Energy and the Future

Edited by

DOUGLAS MacLEAN

and

PETER G. BROWN

ROWMAN AND LITTLEFIELD

Totowa, New Jersey

First published in the United States in 1983 by Rowman and Littlefield, 81 Adams Drive, Totowa, New Jersey 07512.

Library of Congress Cataloging in Publication Data
Main entry under title:

Energy and the future.

(Maryland studies in public philosophy)
Includes bibliographical references and index.
1. Power resources—Social aspects. 2. Energy policy
—Social aspects. I. MacLean, Douglas, 1947-
II. Brown, Peter G. III. Series.
TJ163.2.E4643 1983 333.79 82-18609
ISBN 0-8476-7149-6
0-8476-7225-5 (pbk)

Published in the United States of America

7

Conflicting Views on a Neutrality Criterion for Radioactive Waste Management

The Need for Waste Management

The disposal of radioactive wastes, a paradigm of an intergenerational moral problem, constitutes an excellent case study for testing moral intuitions about justice between generations.* The nuclear era in the United States is now nearly forty years old, yet no high-level radioactives wastes produced during this period have been disposed of permanently. Instead, contained in tanks or water-filled cooling pools near the reactors that produce them, they are nearly all awaiting permanent disposal.

Until recently few scientists paid attention to waste management and the other unglamorous issues pertaining to the "back end" of the nuclear fuel cycle, or to such details as the decontaminating and decommissioning of used reactors. Many factors have changed this. Foremost among them, the capacity to store spent fuel at existing reactors has nearly been exhausted. The problem is not merely one of finding an adequate medium and site for burying wastes; the sheer bulk of wastes resulting from nearly forty years of accumulation has created a logistics problem.[1]

During the presidency of Jimmy Carter a debate developed, and gained public attention, about the adequacy of plans to begin a Waste Isolation Pilot Program (WIPP), designed in part to demonstrate safe disposal of transuranic radioactives wastes in a bedded salt formation near Carlsbad, New Mexico.[2] By 1978 the nuclear waste issue

*This introduction was prepared by the editors from material drawn from earlier drafts of Cochran's and Bodde's essays.

was volatile and politically charged, and President Carter formed an interagency review group (IRG) to report on nuclear waste management (March 1979). Following the recommendation of the majority of the IRG, the president canceled the WIPP Project and, on February 12, 1980, proposed a radioactive waste policy that closely followed the IRG report recommendations. Although it may change, the current policy for managing and disposing of radioactive wastes is the one announced by President Carter.

President Carter's announced policy was well received. It made the usual acknowledgments about the importance of protecting the public's health and safety, but it also suggested ways of accomplishing these goals. The policy set a timetable to pick a repository site by 1985 and to open it around the mid-1990s. This is later than many people would like, but the extra time will allow testing of four or five sites in a variety of geological media. Thus, the policy is more technically conservative than earlier proposals, and it reveals a willingness to weigh safety considerations more heavily than economic considerations. The policy also established a State Planning Council on radioactive waste management to approve the plans for selecting a medium for disposal and for handling the politically volatile issue of siting a repository.

There has been little criticism of Carter's waste policy. Nevertheless, several important problems may not have been solved, but only deferred. No doubt, when the plans for a site are finally announced, criticism—especially from people living in the area of a proposed site—will be renewed. Another difficult problem is setting acceptable criteria for safety and risk from nuclear waste. Everyone involved in designing nuclear policies now agrees, at least in principle, that we must bury nuclear wastes in ways that protect the populations of future generations. This may require sequestering them for millennia.

The essays that follow agree that risks imposed on future generations are acceptable if they meet a criterion of neutrality. A policy is neutral if the risks imposed on future generations are not greater than the risks they would otherwise face if we did not produce the wastes, or, more generally, if equality of opportunity is preserved across generations. The latter formulation of this criterion agrees with the principle of intergenerational justice that is defended in detail by Brian Barry in Chapter 1.

Nevertheless, Cochran and Bodde disagree on the proper interpretation of this neutrality criterion. This debate illustrates some of the complexities involved in trying to apply philosophical principles to public policy, even after we agree on the principles.

* * * * * * *

During the last 35 years, large quantities of nuclear waste have been generated by commercial nuclear power and defense nuclear activities, in the United States and abroad. (Small amounts are also generated through medical applications and other activities that make use of radioisotopes, but these wastes are relatively small in quantity and low in radioactivity.) While radioactive wastes are encountered at most stages of the nuclear fuel cycle, those of greatest potential concern are found in spent fuel. These wastes can either be separated from the plutonium and residual uranium in the spent fuel or, if plutonium recovery is not desired, they can be retained in the spent fuel elements. In military nuclear programs, where plutonium recovery is desired for the production of nuclear weapons, reprocessing is an essential step. The spent fuel from military reactors is therefore chemically reprocessed, and the resulting wastes are stored retrievably in solid and liquid form in steel tanks at three federal installations. In the U.S. civilian nuclear program, reprocessing of spent fuel was indefinitely deferred by President Carter in 1977, in an effort to slow the proliferation of nuclear weapons. The spent fuel from commercial reactors is now stored temporarily at the reactor sites themselves. The furthest developed proposal for ultimate disposal of nuclear waste, either as spent fuel or as a reprocessed solid, is internment in geological formations of high stability.

