

PERSPECTIVE

The Environmental Paradox of Nuclear Power

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Introduction

At the beginning of 2001, California was reeling from electricity shortages, natural gas prices had risen sharply, the United States as a whole was shaken out of complacency about energy supplies, and evidence was building that global climate change was a major threat. At the same time, US nuclear power plants were operating with unprecedented reliability and economy, and a new generation of still safer nuclear power plants was waiting in the wings. Under these circumstances, one might imagine widespread calls for the expansion of nuclear power.

But such calls are rare. Nuclear proponents remain convinced that there is a very strong case for nuclear power—especially an environmental case. But at present they have neither the numbers nor the organization to overcome the continuing opposition to nuclear power on the part of the major environmental groups and their supporters. The thesis of this article is that this opposition is counterproductive.

Nuclear Safety

Concerns about nuclear power are intertwined with fears of radioactivity, because most of the potential harm involves radiation exposures. Radioactivity has always been an integral constituent of the Earth, originating in the initial formation of the chemical elements, and is inescapably present everywhere. This natural radioactivity, plus cosmic rays, results in an average dose in the United States of about 300 millirem per year.

Compared to these natural doses, the exposures received from the operation of the over 100 nuclear reactors in the United States are negligible, because virtually no radioactive materials are released in nor-

mal reactor operation. Even in the 1977 Three Mile Island accident—the one major nuclear accident outside the former Soviet Union—the most exposed members of the general public received radiation doses of under 100 millirem.

But, although the environmental harm from Three Mile Island was small, it impressed upon the public, the nuclear industry, and the federal government that such an accident was unacceptable. This led to major modifications of reactor equipment and procedures. The success of these measures is shown by “precursor analyses.” In a modern nuclear reactor a major accident can occur only if a series of things go wrong. An early malfunction can be termed an “accident precursor.” Analyses of precursor events by the US Nuclear Regulatory Commission indicate that the chance of a major accident fell by the late 1990s to about one-hundredth of the chance before the Three Mile Island accident.^{1,2}

Society accepts the currently operating reactors as being adequately safe, in the sense that there is little demand for their closure. However, new reactors would probably face strenuous opposition. This is hardly consistent. Present US nuclear reactors were all ordered before 1974. In the interim, nuclear engineers have designed new and still safer reactors. Three such designs received a preliminary seal of safety approval from the US Nuclear Regulatory Commission in 1998 and 1999, in the form of a Standardized Design Certification. Two plants based on one of these designs, General Electric’s Advanced Boiling Water Reactor, are already operating in Japan.

The calculated risks of living near one of the new reactors are so small that the numbers are probably meaningless—far less, for example, than the risk of being fatally struck by lightning. Some people will find such calculations reassuring. Others will not. But it would be remarkable for nuclear power to be an exception to the general experience that technologies become safer with time, especially given the emphasis placed upon reactor safety by both the industry and government agencies.

Two Wastes: Spent Fuel and Carbon Dioxide

Concern about nuclear waste disposal is probably even more widespread than concern over reactor safety, perhaps because nuclear wastes are thought to threaten not only ourselves but also future generations. For the United States, the relevant nuclear waste is primarily the “spent fuel” that is removed from a reactor at the end of the fuel’s useful life. The volume of spent fuel is very small. It is in solid form, contained in many individual thin-walled protective metal cylinders. For disposal, these cylinders are to be placed in rugged thick-walled canisters and deposited in tunnels that are deep in an underground repository. Retrieval of the canisters and wastes is to be possible for the first 100 years or so, and then the repository is to be sealed.

The US waste disposal program is now focused on the study of a potential repository at Yucca Mountain, Nevada. If a decision is made by the federal government to proceed with Yucca Mountain, the decision will undoubtedly face vigorous political and legal challenges.

The goal in designing the repository is to keep appreciable amounts of radioactive materials from reaching the biosphere. Basic factors working to make this possible include the small volume of the wastes, the decrease with time in the level of radioactivity, the dry environment at Yucca Mountain, the corrosion resistance of the metal canisters which hold the wastes, and the slow rate at which water moves to and from the repository region.

According to the USEPA’s proposed protective standard, for the next 10,000 years the radiation dose received by “the reasonably maximally exposed individual” living about 20 kilometers from Yucca Mountain should be no more than 15 millirem per year.³ This is about 5% of the dose that the average person in the United States now receives annually from natural sources. This hypothetical person is assumed to drink two liters of water per day from local wells. There are likely to be only a few such individuals—probably in the tens or hundreds. To get some sense of scale, if 1000 people

each received a dose of 15 millirem annually, if there are no improvements in cancer treatment over the next few thousand years, and if present estimates of radiation hazards are correct, the exposure would cause about one cancer fatality per century.

