

Part I: Getting Started

How to Use the Handbook

If you need just a definition or quick explanation, go directly to the glossary in Part III. For example, if you want to know what a “curie” is, go to the glossary and look up the definition. You will find that it is “the basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion (3.7×10^{10}) disintegrations per second, which is approximately the activity of 1 gram of radium.” If you want a more detailed discussion of a particular topic, go to the table of contents and look over the topics in Part II. For example, for information on how a curie relates to a becquerel and how both are related to health impacts, turn to Section 1 of Part II. It provides background information about radionuclides, key issues related to public health, possible stories, and pitfalls noted in previous coverage of health impacts.

Each brief is self-contained. Reporters should be able to get what they need from a given brief; in other words, we hoped to reduce the need to search through the book. This means that there is some unavoidable redundancy among the briefs. To assist those who need more information, within the briefs, we cross-reference other briefs. The index provides further guidance.

We clustered the briefs into five sections within Part II. Section 1 examines nuclear materials and radioactivity—that is, what they are, how they are formed, where they are found, and most important, effects of radiation on humans. Section 2 examines nuclear power and other nonmilitary uses of radionuclides, including nuclear medicine and food irradiation. It explores issues that have arisen during the past half-century, such as nuclear-energy safety systems, the Chernobyl and Three Mile Island events, and the economics of nuclear power. Section 3 focuses on nuclear waste management. Briefs describe nuclear waste, how and where it is managed, monitoring of waste management sites, the ecological impacts of cleanup, and long-term surveillance and maintenance of waste management sites. Section 4 focuses on military-related nuclear issues, such as managing nuclear weapons, radiological dispersal devices (dirty

bombs), nonproliferation initiatives, nuclear terrorism, and international and national policy related to these. Section 5 reviews climate change, public perception, and risk communication focused on nuclear energy and waste issues.

Reporters who are not familiar with environmental risk, economic, and technology assessment, risk perception, and theories about how technology fits into the larger context of resource management will find helpful background in the short overviews in Part I, “Crosscutting Themes.”

Why Now? Why This Discussion?

Written by Michael R. Greenberg, with comments by
John F. Ahearne and Richard L. Garwin

The simple answer to “Why now?” is that the governments and people of the world are being driven to consider nuclear power and other energy sources, along with conservation, as options for meeting increasing energy demand. This is not the first time this pressure has gripped the United States, but the increasing fear about climate change has added another dimension. Also, the United States, Russia, France, and Great Britain face major nuclear weapons waste issues as a cold war legacy.

Beginning with the nuclear energy issue, on October 17, 1973, the members of the OAPEC (Organization of Arab Petroleum Exporting Countries) embargoed petroleum shipments to the United States, some of Israel’s allies in Western Europe (initially the Netherlands) and Japan because of their support for Israel against Egypt and Syria in the Yom Kippur War. Just before the oil embargo in 1973, the average gas price at the pump was \$1.80 per gallon (adjusted for inflation to 2007 dollars). In 1981, the average price was \$3.00 (a 70% increase). These price increases sent a recessionary ripple through the economies of the dependent nations that spread across the world. High oil prices persisted until 1986. The embargo and price increases sparked an interest in exploration for conservation and new sources of fossil fuels. Governments’ monetary policies became more restrictive, and interest in nuclear power increased.

France, Belgium, Sweden, and Japan now heavily depend on nuclear power. In the United States, even before the Three Mile Island nuclear reactor meltdown in 1979, U.S. commercial business interest in nuclear power was waning. A worldwide recession during the oil embargo caused economists to reduce their estimates of the growth of electricity demand, and the price of new reactors seemed high to U.S. utilities. Furthermore, the U.S. economy grew despite the lack of growth of energy use. Serious efforts were made by all sectors of the U.S. economy to economize energy use. After 1986, the year of the Chernobyl nuclear incident, the economy continued to grow; while

oil prices declined and remained relatively low until the new millennium. Reprocessing nuclear fuel that has been used once in a nuclear reactor to generate electricity was considered too risky by the United States because it has the potential to be used for nuclear weapons proliferation. The incident at Chernobyl along with the extensive time required to construct and license nuclear power plants increased costs and further undermined the credibility of nuclear power. National leaders and utilities concluded that nuclear power in the United States was a bad idea. Other countries, such as Japan and France did not agree and moved forward with nuclear power plant operations.

