ISSUE 12

Is It Time to Revive Nuclear Power?

YES: Allison MacFarlane, from "Nuclear Power: A Panacea for Future Energy Needs?" *Environment* (March/April 2010)

NO: Kristin Shrader-Frechette, from "Five Myths About Nuclear Energy," *America* (June 23–30, 2008)

Learning Outcomes

After studying this issue, students will be able to:

- Compare the hazards of nuclear power and global warming.
- Explain how nuclear power avoids the release of greenhouse gases.
- Explain why it will be difficult to shift from fossil fuels to nuclear power rapidly.
- Describe the obstacles that must be overcome before nuclear power can be more widely used.

ISSUE SUMMARY

YES: Allison MacFarlane argues that although nuclear power poses serious problems to be overcome, it "offers a potential avenue to significantly mitigate carbon dioxide emissions while still providing baseload power required in today's world." However, it will take many years to build the necessary number of new nuclear power plants.

NO: Professor Kristin Shrader-Frechette argues that nuclear power is one of the most impractical and risky of energy sources. Renewable energy sources such as wind and solar are a sounder choice.

The technology of releasing for human use the energy that holds the atom together did not get off to an auspicious start. Its first significant application was military, and the deaths associated with the Hiroshima and Nagasaki explosions have ever since tainted the technology with negative associations. 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. Safety measures have worked well when needed—Three Mile Island, often cited as a horrific example of what can go wrong, 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 proved to add 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, or 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. Avoiding the use of fossil fuels is an important benefit; see Robert L. Hirsch, Roger H. Bezdek, and Robert M. Wendling, "Peaking Oil Production: Sooner Rather than Later?" *Issues in Science and Technology* (Spring 2005). But avoiding carbon dioxide emissions may be more important at a time when society is concerned about global warming, and this is the benefit that prompted James Lovelock, creator of the Gaia Hypothesis and hero to environmentalists everywhere, to say, "If we had nuclear power we wouldn't be in this mess now, and whose fault was it? It was [the anti-nuclear environmentalists']." See his autobiography, *Homage to Gaia: The Life of an Independent Scientist* (Oxford University Press, 2001).

Others have also seen this point. The OECD's Nuclear Energy Agency ("Nuclear Power and Climate Change" (Paris, France, 1998); 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. Robert C. Morris published *The Environmental Case for Nuclear Power: Economic, Medical, and Political Considerations* (Paragon House) in 2000. "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). Stewart Brand, for long a leading environmentalist, predicts in "Environmental Heresies," *Technology Review* (May 2005), that nuclear power will soon be seen as the "green" energy technology. David Talbot, "Nuclear Powers Up," *Technology Review* (September 2005), notes, "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. Iain Murray, "Nuclear Power? Yes, Please," *National Review* (June 16, 2008), argues that the world's experience with nuclear power has shown it to be both safe and reliable.

Costs can be contained, and if one is concerned about global warming, the case for nuclear power is unassailable.

Robert Evans, "Nuclear Power: Back in the Game," *Power Engineering* (October 2005), reports that a number of power companies are considering new nuclear power plants. See also Eliot Marshall, "Is the Friendly Atom Poised for a Comeback?" and Daniel Clery, "Nuclear Industry Dares to Dream of a New Dawn," *Science* (August 19, 2005). Nuclear momentum is growing, says Charles Petit, "Nuclear Power: Risking a Comeback," *National Geographic* (April 2006), thanks in part to new technologies. 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."

Stephen Ansolabehere et al., "The Future of Nuclear Power," *An Interdisciplinary MIT Study* (MIT, 2003), note that in 2000 there were 352 nuclear power plants 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—from 1000 to 1500—will not stop all releases of carbon dioxide. In fact, if carbon emissions double by 2050 as expected, from 6500 to 13,000 million metric tons per year, the 1800 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." Christine Laurent, in "Beating Global Warming with Nuclear Power?" *UNESCO Courier* (February 2001), notes, "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 the 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.

Even though President Obama declared support for "a new generation of safe, clean nuclear power plants" in his January 27, 2010, State of the Union speech and the Department of Energy soon proposed massive loan guarantees for the industry (see Pam Russell and Pam Hunter, "Nuclear Resurgence Poised for Liftoff," *ENR: Engineering News-Record* (March 1, 2010), 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." Charles Forsberg, "The Real Path to Green Energy: Hybrid Nuclear-Renewable Power," *Bulletin of the Atomic Scientists* (November/December 2009), suggests that the best use of nuclear power will be to provide energy for biofuel refineries and as backup for solar and wind power.

