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THE HIDDEN COMMITMENT OF NUCLEAR WASTES

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RADIOACTIVE WASTE

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One of the critical factors that must be considered in the decision-making process required in solving the radioactive waste management problem is the issue of costs. The accumulation of both government- and commercially generated wastes is estimated at some 200 million gal of high-level waste, 400 million ft^3 of low-level waste, and 85 million ft^3 of alpha wastes by the year 2000. Cost projections are made for high-level waste management (exclusive of ultimate disposal), for low-level waste burial, and for alpha waste burial. These cost estimates indicate some $7 billion to be committed for waste management by the year 2000. In addition, the cost for ultimate disposal of high-level wastes could exceed $1 billion by the year 2000, depending on the government surcharge for handling these wastes. Therefore, explicit attention should be given to the possibility that an interim engineered storage system may become permanent solely due to economic costs.

INTRODUCTION

To meet its energy requirements, the United States is committing an increasingly significant portion of its resources to the production of nuclear energy, although an acceptable plan for managing the radioactive wastes associated with this energy production method has not been fully demonstrated. Inherent in the decision to pursue this course is the assumption that the United States will have the technology to safely manage radioactive wastes and the confidence that nuclear energy can be shown to be the most environmentally desirable means of meeting our current energy requirements.

There is not just one nuclear waste problem, but a variety of nuclear waste problems that must be solved before this assumption can be shown to be justified. The purpose of this paper is to identify and illustrate one of the critical factors that must be seriously considered in the decision-making process that will be required in solving the radioactive waste management problem. The critical factor to which these remarks are addressed is that of cost.

The problem is that even assuming the technical capability exists to ensure total containment for the hazardous lifetime of the nuclear wastes, the cost of implementing the means to contain these wastes is enormous. Until the cost commitments, including the cost of perpetual care, are well understood, the societal commitments involved cannot be evaluated. In an attempt to illustrate this situation, the Environmental Protection Agency (EPA) has made some first-order estimates using existing data sources.

Predictions of the volumes of radioactive wastes were made for alpha, high-, and low-level wastes from the government and the commercial sectors up to the year 2000. Estimates of the costs incurred for maintenance, treatment, and "ultimate disposal" of these wastes were then prepared. The magnitude of these fiscal costs to the society, even considering the uncertainty in the data used, is a commitment of which the public must be made aware and the nuclear industry must recognize.

DEFINITIONS

First, one must define the various types of nuclear wastes and what is meant by waste management.

Types of Wastes

There are six types of wastes to be discussed: government-generated high-level wastes (high-level wastes are those wastes with characteristics that prohibit them from being placed into a shallow land burial site); government-generated low-level wastes; commercially generated high-level wastes; commercially generated low-level wastes; and two other types of wastes that are becoming increasingly important—the government- and commercially generated transuranium-contaminated (alpha) wastes. Because of the extremely long half-lives of the isotopes involved and the recent pronouncements of the U.S. Atomic Energy Commission (USAEC) concerning their intention that transuranic wastes be separated from other wastes, these latter two categories will become of increasing importance in the future.

By far the greatest amount of government high-level waste is located at the USAEC's major production facilities at Hanford, Washington, Savannah River, South Carolina, and the National Reactor Testing Station in Idaho. The waste is currently present in the form of liquid wastes from reprocessing operations (either in acid or neutralized form) or as a sludge, salt cake, calcined solid, or other solidified form. The only existing commercial high-level waste is located in the liquid waste tanks at the Nuclear Fuel Services Fuel Reprocessing Plant in New York.

Government low-level waste is found in many physical forms at many USAEC sites throughout the country. Generally it is buried, within various forms of packaging, in shallow earth trenches. At the present time, there are six commercial burial sites located in six different states that accept low-level radioactive wastes of varying physical forms for burial in shallow earth trenches.

Waste Management

Waste management is confinement, i.e., the assurance of the isolation of the waste from the environment (biosphere) for the duration of its hazardous lifetime. Waste material placed directly in contact with the environment, in such a manner that isolation of the hazardous components is not reasonably assured over their hazardous lifetime (either on a planned or accidental basis), is really best considered as just another waste effluent or discharge technique, not waste management.