The events of the current decade are forcing reconsideration of policies examined during the embargo and price increases of the 1970s. The political instability of the world's oil producing nations has created a fear of political blackmail by petroleum supplying nations in the United States and other countries. The rapid rise and fall of petroleum prices seems inexplicable even to some experts. Also, a new consideration is that during the past decade scientists have become convinced that the burning of fossil fuels is leading to global warming, whereas nuclear power does not contribute notably to greenhouse gases that lead to global warming. Therefore, nuclear power, despite its history of environmental and economic risks and despite waste management problems, seems to some like an environmental bargain. Proponents of nuclear power argue that France and Japan have successfully invested in nuclear power generation and have not suffered obvious environmental problems. The United States and other Western nations have observed the rapid growth of the Chinese and Indian economies and are concerned that competition for oil and gas will drive up prices still further and thereby undermine the economies of the developed nations. Nuclear power seems like a logical approach. Yet, there is obvious dissent from this position. Some propose a reduction in the use of carbon and nuclear fuel, arguing for eliminating subsidies for carbon-based and nuclear-based fuels, for heavy investment in solar and other renewable technologies, and for other policy changes that would largely achieve fossil and nuclear fuel reduction objectives in 30 to 50 years (see Makhijani, 2007). Often lost in these discussions are the distinctions between transportation fuels and energy sources for electricity production and industrial use, as well as intermittent (such as from wind) and peak load power production (often from natural gas) and base load power production (such as from coal and nuclear energy). "Used" nuclear fuel, that is, nuclear fuel that has been used once in a nuclear power plant, can be reused as nuclear fuel after conversion; "spent" nuclear fuel no longer has the capacity to be recycled as nuclear fuel. The used/spent nuclear fuel issue is sometimes lost in the very public discussion of

nuclear power because the plutonium can be extracted and manufactured into the right shape and joined with high explosives and a trigger device to produce nuclear weapons. Turning spent nuclear fuel into a nuclear weapon, however, is extremely difficult. Reprocessing, manufacturing, and building trigger devices to produce nuclear weapons is an extraordinarily complicated task, and fuel from commercial nuclear plants has not been used by a proliferate state. Although technically once-through nuclear fuel is “used” not “spent,” the literature refers to it as spent. For consistency with the literature, we call it spent in this volume.

While not as prominent in the public eye as nuclear power, legacy wastes from the production of nuclear weapons place a major environmental management burden on the U.S. Department of Energy and are the focus of the most costly government environmental management program in the world. Between 1989 and 2007, the Department of Energy spent an estimated \$80 billion on managing the waste at over 130 sites across the United States. Many of the sites have closed, but the challenge of controlling high-level waste at the Hanford (WA), Idaho National Laboratory (ID), Oak Ridge (TN), and Savannah River (SC) sites remains. These military waste sites are so technologically, environmentally, legally, and economically challenging that they will need management in perpetuity. While legally the civilian nuclear waste stream and the defense-related waste stream are managed separately, it can be argued that they intersect and that methods used to manage one stream can be applied to the other. There are political and economic reasons to separate and other arguments to combine the civilian and military nuclear waste streams. Russia, with many nuclear weapons and much waste, faces a similar challenge.

In short, the stakes for the world’s nations in considering these issues now have never been higher. The media as always are expected to meet the challenge of writing stories that are accurate, balanced, objective, and responsible about the individual elements and the overall puzzle that ties together nuclear power, nuclear waste, nuclear weapons, global warming, economic development, and public health. It is our hope that this volume will contribute information to what most certainly will be a tough debate.

Reference

Makhijani, A. (2007, August). Carbon-free and nuclear-free: A roadmap for U.S. energy policy. *Science for Democratic Action*, 15(1).

Crosscutting Themes

Written by Michael R. Greenberg, with comments by
John F. Ahearne and Richard L. Garwin

Five themes are central to the issues discussed in this handbook and are explicit or implicit in every brief. These themes are as follows: (1) environmental impact, (2) risk, (3) economics, (4) evidence and public perception, and (5) ripple effects of decisions. Each of these themes is a massive subject by itself. We make no pretense of providing a comprehensive review. The goal is rather to draw the reader's attention to how these themes are core to nuclear power, waste management, and other nuclear-related issues.