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, despite the Obama Administration's declaration that Yucca Mountain, the only U.S. storage site under development, will no longer be supported. On the other hand, some new technologies are available already; see Carol Matlack, "A High-End Bet on Nuclear Power," *BusinessWeek* (March 15, 2010).

Environmental groups such as Friends of the Earth are adamantly opposed, but there are signs that some environmentalists do not agree; see William M. Welch, "Some Rethinking Nuke Opposition," *USA Today* (March 23, 2007). Judith Lewis, "The Nuclear Option," *Mother Jones* (May/June 2008), concludes that "When rising seas flood our coasts, the idea of producing electricity from the most terrifying force ever harnessed may not seem so frightening—or expensive—at all."

In the YES selection, Allison MacFarlane argues that although nuclear power poses serious problems to be overcome, it "offers a potential avenue to significantly mitigate carbon dioxide emissions while still providing baseload power required in today's world." However, it will take many years to build the necessary number of new nuclear power plants. Professor Kristin Shrader-Frechette argues that nuclear power is one of the most impractical and risky of energy sources. Renewable energy sources such as wind and solar are a sounder choice.

YES

Allison MacFarlane

Nuclear Power: A Panacea for Future Energy Needs?

Each week seems to bring further evidence that the Earth is warming at a faster rate than previously estimated. Pressure is building to replace power sources that emit carbon dioxide with those that do not. It is in this "climate" that nuclear energy is getting a second look. Once relegated to the junk heap after the Three Mile Island and Chernobyl disasters brought the dangers associated with nuclear power to everyone's attention, nuclear power may now be undergoing a "renaissance," as the nuclear industry likes to say. Environmentalists such as Stewart Brand, originator of the Whole Earth Catalog, and Patrick Moore of Greenpeace have started pushing nuclear power as a ready solution to the problem of electricity production without carbon emissions.

Over the past few years, more than 40 countries that currently do not have nuclear power have expressed interest in acquiring it to address their future energy needs, and a few are making significant progress. "Every country has the right to make use of nuclear power, as well as the responsibility to do it in accordance with the highest standards of safety, security, and non-proliferation," stated Mohamed ElBaradei, then–Director General of the International Atomic Energy Agency (IAEA).

All this enthusiasm for nuclear power must be tempered by plain reality. Construction of new nuclear power reactors is still one of the most capital-intensive ventures compared with other energy sources such as coal and natural gas. High-level nuclear waste from the nuclear industry waits in above-ground temporary storage until a final solution is implemented. And the connection between nuclear power and nuclear weapons continues to be perceived as a threat by the international community. Given the pushes and pulls for nuclear power, what is the likelihood that the future will entail a vast expansion of nuclear power on a global scale, and if so, what are its implications, and can this expansion be considered "sustainable" in a development sense?

How Does Nuclear Perform Now?

Globally, there are 436 reactors with a generating capacity of 372 GWe (gigawatts electric) located in 31 countries. [In] 2006, nuclear power generated 15 percent of the world's electricity. Currently, the IAEA estimates that 52 reactors are under construction, whereas the World Nuclear Association lists 71 reactors that will come online between 2009 and 2015. Of the 52 listed by the IAEA, . . . over 85 percent of them are located in Asia and Eastern Europe, and they would add 46 GWe to the existing generating capacity. Of the 52 under construction, 12 of them began construction before 1990, and it is not clear that these projects will ever be completed. At the same time, existing reactors are aging. The average age of the operating fleet in 2007 was 23 years. Most reactors were originally designed for a 40-year life span, but some countries, such as the United States, have recently been granting 20-year life extensions to their fleet.

Carbon Dioxide Emissions Reductions

Nuclear reactors do not emit carbon dioxide to produce electricity because their fuel is uranium-based. This is not to say that nuclear power is emission free—it is not. Carbon dioxide is emitted during the lifecycle of nuclear power production, particularly during the uranium mining, milling, and fuel fabrication processes, and during the construction of new nuclear plants. Nonetheless, nuclear power displaces large volumes of carbon dioxide in comparison with fossil fuel plants.

For instance, in 2006, global nuclear power provided 2594 TWh of electricity. If that electricity was produced by coal and natural gas plants combined, it would have added 3904 million tons of carbon-dioxide equivalent to the atmosphere. Compared to annual emissions of 29,195 million tons of CO_2 equivalent from fossil fuel burning, nuclear power saved about 13 percent.

Certainly if nuclear power grew its capacity, it could contribute significantly to carbon dioxide emissions reductions. Scholars have suggested that 1000 GWe nuclear capacity (in addition to the existing capacity) could reduce potential carbon dioxide emissions growth by 15–25 percent by 2050. Of course, adding 1000 GWe is equivalent to building 1000 new large-scale 1000-MWe plants over the next 40 years, which requires that 25 plants be built per year, an ambitious schedule, but doable. Such plans are not on anyone's drawing board at the moment, though.

