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Managing Nuclear Wastes: An Overview of the Issues

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MANAGING NUCLEAR WASTES: AN OVERVIEW OF THE ISSUES

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The primary purpose of this special symposium is to set out the broad range of issues relevant for a problem that is, and will likely continue to be, of particular importance to our society—the management of nuclear wastes. In setting out these issues, the intent is to illuminate the present state of the arts for assessing policy alternatives relevant for the management of nuclear wastes, thereby identifying policy questions and trade-offs which may warrant priority in terms of future research concerning this important management problem.

The need for a critical overview of research priorities concerning nuclear waste management (NWM) arises as a result of the confounding uncertainties inherent to NWM problems. There are uncertainties surrounding the scope of the problem; for example, away-from-reactor storage capacities for 560 metric tons of nuclear wastes will be required by 1983 according to a DOE estimate while the GAO's estimate is but 152 metric tons for 1983.[1] There are uncertainties concerning the nature of the NWM problem; for example, considerable controversy exists as to the extent of dangers to public health and safety associated with the transport (and storage[2]) of nuclear wastes: could accidents result in nuclear explosions, tens, or hundreds, of fatalities?[3] Moreover, there are uncertainties as to the best way to store nuclear wastes,[4] how one best prepares for any waste-related emergency,[5] who is liable for effects from any waste-related accident[6] (and the role of the NRC in this regard[7]), as well as to how one

1. *See* B. Cohen, *High Level Radioactive Waste,* 21 NATURAL RESOURCES J. 703 (1981).
2. See, for example, S. E. LOGAN, DEVELOPMENT AND APPLICATION OF RISK ASSESSMENT METHOD FOR RADIOACTIVE WASTE MANAGEMENT, REPORT NE-44 (77)-EPA-394-1 (Bureau of Engineering Research, University of New Mexico, March, 1978).
3. See R. G. CUMMINGS, *et al.* THE PROPOSED WASTE ISOLATION PILOT PROJECT AND IMPACTS IN THE STATE OF NEW MEXICO, EMD 2-67-1139, 713-714 (New Mexico Energy Research and Development Institute, Albuquerque, New Mexico, April 1981); see, also Norton, *Policy Issues in the Routing of Radioactive Materials Shipments,* 21 NATURAL RESOURCES J. 735 (1981).
4. *See* Cohen, *supra* note 1.
5. *See* Church and Norton, *Issues in Emergency Preparedness for Radiological Transportation Accidents,* 21 NATURAL RESOURCES J. 757 (1981).
6. *See* L. Cohen, *Who Pays the Bill: Insuring Against the Risks from Low Level Nuclear Waste Disposal,* 21 NATURAL RESOURCES J. 773 (1981).
7. *See* Quirk and Terasawa, *Nuclear Regulation: an Historical Perspective,* 21 NATURAL RESOURCES J. 833 (1981).

evaluates potential impacts on future generations from nuclear waste management policies adopted at this point in time.[8]

Indeed, uncertainty is the aspect of the nuclear waste management problem that sets it apart from the bulk of policy issues confronted by the government, and may be viewed as the unifying theme for the papers in this volume. In these terms, Professor Bernard Cohen's paper may be viewed as representative of the position taken by many physical scientists regarding nuclear waste management, that uncertainties concerning NWM are few and that, in any case, threats to public health and safety from nuclear waste disposal pale in significance when compared with analogous threats associated with the use of coal and the disposal of wastes from burned coal. To some extent, Cohen's argument parallels those by other scientists who argue that the major cause for public concern regarding the use of nuclear power and nuclear waste disposal options is a break-down in communications between the scientific community and the general public—i.e., the public simply doesn't understand the issues involved and the relative safety of nuclear options. Thus, Hammond observes that "the early developers of nuclear power had three failings—they knew too much about radioactivity, not enough about geology, and almost nothing about dealing with the public and its reactions."[9] As to the relative safety of nuclear power, a 1978 study of risk in energy generation systems (including solar, wind, ocean, thermal, methanol, coal, oil and nuclear) concluded that nuclear power, including waste disposal, along with natural gas, is associated with less risk to public health and safety—on the order of *100 times less risk*—than any of the other technologies considered.[10]