EPA RESPONSIBILITIES AND AUTHORITIES

The EPA's interest in the problem of radioactive waste disposal grows directly out of its mandated mission of protecting and enhancing the quality of our environment. Therefore, the EPA has the responsibility of taking an active role in assuring the development of a permanent waste management system that will provide the required protection of public health and safety and the quality of the environment. The USAEC has the responsibility of developing and regulating waste management facilities.

The EPA has available to it, as a result of legislative action, several direct and indirect responsibilities and authorities. The EPA derives its principal responsibility in the area of waste management from Executive Reorganization Plan #3 (Ref. 1). The Plan transferred to the EPA the responsibility for establishing generally applicable environmental standards for radioactive material in the general environment and the authority for the general guidance function for Federal agencies from the Federal Radiation Council.

Agency involvement is also supported on the basis of the requirements of the National Environmental Policy Act, specifically the statutory responsibility for the review of environmental statements.[2] Importantly, the EPA has broad responsibilities that relate to evaluating, from an overall environmental point of view, the means by which our national energy requirements will be satisfied. By virtue of Section 309 of the Clean Air Act, the EPA has the responsibility to the nation of bringing to light possible environmental impacts from major Federal actions.[3] It is generally recognized that the full development of nuclear power as an energy source can be realized only if an acceptable solution is developed for the long-term management of radioactive wastes. Thus, from this standpoint, the EPA is vitally concerned with this activity.

WASTE-HANDLING TECHNOLOGY PROBLEMS

High-Level Waste

The obvious problem with high-level waste, whether government or commercially generated, is ensuring that it will be effectively isolated from the environment (biosphere) during the duration of its hazardous lifetime. This waste is usually initially present as an acidic or neutralized liquid solution. Present treatment methods involve allowing the liquids, that are normally high-heat, to cool for several years before further treatment. Some wastes are evaporated and separated into sludges, salt cakes, or salt crystal, while other wastes are either calcined into granular solids or converted to a glass-type matrix.

The USAEC has recognized that the resultant wastes from the present treatment processes are not suitable for ultimate disposal. However, while an ultimate disposal form and technique are being researched and developed, the USAEC apparently wishes to provide for an "interim" storage form and technique which, according to available information, will be a near-surface engineered storage facility.

Low-Level Waste

The major problems concerning low-level waste are (a) the lack of a precise definition (at present low-level waste is simply everything which is "other than high-level" waste), (b) the nonuniform nature of the requirements for burial, and (c) the large volumes of waste for disposal.

Alpha Waste

As noted earlier, the alpha waste categories are expected to grow in importance during the coming years. With the majority of the other radioactive waste components having hazardous lifetimes of up to several hundreds of years, alpha wastes, and specifically those from the use of plutonium will have hazardous lifetimes of upwards of a million years. Our ability to isolate these wastes during the required time period will always be uncertain.

Ultimate Disposal or Engineered Storage

The EPA is very interested in proposals for the adoption of an engineered storage concept for the current high-level wastes. The EPA would like to be assured that the construction of an interim engineered storage facility, or even the approval of the concept, will in no way slow down the search for environmentally acceptable ultimate disposal (or permanent management) solutions. If this goal is not vigorously pursued by the USAEC and the scientific community, the day may dawn, and very quickly, when for economic reasons alone the "interim" engineered storage facility will become a "permanent" storage facility. The EPA fervently hopes that this possibility will be thoroughly explored by the USAEC as it completes its economic analysis of the interim engineered storage concept.

WASTE VOLUME GENERATION AND COST ANALYSIS

The generation of radioactive wastes is common to every aspect of the nuclear fuel cycle. To define the costs involved in managing these radioactive wastes, we must first determine the amounts of each which are going to be produced. Specifically, estimates are needed for the following:

1. the projected amounts of commercially produced high-level, low-level, and transuranic wastes that will be produced from reactor, fuel-reprocessing, and fuel-fabrication operations
2. the USAEC-generated low-level solid wastes currently being buried at USAEC facilities and laboratories
3. the USAEC-generated high-level and transuranic-contaminated wastes currently being stored at USAEC facilities and laboratories.