While the quantity of defense waste is expected to increase slowly, this is not the case with civilian waste. The total amount of spent fuel generated will be 64,000 metric tons by 1995. The amount stored at the end of 1979 was 6,000 metric tons. As a crude measure of the toxicity of these materials, it would take more than 60 million billion gallons of water to dilute the fission product wastes accumulated in the United States by 1995 to meet existing federal drinking water standards.

Two broad categories of high-level wastes are produced in the operation of nuclear plants. For periods of up to several hundred years, the dominant source of hazard is fission products—atoms of medium atomic weight formed by the fissioning of uranium and plutonium. These are principally strontium-90 and cesium-137. These fission product wastes are generally characterized by their very intense, penetrating radiation, and their high heat-generation rates. After roughly 600 years, the toxic content of these fission products decays to less than one-millionth of their original activity and ceases to be the principal concern.

Beyond several hundred years, the dominant source of radioactive hazard is the actinides: heavy atoms of actinium, thorium, uranium, plutonium, and so forth. Although actinides are less intensely radioactive and thus generate less heat than do fission products, they are generally highly toxic and take far longer to decay. Using a crude hazard index that ignores the difference in volumetric concentrations, the toxicity of the actinide waste after 10,000 years is comparable to the original uranium ore from which the waste derived. Thus, the actinides require sequestering from the biological environment for times best measured in geological rather than historical terms. Our choices now are of continuing importance, for these radioactive wastes will be with us for millennia to come.

A Criterion for Radioactive Waste Management: A Case Study of Intergenerational Justice

THOMAS B. COCHRAN

Introduction

This report proposes a fundamental criterion for radioactive waste management: to limit the release, into the biosphere, of radionuclides. Because many radionuclides have long half-lives, they will be capable of irradiating populations for hundreds and thousands of years into the future. While the effects on one generation might be small, the cumulative effects over many generations may be substantial. Thus, a fundamental criterion for radioactive waste disposal must include consideration of this intergenerational irradiation and its effects.

While some technologies exist in preliminary form for immobilizing high-level waste, some new and hitherto untried technology is required to demonstrate the feasibility of this geologic disposal. Any judgment that disposal of the wastes meets acceptable levels of risk must ultimately depend on an assessment of what is acceptable.

To date, high-level radioactive waste disposal criteria do not exist in final form, although programs are under way to develop these criteria. Techniques are not yet available, furthermore, to determine whether a specific disposal approach satisfies any set of criteria, and adequate programs are not in place to develop such techniques. Consequently, acceptable isolation of high-level radioactive waste is yet to be accomplished.

Equal Opportunity: The Criteria for Intergenerational Equity

One approach for developing criteria for nuclear waste management that assures intergenerational equity is to frame the problem in the formal terms of analytic decision theory or the theory of social choice. Plausible arguments, on this approach, would center not on maximizing efficiency for the present generation in producing electric power, but on questions of acceptable allocations of benefits and hazards over time. If the economic aspects of the issue were those treated in classical theories of micro-economics, there would be no issue at all: hazards from nuclear wastes dumped into the environment and left for future generations would be externalities, to be ignored by behavioral units such as firms and consumers.

Modern analytic decision science tries to prescribe how an individual who is faced with a problem of choice under uncertainty should go about choosing a course of action that is consistent with his personal basic judgments and preferences.[3] In order to use the procedures and techniques developed by decision analysts, the individual need only be rational and satisfy a few consistency conditions. The essence of the rationality standard is this: if the individual is presented with possible outcomes of his decision, he must be able to express his preferences by making statements like "I prefer outcome A to outcome B" or "I am indifferent between outcome A and outcome B." The essential consistency condition is that the individual must be transitive in his preferences. If he prefers outcome A to outcome B, and prefers outcome B to outcome C, then he should prefer outcome A to outcome C.

The rationality and consistency constraints are imposed not to produce an analysis that suggests action along a recommended ideal, but simply to allow an analysis to occur. They state merely that the individual must be able to express how he feels about outcomes and must be consistent about those feelings. When these standards apply, formal decision analysis can be used to analyze a problem and, via a long, interactive process between analyst and decisionmaker, "solve" it in a way that is perfectly consistent with the decisionmaker's feelings.

If possible, it would be desirable to produce some sort of procedure by which a society can go about making decisions that are rational and consistent in a way analogous to the standards of individual decisionmaking. Decisions produced by society as a whole might relate to allocations of benefits and costs (such as wealth and working hours) among members, or could relate to other societal actions conferring intangible benefits, such as budget allocations for research that might save lives in the future. Procedures that society might use to make decisions could be various market mechanisms, government controls wielded by administrators, voting procedures, or any other processes that result, implicitly or explicitly, in the making of a decision. The study of such procedures is the domain of distributive economics.

In particular, this science tries to develop procedures for societal decisionmaking that promote fairness and justice. Defining exactly what constitutes justice is part of the problem before distributive economists. One measure of the justice of a societal decisionmaking process is how accurately the process aggregates individual preferences into an overall expression, called a societal preference function. Much theoretical work has been done to see if individuals' preferences can be aggregated to form an overall societal preference expression.[4]

This work has shown that interpersonal comparison of preferences requires some means of consulting each individual in the society and quantifying his feelings in an expression that allows comparison with other people's feelings. These general results imply that if a decision is to be fair to all affected by it, the decisionmaker must at a minimum have access to everyone's feelings about the outcomes. A fair allocation of risks and benefits between present and future generations would therefore be one that would be picked by a group preference function that consistently reflected the preferences of all the members of the group, in this case people living in the present and in the future.