As suggested in Professor Burness's paper, however, the preceding line of argument is viewed by many as sanguine, at best. Here it is argued that uncertainty—undefined, non-quantifiable risk—shrouds the NWM issue and that it is impossible to remove this uncertainty.[11] This conclusion rests on the following arguments. Risk analyses for nuclear related activities are based on "fault tree" analyses wherein the analyst must attempt to set out all possible types of system failures or accidents. The following criticisms immediately arise:

8. *See* Schulze, Brookshire, and Sandler, *The Social Rate of Discount for Nuclear Waste Storage: Economics or Ethics?,* 21 NATURAL RESOURCES J. 811 (1981).

9. Hammond, *Nuclear Wastes and Public Acceptance,* 67 AMERICAN SCIENTIST 146 (1979).

10. H. Inhaber, RISK OF ENERGY PRODUCTION (Atomic Energy Control Board, Ottawa, Canada, March, 1978).

11. For an elaboration of this argument beyond that given in the Burness paper, see Cummings, note 3, *supra,* Chapter VIII.

> . . . the analyst essentially is required to imagine that which has never been experienced before.[12]
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> it is very rare that actual system failures are found to be due to hardware failures (i.e., the failure modes that are usually considered in fault-tree analysis). The cause of failure usually turns out to be one that . . . the analyst would have a very hard time imagining–like a specific design error or human error.[13]

Weaknesses in risk assessments based on fault tree studies related to the impossibility of one "imagining" all sources for, particularly, human or design error are succinctly stated in the conclusions of a study prepared by the Massachusetts Commission on Nuclear Safety:

> If one could identify all of the possible chains of events that could lead to a given category of release of radioactivity and could associate a probability of occurrence with each event in these many chains, one could, in principle, calculate the probability of the release in question. In practice, this cannot be done in a rigorous fashion. The probability that a piece of equipment, or an operator, will fail to perform satisfactorily can be estimated only approximately, based on a combination of actual plant experience and experience with similar equipment (and/or men) in other situations. Far more troublesome is the fact that it will be impossible to anticipate all the possible chain of events that might lead ultimately to a release of given characteristics . . .[14]

While serious accidents in the use of nuclear power or in the disposition of nuclear waste have not occurred, criticism of risk analysis based on fault tree approaches of the type cited above cannot be summarily dismissed. An example of a potentially dangerous mishap resulting from human error–unanticipated in a fault tree analyses–is the well known Brown's Ferry incident. An example involving design error is the Three Mile Island (TMI) incident. A malfunction of the type that occurred at TMI was evaluated *via* fault tree analysis and assigned a very small occurrence probability. The *ex ante* fault tree analysis was based on a Westinghouse design, however, whereas the TMI reactor was actually a Babcock-Wilson design. Following the TMI incident, the risk of this type of malfunction was analyzed using the correct, Babcock-Wilson design and the odds of such a malfunc-

12. Zeckhauser, *Procedures for Valuing Lives,* PUBLIC POLICY, 23(4), Fall, 1975, p. 445.

13. Apostolakis, *Probability and Risk Assessment: The Subjectivistic Viewpoint and Some Suggestions,* 19 NUCLEAR SAFETY 313 (May-June 1978).

14. MASSACHUSETTS DEPARTMENT OF HEALTH, MASSACHUSETTS COMMISSION ON NUCLEAR SAFETY (Boston, September, 1975).

tion were shown to be much higher (1 out of 16 reactor years according to Epps[15]) than the earlier estimate.