High-Level Waste

The annual quantities of commercial high-level wastes anticipated are based on projections of nuclear power growth and the associated requirements for spent fuel reprocessing,[4] which indicates a generation rate of 400 gal of high-level liquid waste per tonne of spent fuel reprocessed.[5] Figure 1 shows the projected accumulated high-level waste volumes generated by the USAEC and commercial producers.

The USAEC-generated wastes are listed at some 85 million gal in 1974, based on present inventories and assuming a fairly constant volume (perhaps a slight increase) over the next few decades. The volume includes those wastes in the form of liquids, salt cake, crystals, sludges, and calcined granules.

The estimated annual maintenance cost for operating the USAEC high-level waste management program is \$5 million/yr, based on information received from the USAEC at site information meetings. Note that the commercial waste generation volume will exceed the USAEC waste by the year 2000.

It has been estimated that the high-level waste management cost will be \$10 000 per tonne of spent fuel, or \$25/gal of waste.[6] This cost is assumed to include costs of treatment and interim storage at the chemical processing plant, transportation to an engineered storage facility, and a perpetuity charge at the Federal facility. By using these estimates, an annual cost is calculated for the year in which the spent fuel is reprocessed as shown in Fig. 2. It is recognized that there can be a time lag of up to 10 years before this waste is delivered to the repository.[7] However, the repository charge is committed at the time of reprocessing and is treated as such in this analysis.

The accumulated annual cost is also shown in

Fig. 2 to provide a basis for estimating the cost of ultimate disposal. The basic cost factor of $25/gal is assumed to include the perpetuity cost for engineered storage but not to include the cost associated with ultimate disposal. For comparative purposes, arbitrary values of 10 and 30% of the high-level waste management costs were chosen as estimates for the ultimate disposal costs. These ultimate disposal costs are imposed on the total inventory of high-level wastes in the repository or committed to the repository. They are plotted in Fig. 2, where it can be observed that they rapidly exceed the annual costs. These estimates indicate that the ultimate disposal costs will represent a very large commitment of financial resources.

In these days of rapidly increasing prices, it is interesting to consider the effect that inflation could have on this ultimate disposal commitment. An annual inflation rate of 5% was chosen, based on the experience of the nation's economy during recent years. The projected annual and cumulated annual costs were corrected to 1974 for a 5% inflation rate as shown in Fig. 3. The same arbitrary values of 10 and 30% were used for the estimated inflated ultimate disposal cost. As stated previously, the ultimate disposal costs were not considered in the basic cost factor, and the ultimate cost estimates were calculated for the total inventory of wastes at the repository or committed to it. It can be seen that inflation will drive the ultimate disposal costs up much more rapidly than the noninflated case. In fact, subject to the limitations of the assumptions made here, at the 30% figure ($7.50/gal of high-level waste for ultimate disposal), the total ultimate disposal cost will exceed the total accumulated waste management cost for the entire industry by 1998 at a 5% inflation rate.

These projections of costs for high-level waste management and ultimate disposal appear reasonable, even though no operating experience is available. Probably the most sensitive aspect of this analysis is related to the assumption concerning the time at which charges were imposed. The cost for waste management, including a perpetuity charge at the repository, would occur within a span of 10 years, and most of this cost would occur during the first 5 years due to treatment and interim storage requirements. Therefore, it is estimated that this cost is within a

