is important, he says. In addition, the power is being increased in NRC-monitored stages. But none of this reassures Lochbaum, who points out that this single-unit plant was badly maintained for much of its operating life, making it an especially poor candidate for a practice known to stress reactors. Applications for extended power uprates at six reactors are pending, and the NRC expects nine more through 2011.

The NRC says it is doing a smarter job of regulating the industry today by pinpointing areas likely to need more attention. "The agency and the industry as a whole over the last 10 to 15 years have developed better and better tools to determine what is risk-significant and what is less risk-significant," Richards explains. "So in some cases where in the past we have required more maintenance or surveillance, now those requirements are less stringent, because the components have been demonstrated to be less significant." In other cases, he says, performing too much maintenance can be detrimental, because the components are needed to do their job, and they can be tested "to the point where it causes them to have degradation."

Lochbaum says the flaw in that logic is well illustrated by a near miss at the Davis-Besse plant in Ohio. In 2002 it was discovered that boric acid escaping from the reactor for several years had eaten a 15-centimeter hole in the reactor vessel's steel lid, leaving a thin layer of stainless steel bulging outward from the pressure. Boric acid had been observed on the vessel head in 1996, 1998, and again in 2000, and NRC staff drafted an order in November 2001 to shut Davis-Besse down for a safety inspection. NRC nevertheless allowed the reactor to continue operating until February 2002, when plant workers almost accidentally found the hole. If the reactor head had burst, the reactor would likely have melted down.

Lochbaum and former NRC commissioner Peter Bradford say the Davis-Besse incident and numerous others indicate that the agency seems to be more interested in the short-term economic interest of the nuclear industry than in carrying out its mission to protect public health and safety. Bradford points to an internal NRC survey in 2002 revealing that nearly half of all NRC employees thought they would be retaliated against if they raised safety concerns, and that of those who did report problems, one-third said they suffered harassment as a result. Several critics say the safety culture of the commission changed after Senator Pete Domenici—perhaps the nuclear industry's biggest champion in Congress—told the NRC chairman in 1998 that he would cut the agency's budget by a third if it didn't reverse its "adversarial attitude" toward the industry.

Given the regulatory environment and an aging fleet of reactors, Lochbaum fears that another serious accident is inevitable. He uses the analogy of a slot machine, but instead of oranges, bananas, and cherries, the winning combination is an initiating event, like a broken pipe or a fire; equipment failure; and human error. "As the plants get older, we're starting to see the wheels come up more often, which suggests it's only a matter of time before all three come up at once," he says.

Nuclear proponents claim the new advanced designs are much safer. Unlike current plants with their multiple back-up systems, the new "passive safety" designs, such as Westinghouse's AP1000 pressurized water reactor (PWR) and GE's ABWR (Advanced Boiling Water Reactor) and ESBWR (Economic Simplified Boiling Water Reactor), rely on gravity rather than an army of pumps to push the water up into the reactor vessel and through the cooling system. Because the systems are smaller, there are fewer components to break.

Physicist Ed Lyman, a colleague of Lochbaum's at UCS who has been studying the new designs, is skeptical of the safety claims of the passive designs. He explains that slashing costs, particularly of piping and the enormously expensive steel-reinforced rebar concrete, motivated the new LWR designs, not safety. It was thought that if the power output of the reactors was lower, a gravity-driven system could dump water into the reactor core without the need for forced circulation and its miles of pipes and accompanying equipment.

Numerous tests of the gravity-driven water system for the AP600, the smaller predecessor to the AP 1000, showed the system worked, and NRC certified the design. However, the current trend in reactors is for larger units with higher output. The cost of the AP600 wasn't low enough to offset the loss in generation capacity, so none sold. The AP600 then morphed into the AP1000. GE's new "passive safety" designs followed a similar trajectory beginning with a 600-megawatt design, the SBWR (Simplified Boiling Water Reactor). The company's next design, the ABWR, was 1,350 megawatts, and its ESBWR is 1,560.

The NRC recently certified the AP1000. Lyman is concerned the agency is relying on computer modeling rather than experimental data to demonstrate that gravity-driven cooling will work in these much larger designs. He's also troubled that the containment structures of the new PWRs are less robust than those in the current fleet. NRC's Gary Holahan acknowledges that the agency relied on the tests from the AP600 and computer modeling for the AP 1000, but says that after extensive review by the commission's technical staff and the Advisory Committee on Reactor Safeguards, it determined that additional testing was not necessary. Nor does the NRC have any concerns about the thickness of the AP1000's containment dome compared to those of existing PWRs.