This handbook presents the views of leading experts in nuclear-related issues that during the next decade will require enhanced media coverage. These experts hold strong opinions and reflect a diversity of viewpoints, and it would be wrong to imply that this book presents or indirectly implies a unified viewpoint about nuclear-related issues. It does not. We were not interested in capturing their opinions; rather we tried to understand and then summarize their very nuanced understanding of important parts of this complex subject. In the course of these conversations, however, and as the review process unfolded, we recognized that while these experts might strongly disagree with each other about the details of nuclear-related issues, they all have a deep respect for and concern about the challenges of resource management and technology in a rapidly growing world economy. Behind the details of each brief is the larger story of global resource management and technology, the subject of the last part of this section. Perhaps, it is the big story within the many smaller stories to be written.

Environmental Impact

On January 1, 1970, the National Environmental Policy Act (NEPA) became national policy. Its goal was to “create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, eco-

conomic, and other requirements of present and future generations of Americans” (P.L. 91-190, Chapter 55, 4331(9)). Behind the impressive objective, the law led to the requirement that an environmental impact assessment would be prepared to ensure that major federal government projects or programs would undergo comprehensive review before construction or implementation. The review entails a multidisciplinary, multi-agency public assessment of the environmental, economic, health, and social impacts of individual projects or program proposals, as well as the consideration of alternatives.

Environmental analyses for nuclear-related programs and individual projects are multi-thousand-page documents costing millions of dollars. The U.S. Department of Energy’s massive nuclear waste management program has had numerous programmatic and project-specific assessments. For example, the Yucca Mountain Organization in Eureka County, Nevada, maintains a Web site that lists and discusses the environmental impact statement (EIS) work on the proposed final repository (www.yuccamountain.org/eis.htm). Utilities that want to build a nuclear power plant are required to prepare an environmental assessment. For example, the first author and a colleague prepared the population, land use, and economic elements of the EIS for a proposed nuclear power plant in the Delaware River. That Newbold Island EIS was thousands of pages long. The license was not granted to the utility, in part because of the finding of excess population density in the immediate vicinity of the proposed nuclear power plant.

Whether 200 or 2,000 pages, each EIS is required to contain a detailed description of the following five factors:

1. The environmental impact of the proposed action
2. Any adverse environmental effects that cannot be avoided if the proposed action is implemented
3. Alternatives to the proposed action
4. The relationship between local short-term uses of the human environment and the maintenance and enhancement of long-term productivity
5. Any irreversible and irretrievable commitments of resources that would be involved if the proposed action is implemented

In the original act, states and municipalities “owe no duties under NEPA, but may be subject to alternative environmental legislation fashioned after NEPA.” In fact, many states and local governments have NEPA progeny that require private interests to prepare environmental assessments.

Although the wording varies by agency, the following six topics encompass the essence of environmental impact requirements:

1. Description of the existing environment
2. Description of alternatives
3. Probable impacts of each alternative
4. Identification of the alternative chosen and the evaluation that led to this choice
5. Detailed analysis of the probable impacts of the proposal
6. Description of the techniques intended to minimize any adverse impacts

In addition to generating a good deal of information that has stopped or modified project decisions, the EIS process creates checks and balances among federal, state, and local governments. A federal department may ignore opposition by other government agencies to a proposed program, but this usually does not happen. Public participation can be enhanced because the EIS requires the agency to read and respond to all comments. In short, the EIS process should lead to more effective thinking and planning, raise agency and general public awareness, and create a series of checks and balances.

NEPA has led to the cancellation or postponement of proposals to build dams, airports, highways, nuclear waste disposal programs, outer continental shelf leases, and other projects. More frequently, the process has resulted in design changes, location changes, and other modifications. Yet, critics have not been satisfied with the process. The key issue is that agencies are not obligated to change their decisions. Also, some agencies have decided that their projects are not “major” or “significant” and do not constitute an agency “proposal” or “action.” Finally, length and detail do not necessarily mean that all the scientifically ascertainable impacts are included. Some scientific facts will be missing because information is lacking.

Summarizing, every major nuclear power and defense program initiated since 1970 has required the preparation of environmental analyses that have led to changes, some major and others minor.