Past and Present Safety Issues

Since the Chernobyl accident in 1986, there have been no catastrophic failures at nuclear power plants. That's not to say that there have not been problems, but the overall global safety record since 1986 has been good. This is, in large part, due to vigilant oversight of the nuclear industry and redundant design in safety features.

Issues may arise from aging plants as equipment fails. A case in point is the Davis-Besse reactor in Ohio, which developed an undetected hole in the reactor pressure vessel head, leaving only 0.95 cm of stainless steel to protect against a loss of coolant accident. The hole, which was almost 13 cm in diameter and 17 cm deep, was caused by boric acid corrosion from the borated cooling water in the reactor. The U.S. Nuclear Regulatory Commission's (NRC)

Inspector General found that the NRC itself did not demand more rapid action to address the potentially dangerous issue because it wanted to "lessen the financial impact" on the utility plant operator.

The best way to continue to ensure reactor safety is to follow the advice of the Kemeney Commission, which investigated the 1979 Three Mile Island accident in the United States. They recommended that constant vigilance was required to ensure reactor safety; complacency about the safety of nuclear power would lead to accidents.

Current Waste Management Strategies

With over 50 years of power reactor operation, by 2007 the world had accumulated almost 365,000 m^3 of high-level nuclear waste, including spent nuclear fuel and reprocessing wastes; over 3 million m^3 of long-lived low- and intermediate-level waste; and over 2 million m^3 of short-lived low- and intermediate-level waste. Though many countries have low-level waste disposal facilities and a few have intermediate-level facilities, none have opened a high-level nuclear waste disposal facility. Most spent nuclear fuel remains in cooling pools and dry storage casks at power reactors; some has been reprocessed, and the resulting high-level waste has been vitrified and sits in storage facilities.

Most countries with significant nuclear power generation have decided that high-level nuclear waste should be disposed of in mined geologic repositories. Four countries have been focusing on a single site within their borders. In the United States, the Yucca Mountain, Nevada, site is currently undergoing licensing review for repository construction by the Nuclear Regulatory Commission, although the current Obama Administration has said it will not support the Yucca Mountain site. . . .

Currently there are two management pathways for handling the spent nuclear fuel generated by power reactors. One is the "open cycle," in which spent fuel is considered high-level waste and will be directly disposed of in a repository. The United States, Sweden, Finland, Canada, and others follow this pathway. The second is the "closed cycle," as practiced by France, the United Kingdom, Japan, Russia, and India, in which spent nuclear fuel is reprocessed, the plutonium and uranium extracted, and the remaining waste turned into glass logs destined for a repository. The separated plutonium is then made into new nuclear fuel known as MOX (mixed oxide), but as of yet, it is not reprocessed a second time. The extracted uranium tends to be considered a waste product, as it is too expensive to clean up for reuse.

Reprocessing does reduce the volume of high-level waste by a factor of 4 to 10 times. But this volume reduction does not imply a corresponding capacity reduction in a geologic repository, because volume is not the relevant unit of measure for capacity; heat production and radionuclide composition of the waste are. In addition, reprocessing generates large volumes of low- and intermediate-level wastes, some of which require their own repository. As a result, reprocessing as it is currently practiced has a limited impact on repository size. And no matter which cycle is used, open or closed, a repository will be required in the end.

Issues for the Future

For developed countries, nuclear power can significantly offset carbon dioxide emissions, whereas for developing countries, nuclear power has the potential to electrify the country as well as provide desalination services to address dwindling water supplies. An expansion of nuclear power will not occur without overcoming significant hurdles, though. Whether nuclear power will be sustainable is another issue. The UK Sustainable Development Commission recently concluded that nuclear power was not necessary to achieve a low-carbon future. Some issues associated with nuclear power are unique when compared with other electricity sources, especially in terms of safety and security.

Safety

To operate safely, nuclear power requires a large, active, and well-established infrastructure. The industry needs a trained workforce for plant construction and operation, and also for the regulatory system. In places like the United States, the existing nuclear engineering workforce is aging, and questions remain as to how rapidly it could be replaced. The construction workforce for nuclear power plants requires specialized skills, and the current number of these workers is small. Moreover, there are supply chain issues globally for the nuclear industry. Most significant is the limited capacity for heavy forgings for the reactor pressure vessels. At the moment, a single Japanese plant is capable of making these, and its availability is limited because of commitments to other industries.