Can so demanding a standard be met? According to recent analyses by the Electric Power Research Institute, the actual performance is likely to be much better.⁴ The retention of radionuclides within or near the repository is projected to be so complete that the dose 20 kilometers away is expected to be below 0.001 millirem per year for the first 100,000 years and never reach a level as high as 1 millirem per year.

Of course, if nuclear power is continued and expanded, more repositories like Yucca Mountain will be needed. However, this is unlikely to be a major problem, because many geologically promising locations exist and it is not expensive to make rugged protective canisters. For the far distant future, it may be desirable to modify the fuel cycle to reduce the output of long-lived wastes.

The estimated risks from nuclear wastes can be contrasted with the risks from the chief “waste” produced from fossil fuels, namely carbon dioxide. Details of the resulting greenhouse effects are not firmly established, but during the next century they will probably include a large rise in temperature, some rise in sea level, and changes in the patterns of rainfall and storms. Storms and floods claimed over 700,000 lives in the period from 1947–1980, and even a slight increase in their frequency or severity could mean many thousands of additional casualties.⁵ The possible collapse of the West Antarctic Ice Sheet raises the prospect of a disastrous five-meter rise in sea level. It is not reassuring to read in that connection that “there is no reason to suppose there is a danger in the short term (for instance, during the next century).”⁶ It is no wonder that the countries most threatened by rising sea levels are among the strongest proponents for implementing the Kyoto Protocol on climate change.

Nuclear wastes and carbon dioxide are closely linked, because a direct way to re-

duce carbon dioxide emissions is to use nuclear fuel instead of coal to generate electricity. This is exemplified by France, which obtains about 75% of its electricity from nuclear power. The carbon dioxide emissions per capita for France in 1999 were 66% those of Germany, 87% of those for Italy, and 71% those for the United Kingdom.⁷ Comparisons normalized to gross domestic product show an even greater advantage for France. If the United States had entirely replaced coal plants by nuclear plants for electricity generation, our 1998 carbon dioxide emissions would have been 32% lower.⁸ More extensive electrification of the energy economy could provide further gains.

The problems created by carbon dioxide are much greater than those created by nuclear wastes in terms of the numbers of people impacted, the severity of the impacts, and the immediacy of the dangers. Unfortunately, society does not yet appear ready to accept the minute risks from the one to help forestall the tremendous risks from the other.

The Weapons Connection

Objections to nuclear power also arise from the weapons connections. One aspect is largely sociological. US nuclear power is historically a fruit of the original nuclear weapons program, which provided much of the basic scientific background and some of the early workers. Turning the technology of swords to the building of plowshares is clearly constructive, but as long as the swords are kept close at hand the plowshares may seem morally tarnished.

A more tangible connection between nuclear explosives and nuclear power is the head start, in trained people and relevant equipment, that a nuclear program for electricity generation might give a country that suddenly decides to develop nuclear weapons. But to date, civilian nuclear power has played no part in the start of the weapons programs in the ten or more countries that have seriously attempted, successfully or not, to develop nuclear weapons. In some cases, however, research reactors obtained for ostensibly peaceful purposes have been used for the bomb

program. It is a dangerous reality that, with or without pre-existing nuclear power, any country with a moderately strong industrial base or with funds to obtain external help can build a bomb, either with plutonium-239 from a reactor or with uranium-235 obtained by enriching natural uranium.

Another fear is that terrorists or subnational groups might obtain plutonium from the civilian nuclear fuel cycle. In principle this might be possible, but there are very formidable difficulties.⁹ Terrorists may have more favorable alternatives in biological and chemical weapons, as well as in strategically placed conventional explosives.

On the other side of the ledger is the connection between war and competition for energy, especially oil—as exemplified by Japan’s entry into World War II and the more recent war with Iraq. There are also speculations about future disputes over water. Nuclear power alone cannot prevent future energy and water shortages. But it can make a major contribution—conceivably providing one-third of the world’s energy supply by the middle of this century.¹⁰ This could help relieve the pressures on oil supplies and allow for desalination of ocean water.

Overall, nuclear power may do as much to reduce the weapon risks as to heighten them. In any event, it serves little purpose for the most responsible countries to give up nuclear power in a quest for a weapons-free world unless there is a universal taboo against all things nuclear. This is very unlikely, given the heavy dependence of many countries on nuclear power and the vital role of nuclear technology in medical diagnosis and treatment.

Obtaining the “Right” Amount of Energy

Fossil fuels now supply about 85% of the world’s primary energy. The supplies of accessible oil and natural gas are limited. The more urgently they are needed, the greater will be the efforts to secure them wherever possible, perhaps peacefully in the Arctic

National Wildlife Refuge or perhaps less peacefully in the Persian Gulf.