Risk

Risk analysis is a multistage process for determining the likelihood of adverse human and ecological effects of exposure to biological, chemical, and physical hazards and then reducing the risk. Potential hazards include toxins (e.g., asbestos), structures (e.g., dams), and activities (e.g., driving while intoxicated). We briefly describe the process, highlighting some of the key strengths and weaknesses and focusing on hazardous materials. The seven steps in the process would be slightly altered for structures and activities. Risk depends on (1) the

hazardousness of the material, (2) its quantity, (3) the probability of release, (4) the dispersion of the hazard, (5) the population exposed, (6) organism uptake, and (7) response of officials to the hazard before, during, and after release.

To assess the hazardousness of a material, scientists have identified hazards by studying historical records of human exposure and health outcomes. Research on asbestos is an excellent example of how retrospective data is used to link a strong hazard and diseases. Sometimes researchers follow people for years and observe as some become ill and others do not. The Framingham doctors and nurses studies are three multiyear large-sample prospective studies that have produced important findings about the hazards of high cholesterol, smoking, and other hazards, and the advantages of behaviors such as exercising. The bulk of assessments, though, rely on laboratory testing of mice and other species that are sentinels for human effects, which does not always work to identify human hazards.

After gathering data, scientists use statistical models to estimate the excess risk associated with exposure to the likely hazard. Some models assume that human response increases directly with dose, that the relationship is linear. Others—called threshold models—assume that some substances are harmless unless a threshold dose is reached. There is also a set of nonlinear threshold models and a set of no-threshold models. Debates are common because the form of the model adopted by government regulators influences the risk estimates. Since adequate low-dose exposure and response data are difficult and expensive to acquire and thus are scarce, policy makers must decide which model assumption to use based on higher exposure data where the effects are more frequent and then must make assumptions about the effects at low doses. With regard to radioactivity, the linear assumption has prevailed as a conservative model.

Preventing a hazardous substance from being released is a key component of risk assessment and management. If we know the hazard posed by a substance and we know its location, then we should be able to contain it. But managers often resist spending money on containment if a problem is unlikely to occur, because there are always other pressing needs for limited resources.

Dispersion of hazards is another concern in risk analysis. Contaminants can spread through direct contact, air, water, and soil. Scientists have developed mathematical and physical models to detect the spread of hazards. For example, water quality dispersion models are widely used in risk analyses to estimate the impact of discharges into rivers from electricity-generating stations, refineries, and sewage plants.

The human and ecological population at risk is also considered. Some hazards are ubiquitous, such as cigarette smoke and auto emissions. Others

are not. Atomic Energy Commission (now U.S. Nuclear Regulatory Commission) guidelines require that nuclear power plants not be located in urban centers. Some nuclear plants have not been built or never operated as a result of risk estimates, for example, one proposed near Trenton, New Jersey, and Philadelphia, another proposed in New York City directly across the river from the United Nations headquarters, and a third that was built in Shoreham, New York, but never operated. The first two were relocated to more “remote” locations. However, one of these, Indian Point, New York, is no longer a remote location and has been a focal point for criticism about the location of nuclear power plants. One of our reviewers pointed out that U.S. policies regarding dispersion studies are not consistent. For example, he observed that radiation dispersion studies are not required for coal plants even though the amount of radioactivity they emit equals or exceeds that from a nuclear power plant (from radioactive elements naturally present in coal). Likewise, the requirements for public and private facilities that emit pollutants may be different.

The final components of risk assessment and management are uptake of the hazard and response to the dose, and government, private organization, and personal response to a hazard. Some people and species are more sensitive to some hazards than are others. Government agencies normally assume those exposed are the most or among the most sensitive people when they set environmental exposure standards. For example, the ambient air quality standard for lead is set for children, whose central nervous systems are sensitive to lead uptake.

Using accurate and rapid risk characterization and communication, government and individuals can prevent or reduce exposure or the effects of exposure. For example, all nuclear power plants are required to have a buffer area around them in which there are no homes. Power plant managers can devise other protective systems to reduce exposure, including shielding. For example, alpha particle penetration can be stopped by a single sheet of paper, whereas beta particles, which have a much smaller mass and much higher speeds, require more material, or denser material, such as lead or iron to stop penetration. Should a notable emission occur, sheltered protection and sometimes evacuation may be required. In some cases, prophylactic steps may be possible. For example, a person can consume stable iodine to prevent radioactive iodine 125 and 131 from being absorbed by the thyroid.