For countries with no nuclear plants, an indigenous workforce would have to obtain training abroad, they would need to hire foreign workers, or they would have to rely on the reactor suppliers for a workforce. The same will be true for a regulatory infrastructure. Countries with no existing reactors will need to establish a nuclear infrastructure, again by developing it from the bottom up or by hiring/adapting one from abroad. For example, the United Arab Emirates has hired a former U.S. Nuclear Regulatory Commission official to be the Director-General of its Federal Authority for Nuclear Regulation.

Another key issue for emerging nuclear energy countries is that of liability in the case of nuclear accident for adequate protection of the victims and predictability for nuclear suppliers and insurers. A catastrophic nuclear accident could result in compensation costs that would run into the hundreds of billions of dollars. There is no single global liability regime, and currently 236 of the 436 operating reactors are not covered by liability conventions. Those countries that are party to liability conventions must assure that the legal liability is the responsibility of the reactor operator, and that there are monetary and temporal limits on liability claims.

Cost

Costs associated with the construction of new nuclear reactors may pose the greatest roadblock to the global expansion of nuclear power. . . .

Historically, reactor construction experiences delays and cost escalation. Costs of constructing U.S. nuclear power plants exceed original estimates by 200 percent to 400 percent on average. Experience in the U.S. also shows that increased construction times lead to greatly increased costs from accumulating interest costs. And construction time has not improved that much. Average construction time globally, in most recent experience between 2001–2005, was 6.8 years; at best it was five years, on average.

In the United States, nuclear reactors may cost even more per unit. Florida Power and Light, the utility poised to build two new reactors at its Turkey Point site, recently released figures of $5,780/kW to $8,071/kW, for a total of $12.1 billion to $24.3 billion, depending on the type of plants built. Costs such as these will be prohibitive for many developing countries and even for most utility companies in developed countries. Indeed, the U.S. nuclear industry is seeking further loan guarantees from the federal government over the original $18 billion laid out in the Energy Policy Act of 2005.

All of the reactor designs currently available for construction ("generation III") are large reactors, ranging in size between 600 MWe and 1700 MWe, with most averaging around 1000 MWe. The reason for this is the economies of scale associated with large reactors. Costs associated with reactor design, licensing, regulation, and operation are independent of reactor size, so larger reactors tend to cost less per kilowatt than smaller reactors. These large reactors require large, sophisticated electrical grid networks, something that many developing countries lack. Developing countries seeking nuclear power for electricity production or desalination would be better served by smaller reactors, but none is currently available, though new designs are being put forth.

Capital costs can be decreased by shortening construction time, building standardized designs (in the United States, all existing plants have unique designs), using factory construction of plant components, relying on local resources for labor and construction materials, and building more than one reactor at a site, which allows for costsharing in licensing. For example, Westinghouse's new AP-1000, under construction in Sanmen, China, uses a modular design in which factory prefabricated components can be assembled at the reactor site and put in place using a large crane. Smaller reactors might be helpful in reducing capital costs, because the industry might be able get the economic advantages of producing many units, thus overcoming the problems associated with site-built reactors. Moreover, for small, modular reactors, it may be possible to do the licensing at the manufacturing plant instead of the individual site, greatly reducing costs.

Security

One of the main security concerns about nuclear power programs is their connection to nuclear weapons development. This concern is the reason for international agreements, such as the Nuclear Nonproliferation Treaty (NPT), which guarantees that countries that do not have nuclear weapons are allowed nuclear energy technology, and for institutions such as the IAEA, whose main charge is to monitor nuclear energy programs. The general problem is that the

fuel for nuclear power plants is also the same fuel for nuclear weapons: highly enriched uranium or plutonium.

Running a nuclear power reactor poses little proliferation threat. The problem comes either at the "front-end" of the nuclear fuel cycle, associated with fuel production, or the "back-end," associated with the reprocessing of spent nuclear fuel. . . .

One additional security issue requires comment. Nuclear power plants could become terrorist targets in the future. Terrorists might desire to cause a loss of coolant accident of some sort. Particularly vulnerable in this situation are older plants with near-full or full cooling pools in which the fuel is placed in high density arrangements. These pools are located in different areas depending on the reactor design, though some are located several stories above ground. Were the pool to lose coolant, a fire could ensue, causing the release of huge amounts of radioactivity (more than Chernobyl). Fortunately, unlike dealing with proliferation issues associated with the fuel cycle, there is a relatively straightforward solution to this problem. Older fuel can be moved from the cooling pools into dry cask storage on site. Dry casks are passively cooled and therefore much safer if attacked. One of the only reasons reactors have not gone to low-density fuel arrangement in pools is cost.