Conservation can help substantially in reducing the need for energy sources. But new sources are nonetheless required. The major non-fossil alternatives to nuclear fission energy are fusion energy, with very uncertain prospects, and renewable energy. Renewable sources carry their own environmental liabilities. For instance, there is a conflict in the Pacific Northwest between hydroelectric power and salmon runs. Biomass plantations for producing fuel for electricity generation would require several thousand square kilometers to replace a single large nuclear power plant, as well as water and fertilizer. To obtain the same electrical output from wind power would require, in one illustration, approximately 4000 750-kilowatt wind turbines with blades that are about 150 feet in diameter.¹¹ It is too soon to know the full environmental impact of large wind farms.

Overall, it is likely that a future based on renewable energy would have to be one with a low total energy consumption. Thus, David Pimentel and colleagues estimate that with solar energy "a [world] population of 1 to 2 billion could be supported living in relative prosperity" and they appear to prefer such a world to a world of growing population.¹² Along somewhat similar lines, Paul Ehrlich and collaborators take "humanity's energy consumption as a rough, indirect measure of the total impact civilization inflicts on Earth's life-support systems" and argue for a world that uses far less energy than is used today.¹³

There may be a reason for a long-range concern about nuclear power if the environmental impact of industrial development and population growth is seen as more of a threat than the possibility of severe material privation. For the next few decades, however, population growth is inevitable and further industrial development is wanted in most of the world. This

will create great pressures for increased energy supplies, whatever the future successes of population control and conservation. Renewable sources and fusion may eventually provide an appreciable share of this energy, but it is prudent to assume that for many years there will be a de facto choice between more nuclear power and more carbon dioxide.

A Revival of Nuclear Energy?

It is argued above that nuclear power can do little to hurt the environment and much to protect it. If this view is correct, the United States and other countries should embark on a substantial expansion of nuclear power.

Paradoxically, in the context of current positions, the impetus for the needed nuclear revival may have to come from a new cohort of environmentalists. The US federal government is unlikely to take a vigorous lead because traditional "conservatives" tend to be wary of government initiatives and traditional "liberals" tend to be wary of nuclear power. Utilities and other power producers, once big boosters of nuclear power, hesitate to invest in long-term projects that are likely to attract vigorous political and legal challenges. To them, natural gas seems a safer bet, because the plants can be built relatively quickly and the costs of gas can be passed on to the consumer.

Therefore, the most consistently motivated source of support for nuclear energy would be a reoriented environmental movement that looks afresh at the full spectrum of dangers involved in energy choices. It is important that the new look and new approach come soon, so that a nuclear revival can proceed at a deliberate and careful pace rather than, further down the road, as an urgent crash program.

Notes

1. T. E. Murley, 1999, "Developments in Nuclear Safety," *Nuclear Safety* 31(1):1-14; T. E. Murley, 1999, MIT Safety Course.

2. W. D. Travers, 1999, SECY-99-289, Nuclear Regulatory Commission, at: <http://www.nrc.gov/NRC/COMMISSION/SECYS/secy1999-289/1999-289scy.html>

3. US Environmental Protection Agency, 1999, "40 CFR Part 197, Environmental Protection Standards for Yucca Mountain, Nevada; Proposed Rule," *Federal Register* 64(166): 46976-47016.

4. Electrical Power Research Institute, 2000, *Evaluation of the Candidate High-Level Radioactive Waste Repository at Yucca Mountain Using Total System Performance Assessment: Phase 5*, 1000802, Palo Alto, California.

5. J. Houghton, 1997, *Global Warming: The Complete Briefing, Second Edition*, Cambridge University Press, Cambridge, p. 3.

6. J. Houghton, 1997, *Global Warming*, p. 110.

7. Energy Information Administration, 2001, *International Energy Annual 1999*, US Department of Energy, Washington, DC, at: <http://www.eia.doe.gov/iea>.

8. Energy Information Administration, 1999, *Emissions of Greenhouse Gases in the United States*, DOE/EIA-0573(98), US Department of Energy, Washington, DC.

9. See, e.g., D. Bodansky, 1996, *Nuclear Energy: Principles, Practices, and Prospects*, AIP Press/Springer-Verlag, New York, pp. 268-269.

10. W. C. Sailor, D. Bodansky, C. Braun, S. Fetter, and B. van der Zwaan, 2000, "A Nuclear Solution to Climate Change?" *Science* 288:1177-1178.

11. In each case an average annual output of 1000-MWe is assumed: a 1250-MWe reactor with an 80% capacity factor and individual 750-kWe turbines with a 33% capacity factor.

12. D. Pimentel, R. Harman, M. Pacenza, J. Pecarsky, and M. Pimentel, 1994, "Natural Resources and an Optimum Human Population," *Population and Environment: A Journal of Interdisciplinary Studies* 15(5):347-369.

13. G. C. Daily, A. H. Ehrlich, and P. R. Ehrlich, 1994, "Optimum Human Population Size," *Population and Environment: A Journal of Interdisciplinary Studies* 15(6):469-475.

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