Risk analysis has its detractors and proponents. A prominent criticism is that risk estimates are sometimes too uncertain. In some cases, the high estimate of risk is double the low estimate, and sometimes the high estimate is greater than 10 times more than the low estimate. When the range is so

great, the results may not be helpful to managers who must make a yes or no decision. Some critics argue that risk analysis is a way of hiding ethical choices in a body of undecipherable numbers and unstated assumptions, and that the disadvantaged end up bearing a disproportionate amount of the risk burden. Proponents of risk analysis argue that an orderly presentation of data, including disclosure about uncertainty, provides managers with important information and alerts researchers to shortcomings that can be addressed. Further, they would assert that many of the criticisms of risk assessments are being addressed.

In 1990 the federal government created the Commission on Risk Assessment and Risk Management to recommend how risk analysis could be most effectively used in a regulatory framework. The commission published several volumes and seven appendices, all of which are available on the Internet (www.riskworld.com/riskcommission/default.html).

Overall, during the past 2 decades, risk analysis has become a key tool used by engineers and scientists to assess and modify technologies and operations in the nuclear power industry, and in the military and civilian waste management industries.

Economics

To measure the total cost of a product, process, or facility, engineers and economists use life-cycle cost analysis (LCCA). LCCA starts with a concept, design, plan, and development. The second phase, usually the most expensive, includes obtaining land, building facilities, and installing the processes, then operating and maintaining them. The third phase involves disposal, which for a plant may mean all or part of it must be rebuilt or closed down. Some facilities will require remediation and long-term stewardship.

One of the most complex uses of LCCA is in high-level nuclear waste management because of the long half-life of some nuclear elements. A precise estimate of the cost of maintaining facilities that may be needed for thousands of years is beyond our current capacity. The best we can reasonably expect is plausible multigenerational estimates.

In addition to the three phases of LCCA, economists, planners, and engineers must take into account discount rates and depreciation. The discount rate is the interest rate charged for a loan. For federal government projects, the Office of Management and Budget provides guidelines on the value of money and the cost of borrowing it. Depreciation is the decrease in economic value

because of obsolescence, physical deterioration, and losses in the utility of a facility during its productive life.

LCCA has advantages and disadvantages. One advantage is that all costs become transparent, that is, decision makers can see an estimate of what they would be spending in the short term and in the long term. Another advantage is that trade-offs among technologies and operations become clear. For example, a cheaper overall life-cycle cost may assume technological innovations that may not occur. Decision makers can probe those assumptions and decide whether they are too risky.

The longer the expected life-span of the activity and facilities, the more uncertain the cost assumptions and estimates. With regard to nuclear power in the United States, the utility must maintain, possibly replace parts of, and eventually decontaminate and decommission large facilities. In addition, the federal government and utilities must design, build, and maintain facilities to store and manage hazardous materials for hundreds to thousands of years.

Much of the literature about LCCA is written for engineers and economists. For example, major reports and books have been written about LCCA for bridges, roads and pavements, air traffic control, and other key pieces of infrastructure. The U.S. Department of Energy and the U.S. Nuclear Regulatory Commission face an unprecedented challenge in estimating the cost of facilities that are expected to last hundreds to thousands of years.

If “How much will it cost?” is the first question, then “How much will it benefit and who will benefit?” is the second question. Economists, regional scientists, and geographers have developed a set of economic analysis tools that can help answer the economic impact policy questions. The most widely used models use historical records and economic trends from 25 to 30 years back to prepare equations that estimate future economic impacts.

The strength of these models is in their use of historical trends, but that is also one of their weaknesses. Past economic relationships do not always provide accurate predictions of the future. These models cannot account, for example, for major or sudden economic shifts that drastically change the pattern of historical business transactions. Predictions will be only as good as the data used in the models. With massive engineering projects, like those discussed in this book, we need estimates of economic resiliency that take into account unanticipated bottlenecks or opportunities. When the economy does recover, how will it have changed in ways that impact the programs and projects being analyzed?

Evidence and Public Perception

Meshing the scientist's and the public's perspectives on nuclear power, waste management, and technologies is challenging because we have strong evidence that they use different criteria for weighing evidence and deciding what to believe. Scientists are supposed to leave their preferences out of their work and, by training and practice, consider the five following attributes of evidence that come before them.