These theoretical conclusions apply to any methodology used to make decisions, including cost-benefit analysis, voting by individuals, market mechanisms, and so on. They imply that there is no way through which formal analysis or decisionmaking processes of any sort can certify that any course of action allocating hazards to the future will be seen as fair or agreeable by future generations. Fundamentally, this is because there is no way to consult anyone from future generations about his preferences regarding outcomes and risks.

Page argues that the most sensible approach to this problem of intertemporal justice is to use *equal opportunity* as the criterion of intergenerational equity.[5]

Barry converges on the same equal opportunity criterion through his analysis of intergenerational justice. Barry notes that justice concerns the proper division of resources, rights, opportunities, etc. In its simplest terms, it means giving a person his due. In "Circumstances of Justice and Future Generations," Barry rejects Hume's theory of the circumstances of justice and argues instead that claims of future generations fall properly within the scope of theories of justice, proposing that the relevant concept of justice here is justice as equal opportunity.[6] He develops this latter proposition in "Intergenerational Justice in Energy Policy," where he also rejects alternative criteria, for example, those based on utilitarianism.[7]

The conclusions thus far reached are essential to understanding why some positions reached by public officials on the acceptability of nuclear waste risks are incorrect. For example, the Environmental Protection Agency (EPA) has suggested that the levels of danger that may be imposed on future generations can be defined by referring to the acceptability of risks exclusively among the present generation.[8]

The EPA tried to defend the fairness of this recommendation by referring to social choice concepts, yet the EPA conclusion is obviously wrong if one accepts the premise that fundamental precepts of rationality and consistency require the incorporation of every involved individual's feelings into a group decision if that decision is to be fair. Similarly, while the Nuclear Regulatory Commission (NRC) uses $1,000 person-rem as a value placed on human life and offers a rationale for this choice,[9] this can in no way be taken as a fair and reasonable measure of our society's group opinion. This figure's use in government programming demonstrates the government's willingness to use an expedient value judgment, regardless of society's opinion of its morality.

The conclusions of economists like Page and philosophers like Barry give us an ideal goal for our radioactive waste programming: an equal opportunity criterion, implemented through a neutral allocation of benefits and risks to future generations. In appealing to this ideal, we reject arguments that a present commitment to nuclear power is fair because current investments in a technological society via nuclear power will benefit the future by enhancing society more than they harm it through, for example, the proliferation of nuclear weapons and waste hazards. This argument requires weighing benefits now versus costs later to make an allocation that is known to be unfair. The neutrality ideal may be unattainable, but it is essential to minimize unfairness by the closest possible approach to neutrality with the future.

The practical conclusion of distributive economists' constraints on decisionmaking and the equal opportunity criterion proposed by Page and Barry is, then, that society should strive toward making nuclear waste disposal neutral to future generations, in order to be as fair as possible. This is a necessary, if not sufficient, condition for "safe" disposal of waste.

It would appear that we have gone through much theoretical discussion to reach a commonsense conclusion. Everything the present generation does has its impact on an unconsulted future and so is in some measure unfair to future generations; even more unfair, however, is to consciously promote a policy that involves the distribution of benefits now and hazards later. The least unfair mode is one that tries to keep allocations of benefits and costs confined to a single generation, where those subjected to hazards are at least available for comment. Thus, the least unfair way of managing intertemporal relationships is for each generation to try to leave the earth as it was when they arrived.

The Waste Management Criterion

These considerations lead to a fundamental criterion that should be applied to the disposal of radioactive wastes: nuclear operation of all types (such as mining, milling, fuel processing, decommissioning, and waste isolation or disposal) should be conducted so the overall hazards to future generations are the same as those that would be presented by the original unmined ore bodies utilized in those operations. The risk to all future generations from radioactive waste should be less than, or (considering uncertainties in the calculation) comparable to, the risk to all future generations from the original uranium resources from which the radioactive wastes were derived, assuming these uranium resources were left unmined.

The attempt here is to choose a criterion based on a theory of justice and equity. A waste criterion must be fair to future generations independent of the benefits this generation reaps from the use of nuclear power. The criterion above, therefore, simply ignores the net benefits of using nuclear energy. Instead, it considers only the risks to future generations.

CAN THE CRITERION BE MET?

To address this question, it is useful to begin with a simple thought experiment to conceptualize the problem. Suppose it were possible to take radioactive wastes, instantaneously to convert them into an exact duplicate of the original uranium ore whence they came, and to emplace the resultant ore underground in a duplicate of the original ore's geologic environment.

The risks to future generations from waste emplaced in this way would be identical to those posed by the original uranium ore, because the emplaced wastes would be identical to the original ore. In these circumstances, elaborate modeling exercises that estimate risks to future generations would be needless and possibly misleading, because two identical arrangements would be expected to perform identically over time. This expectation is adopted as a basic postulate: identical waste disposal mechanisms, in identical geologic environments, will produce identical risks to future generations.

Under this postulate, the proposed criterion would be satisfied by emplacing wastes in an artificial "ore body" whose characteristics are identical to those of the original unmined ore bodies. In principle, and to a large degree in practice as well, the process employed here requires only comparisons between measurable attributes of source ore bodies and waste treated under various disposal plans.