Environmental/Health Impacts

Life cycle wastes from nuclear power are relatively small in volume in comparison to other energy sources such as fossil fuels. Nuclear power has low emissions from reactor operation, and overall waste production is low, especially in the open fuel cycle. More wastes are generated by reprocessing spent nuclear fuel, though again, in comparison with fossil fuels, they are small. . . .

The bulk of the volume of wastes associated with nuclear power originates from mining and processing the uranium ore for fabrication into fuel. The largest and most problematic wastes associated with mining are uranium mill tailings, which are the rock residue from the extraction of uranium from the ore. The problem is that all the uranium daughter products, in particular radium (Ra-226) and its daughter radon (Rn-222), from millions to billions of years of decay, remain with the residual rock. These pose risks from windblown dust exposure, radon emissions, and leaching into groundwater. . . .

High-level nuclear wastes will increase if nuclear power expands. At current rates of production, an additional 1000 GWe will produce an extra 20,000–30,000 metric tons of spent fuel annually. This amount is approximately one-third to one-half the currently statutory capacity for the proposed Yucca Mountain repository in the United States. Thus, an expanded nuclear world would require more or larger repositories than are envisaged today.

Prospects for the Future

Nuclear power offers a potential avenue to significantly mitigate carbon dioxide emissions while still providing baseload power required in today's world. But nuclear power cannot provide significant baseload power over the next 15 years or so, because it will take many years before a considerable number of new plants are licensed and built. The high capital costs of the plants and the risks of investing in this technology will likely enforce a slow start to large-scale nuclear build. New policies that institute a price on carbon dioxide emissions will certainly improve nuclear power's prospects. In some ways, though, nuclear power suffers from a chicken-and-egg situation: more manufacturing experience may reduce prices, but to achieve the necessary experience, many new plants must first be paid for and built.

New reactors in emerging nuclear energy countries will take even longer because of the large infrastructure required and the need for the international community to respond in an organized fashion to the potential proliferation threats posed by nuclear energy. As a result, nuclear power may begin to provide significant carbon emissions relief in the longer term, starting 20 or 30 years from now.

Unlike most other energy sources, nuclear power does have "doomsday" scenarios. History may repeat itself. Both the accidents at Three Mile Island and Chernobyl had a chilling effect on the global nuclear industry. In the United States, no new nuclear plants have been ordered since the Three Mile Island accident. In Sweden in the 1980s, the country voted to end its use of nuclear power (though they have more recently reversed this decision). If a similar accident occurs, nuclear power's future will grow dim. Similarly, if a country breaks out and develops nuclear weapons using its nuclear energy technology, expansion of nuclear power to non-nuclear energy countries will stop. Countries with nuclear energy technology will be loathe to provide it to emerging nuclear energy nations. Unlike fossil fuels and renewable resources, nuclear energy's success rests on the performance and behavior of all of those involved in producing nuclear power, wherever they are. And this is a somewhat tenuous situation on which to base an industry.

Kristin Shrader-Frechette **NO**

Five Myths About Nuclear Energy

Atomic energy is among the most impractical and risky of available fuel sources. Private financiers are reluctant to invest in it, and both experts and the public have questions about the likelihood of safely storing lethal radioactive wastes for the required million years. Reactors also provide irresistible targets for terrorists seeking to inflict deep and lasting damage on the United States. The government's own data show that U.S. nuclear reactors have more than a one-in-five lifetime probability of core melt, and a nuclear accident could kill 140,000 people, contaminate an area the size of Pennsylvania, and destroy our homes and health.

In addition to being risky, nuclear power is unable to meet our current or future energy needs. Because of safety requirements and the length of time it takes to construct a nuclear-power facility, the government says that by the year 2050 atomic energy could supply, at best, 20 percent of U.S. electricity needs; yet by 2020, wind and solar panels could supply at least 32 percent of U.S. electricity, at about half the cost of nuclear power. Nevertheless, in the last two years, the current U.S. administration has given the bulk of taxpayer energy subsidies—a total of $20 billion—to atomic power. Why? Some officials say nuclear energy is clean, inexpensive, needed to address global climate change, unlikely to increase the risk of nuclear proliferation and safe.

On all five counts they are wrong. Renewable energy sources are cleaner, cheaper, better able to address climate change and proliferation risks, and safer. The government's own data show that wind energy now costs less than half of nuclear power; that wind can supply far more energy, more quickly, than nuclear power; and that by 2015, solar panels will be economically competitive with all other conventional energy technologies. The administration's case for nuclear power rests on at least five myths. Debunking these myths is necessary if the United States is to abandon its current dangerous energy course.