The implications of the above described dilemma for policy research concerning NWT are clear. Fault tree analysis is the only viable tool for scientific studies of risk associated with the transportation and storage of nuclear wastes.[16] However diligent the efforts of scientists in these studies, risk assessments for alternative policies associated with nuclear waste management cannot dispel the uncertainty surrounding the risk of such policies inasmuch as the potential for "unimagined" accidents resulting from design/human error will always remain. Since, for any analysis of risk associated with a NWM policy option, one can always imagine a set of events leading to serious accidents which were not included in the fault tree study, the potential for highly charged controversy concerning *any* NWM policy is simply unavoidable–objective means for quelling fear (Dupont's "nuclear phobia"[17]) do not exist.[18]

The uncertainty theme continues with Professor Norton's discussion of policy issues related to the transport of nuclear wastes. Here attention is focused on three particularly important issues: the potential consequences of radiológical transportation accidents, the appropriate mode of transport (road *vs.* rail) and the use of special trains. Professor Norton concludes that consequences of a transportation accident could well involve tens of fatalities, but hundreds are unlikely in the absence of sabotage, and nuclear explosions would not result from such accidents. Interesting observations are offered by Professor Norton concerning the road *vs.* rail controversy: while the chance of an accident is higher for road transport than for rail transport–arguing for reliance on rail options–the odds of a *severe* accident, involving fire with more than two hours duration, is much higher for rail transport. Uncertainties surrounding the transport mode issue then involve weighing accident probabilities against severity implications of accidents.

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15. Epps, *They Bet Your Life*, THE WASHINGTON POST MAGAZINE, Nov. 18, 1979, at 45.

16. See, for example, U.S. DEP'T OF ENERGY, WASTE ISOLATION PILOT PLANT: FINAL ENVIRONMENTAL IMPACT STATEMENT (1980).

17. See NUCLEAR PHOBIA–PHOBIC THINKING ABOUT NUCLEAR POWER: A DISCUSSION WITH R. L. DuPONT 2, THE MEDIA INSTITUTE (Wash., D. C., March, 1980).

18. Compounding these difficulties is the problem faced by laypersons in interpreting low probability-high consequence events. In such cases, "accident probabilities are usually not given significant weight in an individual perception . . . [T]he size of the potential accident is given more weight than the probability." Starr, Rudman & Whipple, *Philosophical Basis for Risk Analysis*, ANNUAL REVIEW OF ENERGY 632 (1976); see, also, Cummings, note 3, *supra*, Chapter VIII.

Uncertainty and costs are highlighted in Norton's discussion of the special trains issue. An NRC study estimates that the cost of operating special trains for nuclear waste transport would be many-fold higher than savings (including loss of life) from their use. Serious questions then arise concerning methods used for valuing a life. If dollar measures are to be the yardsticks against which policy options are to be assessed, methods used for valuing lost lives must be defensible on methodological and ethical grounds. Norton argues that such is not the case with state of the arts methods used for valuing life, in which case alternative frameworks are required for assessing policy options involving potential loss of life.[19]

Based on the above, controversy centered on safety will likely be a necessary part of any consideration of NWM policy options: therefore, risk minimization must be at the forefront of analyses related to such options. The minimization of risk in nuclear waste management is the central theme of three papers in this volume. Church and Norton consider this issue in terms of optimal programs for emergency preparedness. Two major topics included in their discussion are problems associated with the assessment of responsibilities for such things as evacuation and, particularly important, problems associated with defining criteria which can be used in addressing the question of how safe is safe enough? This question is of paramount importance in determining the scale of emergency preparedness programs, e.g., training of public safety officers, emergency radiological equipment, hospital staffing and facilities, highway upgrading, etc. Church and Norton raise provocative questions as to the usefulness of standard, benefit-cost analyses in addressing the "how much" question related to emergency preparedness programs. Paralleling our earlier discussion of risk per se, the issue here is the appropriateness of comparing dollar costs for emergency preparedness programs with surrogate measures, in dollars, for loss of life.