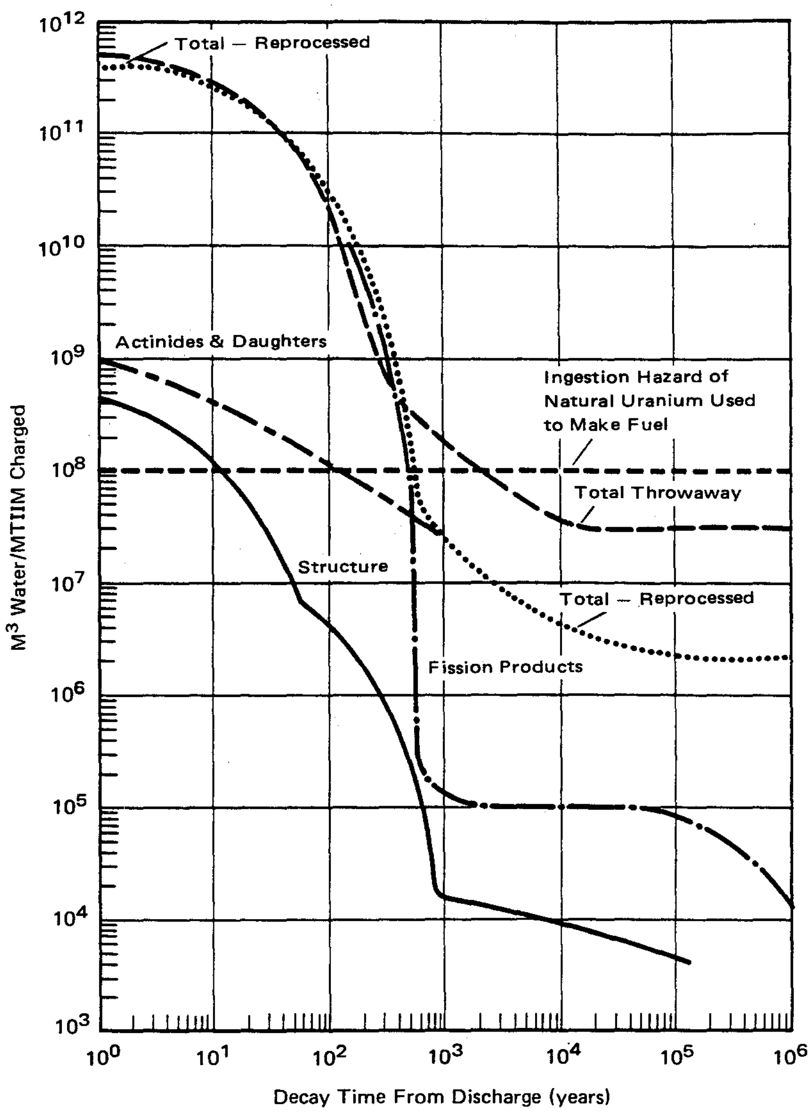
Source ore contains primarily uranium-238, a very long-lived isotope of uranium, and its decay products, such as thorium, radium, and radon. Because of the uranium isotope's long half-life, source ore radiotoxicity changes little over spans of tens of millions of years, and so can be viewed as a steady-state variable over extremely long time periods. Radioactive waste, on the other hand, is a highly complex mixture of artificial and natural radionuclides, most of which undergo some decay activity and produce daughter products that may also be radioactive. The exact mixture at any point in time depends on details of initial fuel composition, irradiation variables, postirradiation processing, and time elapsed since irradiation.

Figure 7.1 is a comparison over time of an ingestion hazards index of the radioactive waste to that of source ore, expressed in terms of the amount of water necessary to dilute a unit of waste, or ore, in order to meet current federal radiation protection standards.[10] This figure shows how the toxicity of radioactive waste resulting from various fuel utilization programs changes over time. Since the goal is to mimic the reference-ore hazard over time, the waste disposal plan, to be able to prevent movement of radioactivity to the biosphere, must have higher performance standards in the first 2000 years or so than in later years.

Exactly how characteristics of waste plans may be compared and judged identical to those of natural ore bodies is a complex matter when viewed in detail. Further, it should be clear that although perfect equivalency with ore bodies is a worthy goal, it is impossible to obtain with absolute certainty. Differences between radioactive waste and source ore combine with other incommensurables to inject some doubt about the future performance of disposal plans, no matter how closely the currently measurable characteristics of the plan match those of natural ore bodies. The important point here, however, is not that the criterion is faulty, but that one is still faced with the basic uncertainties common to all predictions, and these uncertainties are bound to infect any effort aimed at judging any waste disposal plan's acceptability.

There are two very different alternative approaches for managing this problem. The first applies the "defense-in-depth" philosophy utilized in the licensing of nuclear power plants, and the second is based on extensive use of risk-consequence modeling. I believe the latter is likely to increase the doubt that a waste plan will meet desired goals, while the former diminishes this uncertainty. In either case, again, the question here is not whether the criterion is appropriate but how one manages uncertainties and whether one is satisfied with the regulatory approach taken in judging whether the criterion is met.