Myth 1. Nuclear Energy Is Clean

The myth of clean atomic power arises partly because some sources, like a pro-nuclear energy analysis published in 2003 by several professors at the Massachusetts Institute of Technology, call atomic power a "carbon-free source"

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of energy. On its Web site, the U.S. Department of Energy, which is also a proponent of nuclear energy, calls atomic power "emissions free." At best, these claims are half-truths because they "trim the data" on emissions.

While nuclear reactors themselves do not release greenhouse gases, reactors are only part of the nine-stage nuclear fuel cycle. This cycle includes mining uranium ore, milling it to extract uranium, converting the uranium to gas, enriching it, fabricating fuel pellets, generating power, reprocessing spent fuel, storing spent fuel at the reactor and transporting the waste to a permanent storage facility. Because most of these nine stages are heavily dependent on fossil fuels, nuclear power thus generates at least 33 grams of carbon-equivalent emissions for each kilowatt-hour of electricity that is produced. (To provide uniform calculations of greenhouse emissions, the various effects of the different greenhouse gases typically are converted to carbon-equivalent emissions.) Per kilowatt-hour, atomic energy produces only one-seventh the greenhouse emissions of coal, but twice as much as wind and slightly more than solar panels.

Nuclear power is even less clean when compared with energy-efficiency measures, such as using compact-fluorescent bulbs and increasing home insulation. Whether in medicine or energy policy, preventing a problem is usually cheaper than curing or solving it, and energy efficiency is the most cost-effective way to solve the problem of reducing greenhouse gases. Department of Energy data show that one dollar invested in energy-efficiency programs displaces about six times more carbon emissions than the same amount invested in nuclear power. Government figures also show that energy-efficiency programs save $40 for every dollar invested in them. This is why the government says it could immediately and cost-effectively cut U.S. electricity consumption by 20 percent to 45 percent, using only existing strategies, like time-of-use electricity pricing. (Higher prices for electricity used during daily peak-consumption times—roughly between 8 a.m. and 8 p.m.—encourage consumers to shift their time of energy use. New power plants are typically needed to handle only peak electricity demand.)

Myth 2. Nuclear Energy Is Inexpensive

Achieving greater energy efficiency, however, also requires ending the lopsided system of taxpayer nuclear subsidies that encourage the myth of inexpensive electricity from atomic power. Since 1949, the U.S. government has provided about $165 billion in subsidies to nuclear energy, about $5 billion to solar and wind together, and even less to energy-efficiency programs. All government efficiency programs—to encourage use of fuel-efficient cars, for example, or to provide financial assistance so that low-income citizens can insulate their homes—currently receive only a small percentage of federal energy monies.

After energy-efficiency programs, wind is the most cost-effective way both to generate electricity and to reduce greenhouse emissions. It costs about half as much as atomic power. The only nearly finished nuclear plant in the West, now being built in Finland by the French company Areva, will generate electricity costing 11 cents per kilowatt-hour. Yet the U.S. government's Lawrence Berkeley National Laboratory calculated actual costs of new wind plants, over the last seven years, at 3.4 cents per kilowatt-hour. Although some groups say nuclear energy is inexpensive, their misleading claims rely on trimming the data on cost. The 2003 M.I.T. study, for instance, included neither the costs of reprocessing nuclear material, nor the full interest costs on nuclear-facility construction capital, nor the total costs of waste storage. Once these omissions—from the entire nine-stage nuclear fuel cycle—are included, nuclear costs are about 11 cents per kilowatt-hour.

The cost-effectiveness of wind power explains why in 2006 utility companies worldwide added 10 times more wind-generated, than nuclear, electricity capacity. It also explains why small-scale sources of renewable energy, like wind and solar, received $56 billion in global private investments in 2006, while nuclear energy received nothing. It explains why wind supplies 20 percent of Denmark's electricity. It explains why, each year for the last several years, Germany, Spain and India have each, alone, added more wind capacity than all countries in the world, taken together, have added in nuclear capacity.

In the United States, wind supplies up to 8 percent of electricity in some Midwestern states. The case of Louis Brooks is instructive. Utilities pay him $500 a month for allowing 78 wind turbines on his Texas ranch, and he can still use virtually all the land for farming and grazing. Wind's cost-effectiveness also explains why in 2007 wind received $9 billion in U.S. private investments, while nuclear energy received zero. U.S. wind energy has been growing by nearly 3,000 megawatts each year, annually producing new electricity

WHAT DOES THE CHURCH SAY?