1. **Rigor.** A good study will have clear and answerable research questions, and it should describe data and methods in detail. A rigorous study uses the best scientific practices or explains why they could not be used. It also describes any limitations and their implications.
2. **Corroboration.** A good study will be confirmed by multiple independent scientists.
3. **Power.** A good study will have enough samples that the effect it was designed to look for will be easily detected.
4. **Universality.** A good study will show similar results among different test groups, such as, in a laboratory study, multiple species or several exposure routes (e.g., skin, respiratory system, digestive system). Similarly, in a study involving spatial data, scientists would look for similar results in different geographical locations, among different cultures, or across racial/ethnic and income/education groups.
5. **Relevance.** A good study will have enough evidence to allow scientists to attribute the effects to appropriate social, economic, political, chemical, physical, biological, or other theoretical constructs.

In contrast, Sandman (1993) maintains that public reaction to hazard and risk is driven by “outrage” factors. He has described more than 20 factors that cause people to evaluate some hazards as higher than others but that do not relate to their scientifically calculated risk. We list nine of them with brief examples to show the remarkably different ways experts and the public evaluate risk.

1. **Lack of control.** Holding a nail while someone else hammers it into a wall seems significantly more dangerous than doing the hammering oneself.
2. **Imposition/coercion.** Vaccinations that are required seem riskier than allergy injections one volunteers to receive.
3. **Inequity.** Locating a county incinerator in a poor neighborhood that did not volunteer to receive it and that already has multiple risks seems more risky

- than locating it in a wealthier neighborhood or business district that has few other risks.
4. Lack of familiarity. A new chemical agent seems riskier than tobacco smoke.
 5. Memorability. The negative image of a nuclear mushroom cloud is virtually indelible.
 6. Concentration. Fear is increased by events in which large numbers of people die or are injured in a short time or in a confined area, such as in the crash of a large passenger aircraft or destruction by a hurricane.
 7. Immorality. Actions such as using animals for scientific research or cutting down a forest are rejected because they are considered to be immoral, irrespective of the actual risks they involve.
 8. Lack of candor. Learning from the media that a road is being put through one's neighborhood after city officials insisted it was only under preliminary consideration increases the sense of risk associated with the project.
 9. Human-made risks. Hazards caused by human error, such as an oil spill, are considered to be more dangerous than natural hazards, such as a flood, even if the actual impacts are similar.

Arguably, these nine outrage factors are a distraction from reality, leading people to make bad choices that are not supported by science. Yet, they have been observed in studies around the world among men and women in different age, ethnic, racial, religious, and socioeconomic groups. These outrage factors are psychologically driven guides that people use consciously and subconsciously to consider evidence.

Reporters must respect both the science and the outrage factors, recognizing that whereas scientists trust authority and expertise, weigh accumulated evidence, rely on scientific theories and consistent findings, and live with uncertainty, the public trusts traditions, peer groups, open processes, and notably widespread public participation, and they will consider anecdotal information and worry about uncertainty. The American public distrusts linear, reductionist, and expert-based decision-making processes funded by those it considers to have a vested interest in the outcome. They want an opportunity to participate and not have the scope limited to discussions of “proven” quantitative scientific results.

Ripple Effects of Decisions

We cannot precisely follow the impacts of decisions to every location, nor can we say with confidence what will be the long-term impacts of an action. Yet,

we can try to foresee and try to understand the major effects. Reporters may find that some of the distant ripples are worth investigating.

To bring the metaphor to life, we pose a hypothetical policy question: Should a new electricity peaking facility that burns natural gas be built adjacent to a river on a brownfield site that was abandoned 20 years ago? Alternatively, should the facility be constructed at an existing coal-fueled baseload electricity site 10 miles away? Or should nothing be built locally?

For context, the area on the side of the river opposite the proposed location has only a few houses and the river is used mostly by sport fishermen and boating enthusiasts. Elected officials on this relatively undeveloped side oppose the facility. Their counterparts on the side of the river with a brownfield strongly support it.

The first ripple is the direct environmental impact and the immediate financial impact associated with the proposed new electricity plant. For example, the old factories will be demolished and the site will be remediated. This means that some of the residual contamination will be remediated and the remainder will be left in place and capped. The project will necessitate short-term disruption of the river flow away from the location while the facility is constructed and when pipelines are extended to supply the natural gas to the site. Some fish and other species will find their passage more difficult when the flow of the river is temporarily changed. Small-boat traffic can continue but will be slowed down for a time. Doubtless, there will be some work-related injuries during the construction. The utility will pay nearly all the cleanup cost, but local governments will need to pay for off-site improvements to accommodate the facility unless they successfully bargain with the utility. These are the kinds of impacts reporters would normally cover—that is, the direct environmental and immediate financial impacts.