The defense-in-depth design philosophy embodied in nuclear reactor licensing procedures of the U.S. Nuclear Regulatory Commission (NRC) implicitly acknowledges that things rarely go as one would like, especially with complex plans. To manage uncertainty, it uses the ideas of independence and redundancy to ensure that plans meet its goals. Under this philosophy, plans are designed around multiple independent components, the operation of any one of which is sufficient to meet the basic goals, even if the other parts are arbitrarily assumed to have failed. In other words, under this



Source: Arthur D. Little, Inc., *Task A Report*, p. 35.

Figure 7.1. Ingestion Hazard Index (Throwaway vs. Reprocessed and Recycled LWR Fuel)

philosophy, failure of *all* the components must occur for the overall plan to fail.

Uncertainty still exists, of course, as a result of possible common mode failure, and as a result of residual uncertainties that each component, on its own, really is sufficient if the others should fail. Nonetheless, the application of defense-in-depth as a design philosophy can diminish the uncertainty of reaching one's goals.

The second approach—favored by some people within government agencies but believed by this author to be unacceptable—might best be described as systems analysis using risk-consequence modeling. To judge whether a given waste disposal plan is acceptable under this philosophy, the entire plan, from waste form to general site, is plugged as a unit into a mathematical model purported to function as an analog to the real world. The model yields what is taken to be an accurate or conservative (in terms of safety) simulation of the behavior of the waste disposal plan over time. If the predicted behavior is within limits, the waste plan passes; if not, it fails.

This approach can lead to increased uncertainty: first, because failure of a single key component could jeopardize the entire plan and, second, because, in addition to the probabilistic nature of the model, one is faced with the very real uncertainty of whether the model accurately represents all of the many things that might occur over hundreds of thousands of years—that is, whether the model represents the real world or simply represents what its author thinks the real world is.[11]

Radioactive Wastes: Pragmatic Strategies and Ethical Perspectives

DAVID L. BODDE

Some say the world will end in fire.
Some say in ice.
—Robert Frost, "Fire and Ice"

The disposal of radioactive waste, for many years treated as a matter of secondary importance, has emerged as a central feature of the public debate over nuclear energy.[12] This early neglect resulted from the presumption that guided the salad days of the commercial nuclear enterprise: that simple, purely technical solutions were readily at hand and that attention could be devoted to more urgent matters. But if the error of the past was to presume that the problem of radioactive waste disposal was trivial, the error of the present may be to presume that it is ethically decisive. It does not denigrate the importance of responsible disposal of nuclear waste to claim that neither view is correct.

In fact, the management of radioactive waste is prototypical of the issues facing a rapidly multiplying humanity armed with technologies that have direct implications for persons who might live many generations in the future. Examples abound. Toxic chemical wastes, the nascent imbalance of carbon dioxide in the atmosphere, and nuclear warfare over increasingly scarce energy resources come readily to mind.

While the disposal of radioactive waste is prototypical of these concerns, it is only prototypical. There is nothing inherent in the problem to warrant attention out of proportion to the other societal dangers that face us. In this essay, I contend that if our moral concern is the preservation of equal opportunity for future generations[13]—and I personally believe this to be correct—then our duty is to create solutions to the disposal of radioactive waste in the context of the other threats to human existence, rather than in isolation. This implies a more holistic approach than has heretofore been taken. It implies balancing our attention and resources in proportion to the magnitude and nearness of the danger.

Suppose we were to see a person standing on a railroad track smoking a cigarette and unaware of a rapidly approaching express train. We recognize that both the smoking and the train are capable of shortening that person's life, albeit on different time scales. But we have little doubt what our first duty is: to warn of the train, thus providing the opportunity for subsequent reform of the smoking. Similarly, a necessary condition for preserving equal opportunity for future generations is the avoidance of catastrophic events of such scale as to seriously diminish the rights and welfare of those who follow.

Thus, a moral concern for the preservation of equal opportunity for future generations would suggest the following principles be applied to radioactive waste management and to energy policy in general:

- resource-balancing strategies for the management of radioactive waste that ensure that the hazards to future generations are no worse than other technology-related threats to human rights and welfare;[14]
- continuance of technological progress to ensure compensation for the depletion of nonrenewable resources; and

- nurturing of institutions, national and international, whose scope and capabilities match the nature of the social-technical problems before them.

More of this subsequently: first it is necessary to understand more about radioactive waste and the energy problem in general.

Radioactive Waste Disposal

Three salient characteristics of radioactive waste disposal are basic to our discussion. First, as is true for any human activity, there is no such thing as zero risk. No matter how cleverly one designs the system for waste storage and disposal, a non-zero probability remains that some persons alive today or in the future will be harmed. To be sure, we can reduce our a priori assessment of the probability of an accident to a number that is arbitrarily small. But that number can never be zero.

The second characteristic is a consequence of the first. Since there is no theoretical limit to how safe any disposal system can be made, there is always room for improvement. For example, if a barrier material surrounding a radioactive waste canister is designed to be x meters thick, there will be some improvement in performance if the thickness is increased to 2x; similarly to 3x; and so on. While diminishing returns to such modifications are clearly evident, there is no equivalent of the Second Law of Thermodynamics, which sets the maximum thermal efficiency of heat engines independent of their configurations. As a result, one can always argue that since a better site can be found or a better design made, it should be. There is no natural stopping point.