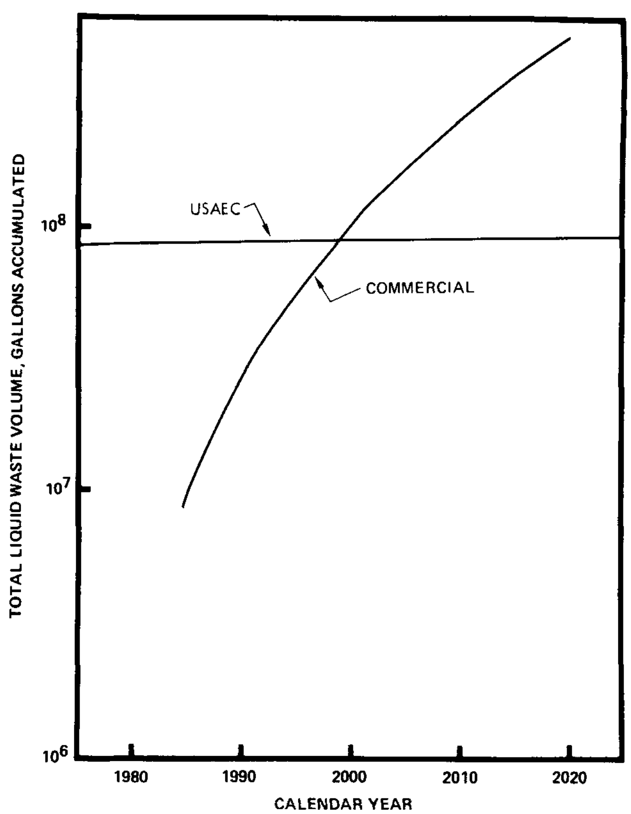

Fig. 1. Projected high-level waste volumes.

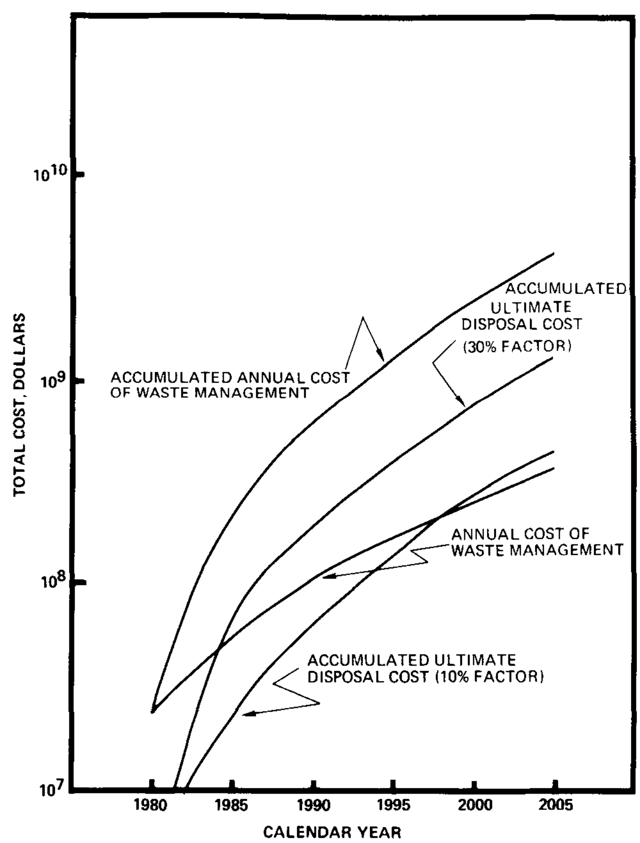

Fig. 2. Projected costs of commercial high-level waste management.

factor of 2 of what the actual cost might be. However, because of the time element and other factors, no reasonable estimate can be made concerning the accuracy of the ultimate disposal cost. It is possible, for example, to assume that the engineered storage perpetuity charge would be high enough to cover the final disposal cost.

Low-Level Wastes

The annual quantities of commercial low-level beta-gamma wastes to be generated by the nuclear industry are based on information from Oak Ridge National Laboratory, which indicates that by the year 2000 some 350 million ft^3 will require burial.[8] The USAEC-generated low-level wastes are estimated to accumulate at about 1 million ft^3/yr or some 50 million ft^3 by the year 2000 (Refs. 9 through 12). Figure 4 illustrates the projected accumulated low-level waste volumes generated by the USAEC and the commercial reactors, fuel fabricators, and fuel reprocessors.