The issue of minimizing potential damages associated with nuclear waste transport and storage is expanded in Professor Hageman's analyses concerning effects on property values. While Professor Hageman finds little available evidence that would support the notion that property values are adversely affected by proximity to waste disposal sites or transport routes, she does point to trends that suggest that such effects may become important as disposal sites increase in num-

19. The "how safe is safe enough?" issue is given an interesting treatment in R. C. SCHEWING and W. A. ALBERS (editors), *Societal Risk Assessment* (Plenum Press, New York 1980); see also, the initial issue (Vol. 1, No. 1) of the journal, RISK ANALYSIS (Plenum Press, March, 1981), particularly the paper by Graham and Vaupel, *Value of a Life: What Difference Does It Make,"* (at 89).

ber and public awareness increases as to possible implications associated with close proximity to waste site and transport routes. Readers will find particularly interesting the analytical framework for assessing property value effects developed by Professor Hageman which may be used in future research.

The third paper dealing with costs and risk minimization is by Quirk and Terasawa wherein the issue of regulation is taken up. Given our limited expeience with away-from-source (reactor) storage of nuclear wastes–and that experience is essentially limited to low-level wastes–one can only speculate as to the desirability of extensive licensing processes for waste sites, particularly in terms of NRC licensing. Drawing from the U.S. experience with the nuclear power industry, Quirk and Terasawa address two related questions which are relevant for nuclear waste management. First, what are the costs associated with NRC licensing? Second, what do growth trends in the nuclear power industry suggest in terms of the potential scope of the nuclear waste disposal industry in the future? In terms of this first question, there is little doubt that the federal regulatory process involving the "practical value rule", environmental review processes, and intervention processes, in addition to the safety-related regulatory processes of the NRC is costly in terms of time. In the mid-1960s, an average of 5½ years was required to complete the licensing process for nuclear plants; by the early 1970s, the average time required to complete the licensing process increased to *more than 12 years.* While it is clear that such lengthy licensing-regulatory processes impose large costs on applicants, it is not clear that the end result of the lengthier processes *per se* has necessarily made nuclar plants safer. This is obviously relevant for the NWM issue of concern in this volume and, as in earlier instances discussed above, methods simply do not exist for assessing "benefits" from alternative licensing/regulatory processes which could be used to choose optimal processes wherein benefits are in some sense balanced with costs.

In terms of the future growth of the nuclear power industry and, therefore, the potential future magnitude of the wage problem, Quirk and Terasawa point to a number of factors aside from delays from licensing processes which have resulted in a dramatic decline in new applications for power plants. These include many-fold increases in capital costs for nuclear plants (from $187/kw in the 1960s to $849–$1,058/kw in the mid-1970s) and a deterioration in the nuclear industry's fuel cost advantage which has resulted from increases in the cost of yellow cake from $6–$9/lb in the 1960s to $40–$45/lb in the 1970s. To the extent that these trends continue, the scope of the NWM problem (as related to growth in the nuclear industry) may be correspondingly diminished.

The Quirk-Terasawa discussion of licensing-regulatory issues in the United States is extended to international issues in Dr. O'Brien's contribution to this volume. Dr. O'Brien brings sharp focus to the problems associated with implementing the provisions of the 1979 Nuclear Non-Proliferation Act which provides for the storage of nuclear wastes under "effective international auspices and inspection" and for appropriate compensation for the energy content of stored waste. O'Brien identifies a number of problems associated with guaranteeing a participant-country's access and control of jointly stored nuclear wastes, as well as problems in obtaining agreement between participants as to the "desirability" of recovering the energy content of stored waste (which then determines "appropriate compensation"). Looking to our experience with such international organizations as the International Court of Justice and the Court of Justice of The European Communities, O'Brien offers suggestions for the structure and composition of an international organization which might act as an appropriate entity for the management of nuclear wastes under international auspices.