Third, estimates of the soundness of any disposal plan are necessarily *ex ante*. If the desideratum is containment of tens of thousands of years, a demonstration of performance before a repository is opened is necessarily impossible. This means that the verification of *ex ante* performance estimates, which is available in other technology-intensive activities such as aviation, is not possible for radioactive waste repositories. This tends to encourage arguments for unbounded improvements.

Thus, the key question in nuclear waste disposal, what constitutes "good enough," is not resolvable by physical laws or empirical tests. We can turn to ethical principles for guidance, however. If "good enough" is defined in the context of preserving equal opportunities for future generations, then strategies for custodianship need to be balanced with strategies for dealing with other long-term hazards. Such balance is not necessary if a standard of neutrality is applied to radioactive waste alone.[15]

To be sure, neutrality appears sufficient to meet the test of equal opportunity where radioactive wastes are concerned. Indeed, it may be sufficient to ensure equal opportunity in any particular area to which it is applied. But to be most useful, the concept needs to be applied to the energy problem in general. Only if this is done can we hope to develop practical, balanced energy strategies.

Effects on Future Generations

It is important to be precise about the hazards that may face future generations as a result of our creation of radioactive waste—especially if we are to weigh these in even a rudimentary way against the other dangers that we are likely to bequeath.

To do so, I would like to begin with the following postulate: that radioactive waste can be isolated from the biosphere with present technology in a manner that adequately protects the rights and welfare of *present* generations. This is not to say that the risks can be reduced to zero. It *is* to postulate that active surveillance and containment systems, available with present technology, can reduce the probability of release of radioactivity to a level that adequately protects the rights and welfare of those now living. Neither is this to argue that such containment is actually being provided, but rather that it *can* be provided if sufficient intelligence and resources are devoted to the task. Further, it says nothing about our ability to do this tomorrow—only that it can be done today.

If this postulate is correct, future generations can enjoy the same level of protection that we have afforded ourselves as long as they are able to continue practices now available. In that case, our ethical concern for future generations would arise from three possibilities.

- *A cost concern.*[16] Even if the standards for adequate protection (and hence the real costs of management) remain at present levels, it may be unfair to impose radioactive waste management costs on future generations in exchange for benefits that accrue largely to us. Alternately, future generations may desire higher standards which might require them to incur even greater costs for radioactive waste management.
- *A capability concern.* The ability of future generations to retain the present level of technological and managerial capabilities might be lost, perhaps through such disasters as war or rapid climatic change.
- *A concern with mistakes.* In attempting to preclude the first two possibilities, we might inadvertently create a situation in which future generations face an even higher cost of maintenance or in which even present technological capabilities would be insufficient to prevent harm. Thus, those who follow us might be required to bear even larger costs or to develop technological capabilities that do not now exist.

Radioactive Waste in Its Energy Context: Some Important Linkages

When the problem of radioactive waste is separated from its energy context, some important linkages are broken. It is important to reestablish those linkages and assess their implications for strategies through which to fulfill our moral obligations.

The first connection is between radioactive waste and nuclear energy.[17] As a practical matter, the future of nuclear fission as an energy source is linked to the custodianship of its waste and, in particular, to the ability of its custodians to protect adequately persons in the far future in addition to those now living.

The energy problem, in which nuclear energy is embedded, is separable into two distinct issues. The first is a short-term (5- to 10-year) concern with the oil dependence of the West. This results in inflation, massive transfers of wealth to oil-producing nations, and strategic vulnerability. While the nuclear-generating stations now on line and under construction can have an ameliorating effect on this short-term problem, nuclear power is not likely to be a key factor in its resolution. This is due to the long gestation period for nuclear power plants and the close association of nuclear power with electricity production. Coal is similarly limited over this brief period, although the mid-1990s may see the beginning of large-scale synthetic fuel production. Thus, conservation and contingency planning are left as our principal near-term resources.

The second energy issue is the long-term transition from exhaustible, fossil fuels to renewable resources. Nuclear power can be considered one of these resources, together with solar.[18] In its fusion form, the supply of nuclear fuel is essentially unlimited; in its fission form, the breeding of fissionable atoms from the abundant isotopes of uranium and thorium makes these fuels a potential source of energy for hundreds of thousands of years. (Even without breeding, fission can take us at least two score years, and probably more.)

The timing of the transition to the renewables is still a matter of debate. Nonetheless, the following numbers are helpful in orienting the discussion. Ultimate world resources of oil are probably in the neighborhood of 1600 billion barrels. World oil use is about 64 billion barrels per day at present, which would suggest a seventy-year supply, albeit under conditions of increasing severity. Proven reserves are much smaller: 670 billion barrels, or roughly a thirty-year supply. The outlook for natural gas, which is the preferred substitute for many uses of oil, is somewhat more uncertain; but evidence that the situation is substantially different from that of oil is inconclusive.

The importance of these numbers is not in their precision; of course, real economies do not draw on resources at a constant rate until the last bit is gone. Rather it is to illustrate the time scale over which mankind must make the transition away from oil and gas. That transition must certainly be completed within 100 years, and probably much sooner.

Coal is often held to be the bridge from oil and gas to renewable energy resources. Indeed, the magnitude of this resource is impressive. Economically recoverable world coal reserves are the equivalent of about 3200 billion barrels of oil, and the geological resources may be greater by a factor of ten. Most of this is located in the USA, the People's Republic of China, and the USSR, and significant deposits may await discovery elsewhere.[19] If there were no environmental difficulties with coal combustion, the urgency of the eventual transition to renewables would diminish significantly. With wise end-use practices, coal energy resources could last for hundreds of years.