Increasing numbers of nuclear proponents and news reports are describing new reactor designs, such as the pebble bed modular reactor, as "accident-proof" or "fail-safe"—so safe, in fact, that the pebble bed doesn't need (or have) a containment structure. Lyman disagrees. The pebble bed is moderated by helium instead of water and uses uranium fuel pellets encased in silicon carbide, ceramic material, and graphite. He says experiments conducted at the AVR demonstration reactor in Germany, the first one ever built, have shown that the models underestimated how hot the pellets could get. The pellets degrade quickly upon reaching the critical temperature, which could lead to a large release of radiation. "So, they just don't have the predictive capacity or the understanding of how these reactors or the fuel technology work to say it's meltdown-proof," he says.

Going to Waste

In the light-water reactors that make up the majority of the world's reactor fleet, uranium fuel is loaded into the reactor, then bombarded by neutrons to trigger the nuclear fission chain reaction. After awhile all of the fissionable material in the uranium fuel is used up, or "spent." But the neutron bombardment makes the fuel two-and-a-half million times more radioactive, according to Marvin Resnikoff, a nuclear physicist with Radioactive Waste Management Associates in New York. By 2035, American nuclear power plants will have created an estimated 105,000 metric tons of spent fuel that is so deadly it must be completely isolated from the environment for tens or even hundreds of thousands of years. A Nevada state agency report put the toxicity in perspective: even after 10 years out of the reactor, an unshielded spent fuel assembly would emit enough radiation to kill somebody standing a meter away from it in less than three minutes.

No country has yet successfully dealt with its high-level nuclear waste from the first generation of reactors, let alone made plans for the added waste from a vast expansion of nuclear power. Most agree that deep geologic burial is the safest and cheapest disposal method, and countries are in various stages of picking and developing their sites. Steve Frishman of the Nevada Agency for Nuclear Projects thinks the Finns are furthest along, having chosen a permanent repository at a crystalline bedrock site at Olkiluoto that already hosts two operating reactors and one under construction. The site has been tested extensively to ensure it will effectively isolate the waste 420–520 meters down. The repository is expected to open in 2020.

The Swedes also plan to construct their repository in a deep underground granite site, though they have not yet picked the final location. They will encapsulate the spent nuclear fuel in copper canisters surrounded by bentonite clay, which swells up and makes its own watertight seal when exposed to water. Frishman says that's an extra precaution, because while they will probably find some water 500 meters underground where they plan to put the canisters, the water there is not oxygenated and would probably not corrode the canisters even if it did come in contact with them. The Swedish approach is enormously expensive, but they say results, not costs, are guiding their decisions.

These approaches seem reasonably cautious and thus offer some hope that the waste problem—which must be solved no matter what happens to nuclear power—might not be intractable. The U.S. approach, however, is less reassuring. Politics, rather than science-determined suitability, led the U.S. Department of Energy (DOE) to Yucca Mountain, a ridge of volcanic tuff on the edge of the U.S. Nuclear Test Site in the Nevada desert about 145 kilometers northwest of Las Vegas. Nevada was designated by default in an amendment (later tagged as the "Screw Nevada Bill") to the 1982 Nuclear Waste Policy Act that prohibited DOE from considering any sites in granite.

Aside from being located in the third most seismically active region in the country, Yucca Mountain is so porous that after just 50 years isotopes from atmospheric atom bomb tests have already seeped down into the underlying aquifer. But since the mountain was designated as the nation's only repository site, Frishman says DOE has been trying to engineer its way around the problems, and when it can't do that, change the rules. The latest attempt is legislation proposed by the Bush administration that among other things would raise the repository's current legal limit of 70,000 metric tons of high-level waste, remove the nuclear waste fund (money collected over the years from ratepayers by nuclear utilities to build a repository) from federal budgetary oversight, and exempt metals in the underground metal containers from regulation, leaving chromium, molybdenum, and zinc free to contaminate the area's groundwater.