The papers described above have as their central focus NWM programs that are preventative in nature—the issues of concern relate to minimizing the risk of damages. A remaining question of considerable importance is: what happens *if* nuclear waste transport or storage results in damage to the public—who is liable for the damages? Dr. Linda Cohen addresses the liability issue as it is relevant for (among others) two situations: unexpectedly expensive decommissioning costs arise because of difficulties at the disposal site (premature closure); damages arise due to adverse effects on public health. The liability issue is made extraordinarily complex by the many actors involved in the nuclear waste process: generators of waste (owners of the nuclear power plant and, indirectly consumers of electricity), the operator of the waste disposal facility, state governments and the federal government. Dr. Cohen argues the need for all parties to face full costs which provide effective financial incentives for optimal behavior: generators of waste should have incentives to minimize the quantity and (radioactive) quality of wastes; storage site operators should have incentives to uncover, report and treat waste-related problems that pose health hazards to the public. As Dr. Cohen acknowledges, however, the principle of using efficiency prices for nuclear waste loses much of its appeal in efforts to implement pricing programs for many reasons. Unexpected costs are just that, unexpected. Premature closing or health damage costs would likely involve costs well in excess of set-aside funds; bonding and insurance options are thought to be prohibitively expensive or unavailable. Most importantly, the site operator's incentives are to keep the site open—earning revenues. Reporting problems may lead to premature closure wherein the operator's asset becomes a liability; certainly, reporting could be expected to lead to higher bonding/insurance costs. Dr. Cohen offers an interesting, multi-tiered arrangement for treating the liability problem within a context wherein incentives are preserved when possible. In this scheme, the state insures the operator against liability *and* some portion of revenue losses; the federal government insures the states against losses in excess of some agreed upon amount, *a la* the Price-Anderson Act. Implicitly, some portion of the costs associated with this insurance scheme are passed on to producers of waste and the electricity-consuming public. A method for structuring these costs so as to provide incentives for producers of waste to "economize" on waste quantity and quality is an issue remaining for further research.

Finally, research concerning NWM policies must unavoidably deal with flows of consequences—benefits and costs—over time. Long periods of time, multigenerational in nature, may be involved in considering potential health effects from stored wastes after decommissioning of the site. Traditionally, flows of benefits and/or costs over time are discounted so that all values are commenserable; future values are expressed as present values. Professors Schulze, Brookshire and Sandler consider the ethical implications of discounting benefits and cost in evaluating nuclear waste options. The authors present a fascinating discourse on a "consequentialist" approach for assessing the ethical implications of the NWM options. Their arguments lead them to an exploration, buttressed by a case study, of a "democratic" approach for assessing NWM policies wherein procedural or process considerations are given priority over efficiency considerations. Under the democratic ethic, as the authors demonstrate, optimal NWM strategies stress retrievability and monitoring possibilities so as to preserve choice ("maneuverability") for future generations.

We hope the reader will find a nucleus of ideas which will assist in setting the stage for future research concerning policy options related to the management of nuclear wastes. Obviously, considerable research remains for the development of methods which might be used in assessing policies related to the protection of public health and safety under the conditions of uncertainty which surround the NWM issue. In this regard, as is stressed in the bulk of the papers included in this volume, public perceptions of risk, and how such perceptions might be affected, must be a primary consideration in the development of these new assessment methods. In closing this Overview, we offer the following observation by Weinberg which succinctly describes the critical importance of public perceptions for policy formulations related to the nuclear fuel cycle:

> As I compare the issues we perceived during the infancy of nuclear energy with those that have emerged during its maturity, the public perception and acceptance of nuclear energy appears to be the question that we missed rather badly. . . . This issue has emerged as the most critical question concerning the future of nuclear energy.[20]

20. Weinberg, *The Maturity and Future of Nuclear Energy*, 64 AMERICAN SCIENTIST 19 (1976).