Most of the environmental risks from coal use—emission of particulates and oxides of nitrogen and sulfur—are amenable to technological control. But the most troublesome hazard, the prospective build-up of carbon dioxide (CO_2) in the atmosphere, offers much greater difficulty. The CO_2 problem merits discussion in this essay on radioactive waste because it is illustrative of the social-technical concerns arising from mankind's use of energy and of the need for holistic assessments. The range of scientific uncertainty may be greater for CO_2 than for radioactive waste, but to the extent that a problem exists, it is likely to impinge upon us in the next fifty to two hundred years, a time much nearer than the period of concern for radioactive waste.

The release of CO_2 is the unavoidable consequence of burning carbonaceous fuels, and no realistic means of control is yet available.[20] Unfortunately, coal is the worst offender: it releases 25 percent more CO_2 per unit of energy content than oil and 75 percent more than natural gas.

Atmospheric CO_2 is a key regulator of the earth's temperature. In greater concentrations it tends to warm the earth; in lesser, it tends to cool. This is because the atmosphere is largely transparent to incoming solar radiation of short wavelengths. But CO_2, together with water vapor in the atmosphere, absorbs the longer wave-lengths of infrared that are reradiated from the earth's surface. The effect is to trap heat, thus raising surface temperatures.

Although much uncertainty surrounds the precise effects of increased atmospheric CO_2, the following can be taken as reasonably factual. First, the present increases in CO_2 level have been accurately and widely observed. If these increases continue, the amount of CO_2 in the air will double within two generations. Second, while the magnitude of the effect on global temperatures remains in doubt, virtually all analyses suggest a global warming. Whether this warming would be checked by other long-term climatic phenomena is still a matter of scientific debate.[21]

If such a warming does indeed take place, it is reasonable to assume that its effects are not likely to be good. The global pattern of land use was built around existing climatic conditions. Rapid changes in those conditions may not allow sufficient time for the establishment of new productive areas for agriculture.

Thus, when we include environmental and climatic effects in the calculus of equal opportunity, the long-term energy options of conservation, solar, and nuclear take on special significance. Consideration of an adequate strategy to deal with the nuclear waste problem necessarily affects nuclear energy. An ethical proposition that suggests that the effects of radioactive waste on future generations are by themselves sufficient grounds to terminate nuclear energy but that does not include consideration of nearer dangers, such as CO_2 accumulation, does not appear to lead to practical strategies for survival.

Practical Strategies to Provide Equal Opportunity

Although I cannot assert that the following strategies are sufficient, they are clearly necessary elements of any energy policy that would seek equality of opportunity for future generations.

1. *Balanced resource allocation.* If the foregoing is correct, our moral obligations require the allocation of scarce resources in a way that recognizes the magnitude and timing of the dangers before us. Radioactive waste, and for that matter any other hazard, should receive attention in proportion to the nearness and extent of its threat to us.

2. *Technological progress.*[22] The foregoing discussion is at pains to suggest that major societal transitions face mankind over the next one hundred years. All of these are likely to present the same sort of difficulties to future generations as radioactive waste: just as our present consumption of nuclear energy requires future investments in custodianship and incurs risks of failure, so our present consumption of petroleum or coal requires future investments in alternatives and incurs risks of failure. Without enlargement of our technological capabilities, it is unclear how we can provide equality of opportunity to future generations in the face of declining quantities of low-cost resources. They will need to be more artful than we are in deploying solar energy and/or advanced forms of nuclear, and clearly more wise. While we can do little regarding the latter, a continuation of technological progress is essential to the former.

Preservation of nuclear power as an energy alternative may be quite helpful in ensuring technological progress. This is because nuclear power (together with most forms of solar power)[23] can provide energy in a manner independent of the principal long-term constraint on fossil energy, CO_2 build-up. Thus nuclear power offers, at the very least, a hedge against the late deployment of solar power and the fulfillment of our worst speculations regarding the CO_2 problem. Such a hedge is necessary to ensure the availability of energy to an increasingly technology-based society.

This much can be stated without invoking any arguments for the economics of nuclear power. It is worth noting, however, that to the extent that nuclear power is more economical than its alternatives, when all costs are included, it offers the further advantage of greater efficiency in resource allocation.

3. *Institutions adequate for the problems.* National institutions tend to select some problems (such as radioactive waste) for detailed attention while neglecting others (such as CO_2 build-up). In my judgment, this is because we tend to work on that for which the societal instruments exist. In the case of radioactive waste, national institutions, admittedly of varying quality, are available throughout the world to address this problem. And indeed this may be appropriate, since many (though not all) aspects of the radioactive waste management problems seem resolvable within a national context. By contrast, CO_2 build-up cannot be dealt with by national institutions. The problem is too large for that scale of institution, and because it is too large, it tends to be ignored. It seems clear that our obligation to future generations includes the building of institutions of sufficient scope to deal with the problems we bequeath them.

Some Concluding Thoughts

None of this is to denigrate our moral obligations for the careful stewardship of radioactive waste. It is, however, to suggest that our duty to the future is to weave such disposal into the broader fabric of a just and workable civilization.

Notes

1. See Todd R. LaPorte, "Nuclear Wastes and the Rigors of Nearly Error-Free Operations: Problems for Social Analysis," *Society/Transactions* (March 1981).