The accumulated costs, both noninflated and inflated (a 5% annual inflation rate), for burial of the commercial low-level wastes are shown in Fig. 5. The disposal cost, based on commercial and USAEC cost data (exclusive of packaging and shipping), is estimated at $2/$ft^3$ (Refs. 9 and 13). Based on this estimate, it will have cost the commercial producers well over $1 billion by the year 2000.

The USAEC wastes will cost some $2 million/yr to bury and $2.6 million/yr for burial-ground operating expenses.[11] As shown in Fig. 4, the cumulative volume of the commercially generated wastes will surpass the cumulative volume of the USAEC-generated wastes by about 1990.

These projections and costs do not take into consideration any volume reduction techniques that may be employed to reduce the amount of land used for this purpose. Such an approach may be adopted in the near future, in which case the treatment and packaging and shipping costs may add significantly to the overall disposal costs.

Alpha Wastes

The anticipated volumes of alpha wastes from the commercial producers were based on genera-

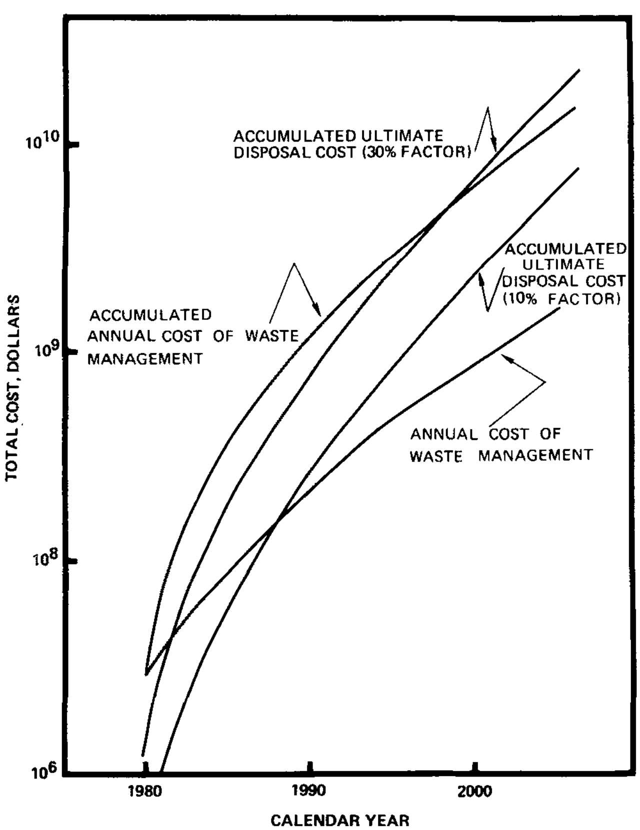

Fig. 3. Projected costs of commercial high-level waste management with a 5% annual inflation rate.