There are “downstream” and “upstream” impacts. The downstream effects are set in motion by the project. On the side with the proposed facility, the mayor and city council can publicly show that the city’s worst brownfield eyesore has been turned into a productive use, and that the city hopes to use that project to attract warehousing and other compatible commercial land uses to adjacent underutilized sites. The city will collect revenues from the utility and expects jobs to follow from the opening of the facility and the other compatible land uses.

On the other side of the river, the most obvious downstream impacts are the noise and air pollution generated by the facility and the visual change it makes to the landscape. Some residents and others who come for fishing or boating may find these effects so objectionable that they choose to leave. Furthermore, a natural gas pipeline is built under the river and onto the less

developed side, causing at least temporary congestion and ecological damage on that side of the river.

The upstream effects are steps that are precluded by the decision. In this case, the plant reduces the attractiveness to developers who had hoped to build a marina and ecological preserves on both sides of the river. A ferry service linking the two sides is shelved. Officials on the less developed side are convinced that the stigma of the buried pipeline and visible and unattractive electricity facility preclude their plans for recreational facilities on their side of the river. Plans for condominiums for recreational boaters and bird watchers are cancelled.

The next set of ripples capture some likely additional spatial and temporal effects. Since the utility does not need to fit the electricity peaking facilities into an existing facility at another location in the region, it can design a new baseload unit on that existing baseload site 10 miles away, which means that it need not purchase expensive electricity from other utilities located hundreds of miles away. It also means that the publicity conscious utility agrees to retrofit the existing coal-fired units at this site to reduce emissions as part of the agreement to expand baseline capacity. The net effect will be less air emissions at the site, despite the increase in capacity.

The decision also impacts another utility group located hundreds of miles away, which had hoped to sell its excess baseline capacity from its three nuclear power plants to the local utility. The decision relieves state government and utility officials of the immediate pressure of convincing state residents that they need to purchase more energy efficient air conditioning units that causes the summer peaking problem. The decision shifts the plan for building an ecological preserve, marina, and condominiums 15 miles downstream, where it is welcomed by local government and residents. In other words, if the first facility is built on the brownfield site, residential and commercial facilities can be built at a site 15 miles away, and energy facilities upgraded on another site 10 miles away.

Still another more distant set of ripples is seen 5 years after the new peak facilities and new baseload capacity have been added. The overall state economy has benefited by these additions and in fact this action has been replicated elsewhere in the state, which wants to be more energy independent. The town that added the new peak electricity site has successfully attracted warehousing to the area, thereby boosting the local economy on that side of the river. Personal disposable income has gone up and is reflected in some new housing and retail opportunities for local residents. More residents can afford health care services and gradually children's health and school attendance improves because poverty has decreased.

On the other side of the river, which opposed the facility and lost the preserve, marina, and condominium complex, no new major development has occurred. The community continues to search for a set of land uses that can use its river edge. Elected officials are angry but have no recourse.

The last ripples are harder to measure but are visible in the distance. The energy projects on site and 10 miles away continued reliance on fossil fuels, although the utility did install the best available technologies to limit emissions. If it had purchased baseload capacity from another utility, additions to local electricity grid systems would have been required. This would have meant excavations for some additional above-ground towers through local parkland. Also, with no new local peak load systems constructed, the local area would have been more vulnerable to summer peak outages, which would have caused new businesses not to build in the area.

In essence, following the ripple effects of decisions requires tracing the likely outcomes of what may appear at first to be straightforward decisions. The reporter who follows the primary story through some ripples in this way will find mostly predictable endpoints, but also some unexpected and counterintuitive outcomes that will be newsworthy. Every brief in this book has ripple effects. However, among the 21, we suggest that “Closing the Civilian Nuclear Fuel Cycle,” “Managing the Nuclear Weapons Legacy,” “Nuclear Nonproliferation,” and “Global Warming and Fuel Sources” have the most local, national, and international impacts and the longest temporal reach.

Worldviews of Technology, Population, Resource Use, and Environmental Degradation

This subsection summarizes a core concern of the authors of this book and of those we interviewed: the relationship between population, resource use, human and environmental degradation, and technology.