On the basis of the geological instability of the site, Nevada is aggressively fighting the repository. In 2004 a federal court ruled that an Environmental Protection Agency (EPA) health standard that applied for the first 10,000 years was inadequate because the National Academy of Sciences determined that peak doses would likely occur at least 200,000 years after the waste was placed in the site. NRC therefore could not license the site. EPA has since proposed another health standard, which appears to ignore the court ruling by allowing radiation exposure to residents of the nearby Amargossa Valley to jump from a mean of 15 millirems per year for the first 10,000 years to a median value of 350 millirems per year subsequently.

Ultimately, Frishman does not believe Yucca Mountain can meet any rea[l] health-based standard. Furthermore, he points out, whatever standard i[s] finally adopted is irrelevant once a licensing decision is made and the waste i[s] placed in the repository: "The site is the standard."

Reprocessing

The nuclear power industry did not expect Nevada's legal challenges to be s[o] successful, and U.S. nuclear proponents have begun to think beyond Yucc[a] Mountain. They maintain that the development of fast breeder reactor which create nuclear fuel by producing more fissile material than they consume, along with reprocessing the spent fuel (separating out the still-usable plutonium and uranium) will reduce the volume of waste and negate the need for geologic disposal.

Since it was originally assumed that reprocessing would be part of the nuclear fuel cycle, commercial reactors were not designed to house all of the waste they would create during their operational lives. Three commercial reprocessing facilities were built in the United States, though only one, at West Valley in western New York state, ever operated. After six years of troubled operation marked by accidents, mishandling of high-level wastes, and contamination of nearby waterways, it was shut down in 1972. In 1977 the Carter administration banned reprocessing due to concerns about nuclear weapons proliferation after India stunned the world by testing its first atomic bomb, which was made with plutonium from its reprocessing facility. According to UCS, approximately 240 metric tons of separated plutonium—enough for 40,000 nuclear weapons—was in storage worldwide as of the end of 2003. Reprocessing the U.S. spent fuel inventory would add more than 500 metric tons.

France, Britain, Russia, India, and Japan currently reprocess spent fuel, and the Bush administration is pushing to revive reprocessing in the United States. It has allocated $130 million to begin developing an "integrated spent fuel cycle," and recently announced another $250 million, primarily to develop UREX+, a technology said to address proliferation concerns by leaving the separated plutonium too radioactive for potential thieves to handle. In addition, the U.S. Congress has directed the administration to prepare a plan by 2007 to pick a technology to reprocess all of the spent fuel from commercial nuclear reactors and start building an engineering-scale demonstration plant.

UCS's Ed Lyman says it is "a myth" that reprocessing spent nuclear fuel reduces the volume of nuclear waste: "All reprocessing does is take spent fuel that's compact, and it spreads—smears—it out into dozens of different places." Current reprocessing technology uses nitric acid to dissolve the fuel assemblies and separate out plutonium and uranium. But it also leaves behind numerous extremely radioactive fission products as well as high-level liquid waste that is typically solidified in glass. In the process, a lot of radioactive gas is discharged into the environment, and there is additional liquid waste that's too expensive to isolate, he says: "So, that's just dumped into the ocean—that's the practice in France and the U.K."

Matthew Bunn, acting director of Harvard University's Project on Managing the Atom, has laid out a number of additional arguments against reprocessing. First, reprocessing spent fuel doesn't negate the need for or reduce the space required in a permanent repository, because a repository's size is determined by the heat output of the waste, not its volume. Second, reprocessing would substantially increase the cost of managing nuclear waste and wouldn't make sense economically unless uranium topped US$360 per kilogram, a price he says is not likely for several decades, if ever. Third, in this new era of heightened violence and terrorism, the proliferation risks—which would not be addressed by the new reprocessing technologies—take on even greater urgency. Fourth, reprocessing is also a dangerous technology with a track record of terrible accidents, including the world's worst pre-Chornobyl nuclear accident (a 1957 explosion at a reprocessing plant near Khystym in Russia) and other incidents in Russia and Japan as recently as the 1990s. Fifth, the new "advanced" reprocessing technologies, UREX+ and pyroprocessing, are complex, expensive, in their infancy, and unlikely to yield substantial improvements over existing reprocessing methods. Finally, Bunn argues, the Bush administration's rush to embrace reprocessing spent nuclear fuel is premature and unnecessary, since the spent fuel can remain in dry casks at nuclear power plants for decades while better solutions are sought.