Though neither the Vatican nor the U.S. bishops have made a statement on nuclear power, the church has outlined the ethical case for renewable energy. In *Centesimus Annus* Pope John Paul II wrote that just as Pope Leo XIII in 1891 had to confront "primitive capitalism" in order to defend workers' rights, he himself had to confront the "new capitalism" in order to defend collective goods like the environment. Pope Benedict XVI warned that pollutants "make the lives of the poor especially unbearable." In their 2001 statement *Global Climate Change,* the U.S. Catholic bishops repeated his point: climate change will "disproportionately affect the poor, the vulnerable, and generations yet unborn."

The bishops also warn that "misguided responses to climate change will likely place even greater burdens on already desperately poor peoples." Instead they urge "energy conservation and the development of alternate renewable and clean-energy resources." They argue that renewable energy promotes care for creation and the common good, lessens pollution that disproportionately harms the poor and vulnerable, avoids threats to future generations and reduces nuclear-proliferation risks.

equivalent to what three new nuclear reactors could generate. Meanwhile, no new U.S. atomic-power reactors have been ordered since 1974.

Should the United States continue to heavily subsidize nuclear technology? Or, as the distinguished physicist Amory Lovins put it, is the nuclear industry dying of an "incurable attack of market forces"? Standard and Poor's, the credit- and investment-rating company, downgrades the rating of any utility that wants a nuclear plant. It claims that even subsidies are unlikely to make nuclear investment wise. *Forbes* magazine recently called nuclear investment "the largest managerial disaster in business history," something pursued only by the "blind" or the "biased."

Myth 3. Nuclear Energy Is Necessary to Address Climate Change

Government, industry and university studies, like those recently from Princeton, agree that wind turbines and solar panels already exist at an industrial scale and could supply one-third of U.S. electricity needs by 2020, and the vast majority of U.S. electricity by 2050—not just the 20 percent of electricity possible from nuclear energy by 2050. The D.O.E. says wind from only three states (Kansas, North Dakota and Texas) could supply all U.S. electricity needs, and 20 states could supply nearly triple those needs. By 2015, according to the D.O.E., solar panels will be competitive with all conventional energy technologies and will cost 5 to 10 cents per kilowatt hour. Shell Oil and other fossil-fuel companies agree. They are investing heavily in wind and solar.

From an economic perspective, atomic power is inefficient at addressing climate change because dollars used for more expensive, higher-emissions nuclear energy cannot be used for cheaper, lower-emissions renewable energy. Atomic power is also not sustainable. Because of dwindling uranium supplies, by the year 2050 reactors would be forced to use low-grade uranium ore whose greenhouse emissions would roughly equal those of natural gas. Besides, because the United States imports nearly all its uranium, pursuing nuclear power continues the dangerous pattern of dependency on foreign sources to meet domestic energy needs.

Myth 4. Nuclear Energy Will Not Increase Weapons Proliferation

Pursuing nuclear power also perpetuates the myth that increasing atomic energy, and thus increasing uranium enrichment and spent-fuel reprocessing, will increase neither terrorism nor proliferation of nuclear weapons. This myth has been rejected by both the International Atomic Energy Agency and the U.S. Office of Technology Assessment. More nuclear plants means more weapons materials, which means more targets, which means a higher risk of terrorism and proliferation. The government admits that Al Qaeda already has targeted U.S. reactors, none of which can withstand attack by a large airplane. Such an attack, warns the U.S. National Academy of Sciences, could cause fatalities as far away as 500 miles and destruction 10 times worse than that caused by the nuclear accident at Chernobyl in 1986.

Nuclear energy actually increases the risks of weapons proliferation because the same technology used for civilian atomic power can be used for weapons, as the cases of India, Iran, Iraq, North Korea and Pakistan illustrate. As the Swedish Nobel Prize winner Hannes Alven put it, "The military atom and the civilian atom are Siamese twins." Yet if the world stopped building nuclear-power plants, bomb ingredients would be harder to acquire, more conspicuous and more costly politically, if nations were caught trying to obtain them. Their motives for seeking nuclear materials would be unmasked as military, not civilian.

Myth 5. Nuclear Energy Is Safe

Proponents of nuclear energy, like Patrick Moore, cofounder of Greenpeace, and the former Argonne National Laboratory adviser Steve Berry, say that new reactors will be safer than current ones—"meltdown proof." Such safety claims also are myths. Even the 2003 M.I.T. energy study predicted that tripling civilian nuclear reactors would lead to about four core-melt accidents. The government's Sandia National Laboratory calculates that a nuclear accident could cause casualties similar to those at Hiroshima or Nagasaki: 140,000 deaths. If nuclear plants are as safe as their proponents claim, why do utilities need the U.S. Price-Anderson Act, which guarantees utilities protection against 98 percent of nuclear-accident liability and transfers these risks to the public? All U.S. utilities refused to generate atomic power until the government established this liability limit. Why do utilities, but not taxpayers, need this nuclear-liability protection?