When people employ technology to create products, deliver services, and engage in activities, what they do has environmental and human impacts. With the caveat that we are generalizing, degradation processes may be divided into two categories. The first, overusing existing resources, is caused by populations growing too rapidly in areas that lack enough water, soil, fuel, and other resources to provide even modest supplies of products and services. The second category, endangering populations, results from the consumption of enormous amounts of resources per capita. While relatively few people in these nations lack shelter or sufficient food compared with those in less developed countries, the so-called developed nations consume so many resources and emit so many

residuals that they potentially have endangered their own populations and arguably everyone else.

For more than 40 years, the United Nations, World Bank, World Resource Institute, Organization for Economic Cooperation and Development, World Watch Institute, and others have warned that we are compromising current populations and future generations. Enacting policies that get as much as possible from each resource, using renewable resources, recycling spent materials, and emitting as little as possible into the environment is essential. The principles of the environmental ethic have been widely touted by some academics, not-for-profits, and individuals who press for pollution prevention and green economic policies. Yet the reality is that management of resources is a complex endeavor involving science, engineering, politics, economics, and social and ethical considerations. In this web of complexity, technology is too often singled out as the culprit or savior for those seeking reasons for failure and success.

The debate about the advantages and disadvantages of new technologies has gone on for centuries, involving vigorous debates and protests about such innovations as skyscrapers; streetcars, trains, and airplanes; and drugs and other medical interventions. Technology debates, we believe, have heated up during the past 20 years because of the exponential increase in scientific exploration and the technologies derived from it.

Not only is scientific uncertainty present in many instances, but research shows that people's ability to perceive the future begins to go dark beyond 15 to 20 years, about a generation. Hence, just below the surface of strongly stated opinions about many technology debates lie two very different worldviews of technology that people revert to when uncertainty about technology and their inability to perceive the future is too great. One involves optimism about the future of technology, the other caution.

Recognizing that the two worldviews presented here are stereotypes that are imperfect fits to real individuals and organizations, we have repeatedly seen information-based arguments fall back to technology-optimism and technology-caution positions. Technology optimists tend to view the world as a place of unlimited resources. Human ingenuity, they feel, will improve public health and the environment, increase wealth and distribute it across the earth, and help solve the world's political problems. They do not believe that we will run out of scarce resources. In fact, they argue that scarcity leads to price increases, which in turn stimulate research, leading to more efficient use of resources, and to resource substitution. For example, as natural gas and oil prices increase, nations will turn more to nuclear power, as well as make more efficient use of fossil fuels.

Technology optimists typically embrace mega-projects that concentrate people and capital to produce massive centralized facilities, such as large clusters of nuclear power plants or gigantic tankers and cargo ships that can transport products across the globe and then offload them in large ports from which they are dispersed on large rail and road networks. Technology optimists do not focus much on population growth because they view people as the key to human, economic, environmental, and political health. They observe that economic development has led to lower birth rates and a stabilized population. In other words, economic development leads to both a decrease in population growth and less poverty.

Their technology-cautious counterparts do not discount human creativity. However, they point to some of our technological creations that have led to human and ecological tragedies. They tend to view resources as finite, they worry about uncontrolled scientific investigations that could lead to problems at a later time, they call for major investments in pollution control and strong regulations, and they worry about population growth. Also, they prefer small-scale technologies to large centralized facilities.

Whereas the optimist group wants to speed up the pace of research, their cautious counterparts prefer a much slower pace of research and demonstration. Some, for example, would argue that increasing reliance on nuclear power means more nuclear waste management in perpetuity and possibly proliferation of weapons grade nuclear materials, arguments that proponents assert are addressed by the projects described in this book. Pointing to Three Mile Island and Chernobyl as illustrations of what is wrong with nuclear power, they argue for a larger number of decentralized facilities that rely on local energy resources, and above all they argue for conservation, which many feel will be undermined by the construction of large centralized nuclear power plants. The issue for reporters and the public is to determine how much the pro and con nuclear arguments are based on science and how much they are grounded in perceptions and values.

In short, large nuclear power plants and waste management facilities are among the most complex and large-scale projects in the world. The opponents and proponents of nuclear power and other nuclear technologies often evoke worldviews of technology as illustrations of their viewpoints. We recommend Simon (1990) as representative of optimism about technology, and Commoner (1971) and Ayres (1998) as representative of concern about the ramifications of technology and unbridled growth.

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