Solution in Search of Problem

In the end, the case for nuclear power hinges on an evaluation of its costs and benefits compared with those of the alternatives. Many observers expect a growing ecological, social, and economic crisis unless we figure out how to retard and ultimately reverse climate change by weaning ourselves off increasingly scarce, expensive, and conflict-ridden fossil fuels. Nuclear power, until recently a pariah due to its enormous cost and demonstrated potential for serious accidents, is now touted as an indispensable solution. Nuclear power's dark side—its environmental legacy, high cost, and danger of accidents and the spread of atomic weapons—is currently downplayed. No energy system is without costs, but alternatives that avoid these particularly grave drawbacks do exist.

Space limitations preclude a comprehensive review of the alternatives, but their prospects have never been brighter. For instance, a 2005 report by the New Economics Foundation (NEF) says a broad mix of renewable energy sources that includes micro, small-, medium- and large-scale technologies applied flexibly could "more than meet all our needs." Besides solar and wind power, the mix includes tidal, wave, small-scale hydro, geothermal, biomass, and landfill gas. Rather than relying exclusively on large baseload suppliers of electricity like nuclear plants, or single sources of renewable energy that are not always available, the foundation says the key is setting up an extensive, diverse, and decentralized network of power sources, which would also be much less susceptible to widespread power outages. The total capital cost of setting up such a system has not been calculated and would vary greatly depending on whether it was implemented all at once or incrementally, building on transition technologies. According to the NEF report, a nuclear-generated kilowatthour of electricity—factoring in construction and operating costs but not waste management, insurance against accidents, or preventing nuclear weapons proliferation—costs up to 15.6 U.S. cents, significantly higher than other sources.

Governments and markets are beginning to recognize the potential of renewable energy and its use is growing rapidly. According to Worldwatch Institute's *Renewables 2005,* global investment in renewable energy in 2004 was about US$30 billion. The report points out that renewable sources generated 20 percent of the amount of electricity produced by the world's 443 operating nuclear reactors in 2004. Renewables now account for 20–25 percent of global power sector investment, and the Organisation for Economic Co-operation and

Development predicts that over the next 30 years one-third of the investment in new power sources in OECD countries will be for renewable energy.

Alternative energy guru Amory Lovins says the investment in alternatives is currently "an order of magnitude" greater than that now being spent on building new nuclear plants. Lovins has been preaching lower-cost alternatives, including energy conservation, for more than three decades, and the realization of his vision of sustainable, renewable energy is perhaps closer than ever. He argues that the current moves to re-embrace nuclear power are a huge step backwards, and that contrary to claims that we need to consider all options to deal with global warming, nuclear power would actually hinder the effort because of the high cost and the long time it would take to get enough carbon-displacing nuclear plants up and running. "In practice, keeping nuclear power alive means diverting private and public investment from the cheaper market winners—cogeneration, renewables, and efficiency—to the costly market loser. Its higher cost than competitors, per unit of net CO_2 displaced, means that every dollar invested in nuclear expansion will *worsen* climate change," he writes in his 2005 paper "Nuclear Power: Economics and Climate-Protection Potential."

[D]oubling the world's current nuclear energy output would reduce global carbon emissions by just one-seventh of the amount required to avoid the worst impacts of global warming. Researchers at the Massachusetts Institute of Technology point out that achieving even this inadequate result would require siting a permanent repository the size of Yucca Mountain every three to four years to deal with the additional waste—an enormous and expensive challenge. Given nuclear power's drawbacks, and the growth and promise of clean, lower cost, less dangerous alternatives, the case for nuclear power wobbles badly. Stripped of the pretext that nuclear power is the answer to climate change, the case essentially collapses.

POSTSCRIPT

Is It Time to Revive Nuclear Power?