Another problem is that high-level radioactive waste must be secured "in perpetuity," as the U.S. National Academy of Sciences puts it. Yet the D.O.E. has already admitted that if nuclear waste is stored at Nevada's Yucca Mountain, as has been proposed, future generations could not meet existing radiation standards. As a result, the current U.S. administration's proposal is to allow future releases of radioactive wastes, stored at Yucca Mountain, provided they annually cause no more than one person—out of every 70 persons exposed to them—to contract fatal cancer. These cancer risks are high partly because Yucca Mountain is so geologically unstable. Nuclear waste facilities could be breached by volcanic or seismic activity. Within 50 miles of Yucca Mountain, more than 600 seismic events, of magnitude greater than two on the Richter scale, have occurred since 1976. In 1992, only 12 miles from the site, an earthquake (5.6 on the Richter scale) damaged D.O.E. buildings. Within 31 miles of the site, eight volcanic eruptions have occurred in the last million years. These facts suggest that Alvin Weinberg was right. Four decades ago, the then-director of the government's Oak Ridge National Laboratory warned that nuclear waste required society to make a Faustian bargain with the devil. In exchange for current military and energy benefits from atomic power, this generation must sell the safety of future generations.

Yet the D.O.E. predicts harm even in this generation. The department says that if 70,000 tons of the existing U.S. waste were shipped to Yucca

Mountain, the transfer would require 24 years of dozens of daily rail or truck shipments. Assuming low accident rates and discounting the possibility of terrorist attacks on these lethal shipments, the D.O.E. says this radioactive-waste transport likely would lead to 50 to 310 shipment accidents. According to the D.O.E., each of these accidents could contaminate 42 square miles, and each could require a 462-day cleanup that would cost $620 million, not counting medical expenses. Can hundreds of thousands of mostly unguarded shipments of lethal materials be kept safe? The states do not think so, and they have banned Yucca Mountain transport within their borders. A better alternative is onsite storage at reactors, where the material can be secured from terrorist attack in "hardened" bunkers.

Where Do We Go From Here?

If atomic energy is really so risky and expensive, why did the United States begin it and heavily subsidize it? As U.S. Atomic Energy Agency documents reveal, the United States began to develop nuclear power for the same reason many other nations have done so. It wanted weapons-grade nuclear materials for its military program. But the United States now has more than enough weapons materials. What explains the continuing subsidies? Certainly not the market. *The Economist* (7/7/05) recently noted that for decades, bankers in New York and London have refused loans to nuclear industries. Warning that nuclear costs, dangers and waste storage make atomic power "extremely risky," *The Economist* claimed that the industry is now asking taxpayers to do what the market will not do: invest in nuclear energy. How did *The Economist* explain the uneconomical $20 billion U.S. nuclear subsidies for 2005–7? It pointed to campaign contributions from the nuclear industry.

Despite the problems with atomic power, society needs around-the-clock electricity. Can we rely on intermittent wind until solar power is cost-effective in 2015? Even the Department of Energy says yes. Wind now can supply up to 20 percent of electricity, using the current electricity grid as backup, just as nuclear plants do when they are shut down for refueling, maintenance and leaks. Wind can supply up to 100 percent of electricity needs by using "distributed" turbines spread over a wide geographic region—because the wind always blows somewhere, especially offshore.

Many renewable energy sources are safe and inexpensive, and they inflict almost no damage on people or the environment. Why is the current U.S. administration instead giving virtually all of its support to a riskier, more costly nuclear alternative?

EXPLORING THE ISSUE

Is It Time to Revive Nuclear Power?

Critical Thinking and Reflection

1. Which is more dangerous? Nuclear power or global warming? (See *The Anatomy of a Silent Crisis,* Global Humanitarian Forum Geneva (2009), www.ghfgeneva.org/LinkClick.aspx?fileticket=pg6PNloVEoA%3d.)
2. How are nuclear wastes handled today?
3. Pretend that your campus is a nuclear power plant. Now devise an evacuation plan to protect the residents of neighboring communities in case of a serious accident.
4. What are the advantages of a "closed cycle" approach to handling spent nuclear fuel?

Is There Common Ground?

There is no argument that today's society needs vast amounts of energy to function. The debate largely centers on how to meet the need (which is projected to grow greatly in the future). The greatest agreement may well be in the solutions people refuse to consider. As an exercise, consider the following major uses of energy:

Global trade

Commuting

Air-conditioning

Central heating

1. In what ways could we change our lifestyles to reduce energy use in each of these areas?
2. Would reducing population help?