2. Transuranic wastes are composed of elements heavier than uranium. The decision to concentrate on only these wastes—which can be considered a subclass of the high-level wastes—involves some complicated reasons having to do, in part, with debates about whether to treat "military" wastes separately from "civilian" wastes.

3. Howard Raiffa, *Decision Analysis—Introductory Lectures on Choices Under Uncertainty* (Redding, Mass.: Addison-Wesley, 1970).

4. See Ralph L. Keeney and Howard Raiffa, *Decision with Multiple Objectives: Preferences and Value Tradeoffs* (New York: John Wiley & Sons, 1976; Kenneth J. Arrow, *Social Choice and Individual Values* (New Haven, Conn.: Yale University Press, 1951); Amartya K. Sen, *Collective Choice and Social Welfare* (San Francisco: Holden-Day, Inc., 1970); Talbot Page, *Conservation and Economic Efficiency* (Baltimore: Johns Hopkins University Press, 1977); and Environmental Protection Agency,

"Criteria for Radioactive Wastes, Recommendation for Federal Radiation Guidance," *Federal Register* 43 (November 15, 1978): 53262.

5. Page, *Conservation and Economic Efficiency;* Environmental Protection Agency, "Criteria for Radioactive Wastes."

6. Brian Barry, "Circumstances of Justice and Future Generations," in *Obligations to Future Generations*, edited by R. I. Sikora and Brian Barry (Philadelphia: Temple University Press, 1978).

7. Brian Barry, Chapter 1, this volume.

8. Environmental Protection Agency, "Criteria for Radioactive Wastes."

9. One person-rem is a unit of collective radiation dose, e.g., one rem dose of radiation to one person, or 0.1 rem to each of 10 persons.

10. Arthur D. Little, Inc., *Task A Report* (draft to Office of Radiation Programs, USEPA, on Contract No. 68-01-4470, Technical Support for Radiation Standards for High Level Radioactive Waste Management, July 1977), p. 35, fig. A-6. The data used to derive this figure have large uncertainties and in some cases are obsolete. The figure, therefore, is displayed only for its qualitative value.

11. This chapter was derived largely from "Radioactive Waste Management" by Thomas B. Cochran, Dimitri Rotow, and Arthur R. Tamplin, Natural Resources Defense Council, April 13, 1979.

12. The other components of this debate are nonproliferation, safety, the need for electricity, and the scale of energy production.

13. See Brian Barry, "Intergenerational Justice in Energy Policy," Chapter 1, this volume.

14. This is not to be mistaken for an argument that we do not need to progress with radioactive waste disposal as long as something worse can be found. But it does suggest that this progress should not consume resources needed to deal with nearer-term, greater dangers. The issue is balance among competing claims on finite resources.

15. In the first essay in this chapter, Thomas B. Cochran has proposed neutrality as a test of moral responsibility regarding radioactive waste. Under this test, adequacy would require that radioactive waste disposal be conducted in such a way that the overall hazards to future generations remain the same as those that would accrue had the original ores remained unmined. Interestingly, present criteria for a radioactive waste repository now being developed by the Nuclear Regulatory Commission would allow leakage rates far lower than those that characterize many natural uranium ore bodies. This suggests dissatisfaction with this "natural" definition of adequacy by the present generation. Are we to suppose that future generations would prefer the more relaxed standard?

16. The term "cost" is here used in its broadest sense: economic costs, societal costs, and the attention of men of intelligence and good will.

17. Military waste is omitted from discussion since the rationale for its creation lies in the rationale for defense with nuclear weapons, which is beyond the scope of this essay.

18. In this context, "solar" includes passive uses, active conversion of solar energy into heat or electricity, wind, biomass, and hydro.

19. See, for example, C. L. Wilson et al., *Coal: Bridge to the Future* (Cambridge, Mass: Ballinger Publishing Co., 1980).

20. The burning of fossil fuel is only partly responsible for the rise in atmospheric CO_2. Global deforestation and the oxidation of the humus in the ground appear to contribute comparable amounts.

21. For a succinct yet complete discussion of this, see C. Tickell, *Climatic Change and World Affairs*, Center for International Affairs, Harvard University, 1977.

22. This uses "technological" in its most general sense: knowledge and the set of institutions and capital equipment that enable its application.

23. Ocean Thermal Energy Conversion (OTEC) may contribute to CO_2 production by bringing large amounts of seawater containing CO_2 from the deep oceans to the surface. In addition, many biomass energy processes, when not in steady state conditions, can cause net CO_2 production.

Energy and the Future

Edited by
DOUGLAS MacLEAN
and
PETER G. BROWN

ROWMAN AND LITTLEFIELD
Totowa, New Jersey

First published in the United States in 1983 by Rowman and Littlefield, 81 Adams Drive, Totowa, New Jersey 07512.

Library of Congress Cataloging in Publication Data
Main entry under title:

Energy and the future.

(Maryland studies in public philosophy)
Includes bibliographical references and index.
1. Power resources—Social aspects. 2. Energy policy
—Social aspects. I. MacLean, Douglas, 1947-
II. Brown, Peter G. III. Series.
TJ163.2.E4643 1983 333.79 82-18609
ISBN 0-8476-7149-6
0-8476-7225-5 (pbk)

Published in the United States of America