Christine Laurent, in "Beating Global Warming with Nuclear Power?" *UNESCO Courier* (February 2001), notes that "For several years, the nuclear energy industry has attempted to cloak itself in different ecological robes. Its credo: nuclear energy is a formidable asset in battle against global warming because it emits very small amounts of greenhouse gases. This stance, first presented in the late 1980s when the extent of the phenomenon was still the subject of controversy, is now at the heart of policy debates over how to avoid droughts, downpours and floods." Laurent adds that it makes more sense to focus on reducing carbon emissions by reducing energy consumption. Robert Evans, "Nuclear Power: Back in the Game," *Power Engineering* (October 2005), reports that a number of power companies are now considering new nuclear power plants. See also Eliot Marshall, "Is the Friendly Atom Poised for a Comeback?", Daniel Clery, "Nuclear Industry Dares to Dream of a New Dawn," *Science* (August 19, 2005), and Josh Goodman, "The Nuclear Option," *Governing* (November 2006). Nuclear momentum is growing, says Charles Petit, "Nuclear Power: Risking a Comeback," *National Geographic* (April 2006), thanks in part to new technologies. John Geddes, "Harper Embraces the Nuclear Future," *Maclean's* (May 7, 2007), notes that the Canadian Prime Minister has endorsed the expanded use of nuclear power as a way to reduce fossil fuel use and greenhouse gas emissions. Karen Charman, "Brave Nuclear World? Part I" *World Watch* (May/June 2006), objects that producing nuclear fuel uses huge amounts of electricity derived from fossil fuels, so going nuclear can hardly prevent all releases of carbon dioxide (although using electricity derived from nuclear power would reduce the problem). She also notes that "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. . . . Burning coal—the single largest source of air pollution in the United States—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."

Michael J. Wallace tells us that there are 103 nuclear reactors operating in the United States today. Stephen Ansolabehere, et al., "The Future of Nuclear Power," *An Interdisciplinary MIT* Study (MIT, 2003), note that in 2000 there were 352 in the developed world as a whole, and a mere 15 in developing nations, and that even a very large increase in the number of nuclear power plants—to 1,000 to 1,500—will not stop all releases of carbon dioxide.

In fact, if carbon emissions double by 2050 as expected, from 6,500 to 13,000 million metric tons per year, the 1,800 million metric tons not emitted because of nuclear power will seem relatively insignificant. Nevertheless, say John M. Deutch and Ernest J. Moniz, "The Nuclear Option," *Scientific American* (September 2006), such a cut in carbon emissions would be "significant." However, says Jose Goldemberg, "The Limited Appeal of Nuclear Energy," *Scientific American* (July 2007), nuclear power is likely to be of limited value to developing nations, which will need to find other options.

The debate over the future of nuclear power is likely to remain vigorous for some time to come. But as Richard A. Meserve says in a *Science* editorial ("Global Warming and Nuclear Power," *Science* [January 23, 2004]), "For those who are serious about confronting global warming, nuclear power should be seen as part of the solution. Although it is unlikely that many environmental groups will become enthusiastic proponents of nuclear power, the harsh reality is that any serious program to address global warming cannot afford to jettison any technology prematurely. . . . The stakes are large, and the scientific and educational community should seek to ensure that the public understands the critical link between nuclear power and climate change." Paul Lorenzini, "A Second Look at Nuclear Power," *Issues in Science and Technology* (Spring 2005), argues that the goal must be energy "sufficiency for the foreseeable future with minimal environmental impact." Nuclear power can be part of the answer, but making it happen requires that we shed ideological biases. "It means ceasing to deceive ourselves about what might be possible."

Alvin M. Weinberg, former director of the Oak Ridge National Laboratory, notes in "New Life for Nuclear Power," *Issues in Science and Technology* (Summer 2003), that to make a serious dent in carbon emissions would require perhaps four times as many reactors as suggested in the MIT study. The accompanying safety and security problems would be challenging. If the challenges can be met, says John J. Taylor, retired vice president for nuclear power at the Electric Power Research Institute, in "The Nuclear Power Bargain," *Issues in Science and Technology* (Spring 2004), there are a great many potential benefits. Are new reactor technologies needed? Richard K. Lester, "New Nukes," *Issues in Science and Technology* (Summer 2006), says that better centralized waste storage is what is needed, at least in the short term.

Environmental groups such as Friends of the Earth are adamantly opposed, saying "Those who back nuclear over renewables and increased energy efficiency completely fail to acknowledge the deadly radioactive legacy nuclear power has created and continues to create" ("Nuclear Power Revival Plan Slammed," Press Release, April 18, 2004, http://www.foe-scotland.org.uk/press/pr20040408.html). However, there are signs that some environmentalists do not agree; see William M. Welch, "Some Rethinking Nuke Opposition," *USA Today* (March 23, 2007).