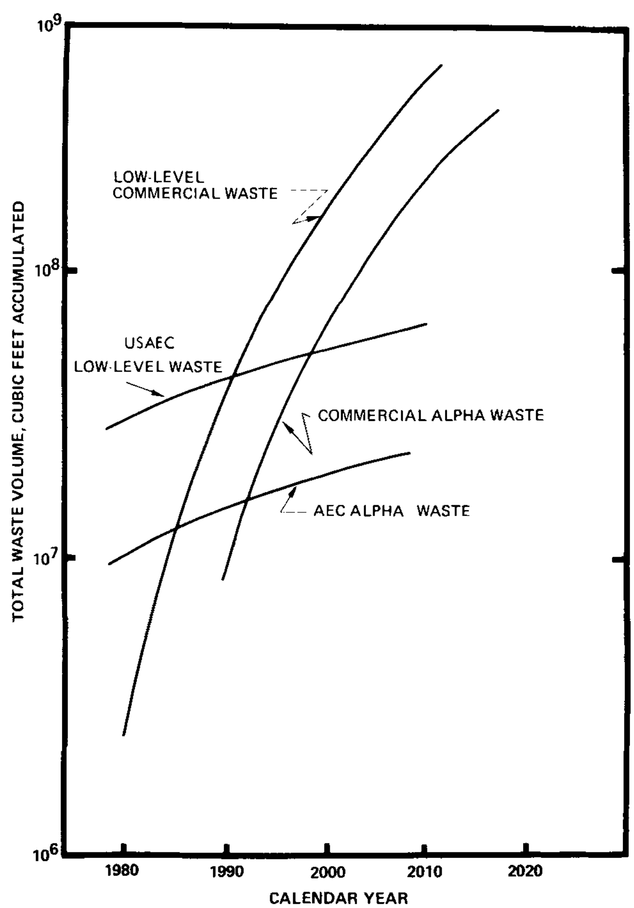

Fig. 4. Projected low-level and alpha waste volumes.

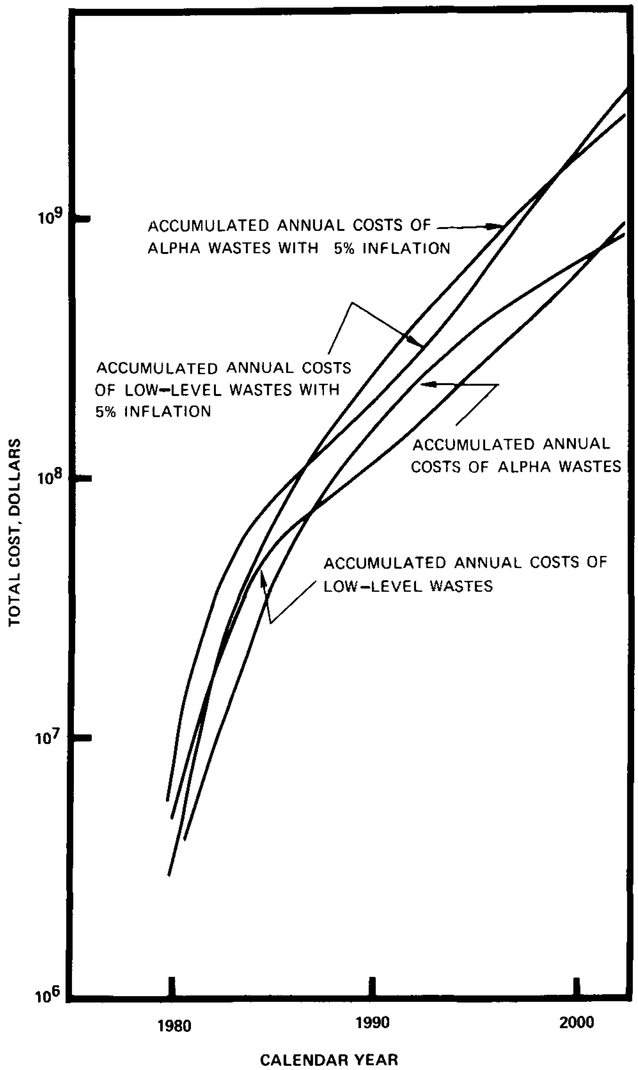

Fig. 5. Projected costs of commercial low-level and alpha waste management.

tion estimates for the light-water reactor and the liquid-metal fast breeder reactor reprocessing and fabrication operations. The estimates indicate that the commercial processors will accumulate over 65 million ft^3 by the year 2000 (Refs. 4, 14, and 15). This will be in addition to the USAEC-generated wastes of some 400 000 ft^3/yr which will accumulate to something like 20 million ft^3 by the year 2000 (Ref. 11). Figure 4 depicts the projected cumulative annual volumes of USAEC- and commercially generated alpha wastes.

The costs for the alpha wastes can increase significantly, especially if retrieval of these wastes becomes necessary. Assuming the wastes are to be treated in some manner and specially encapsulated, the cost could run to \$10/ft^3 and higher for disposal. Figure 5 shows the cumulative cost, both noninflated and inflated (a 5% annual inflation rate), for burial of the commercial alpha wastes. Based on this estimate, it will have cost the commercial producers over \$1 billion by the year 2000 for disposal of alpha wastes.

CONCLUSIONS

The primary purpose of this presentation is to highlight one aspect of the radioactive waste management problem which is of great concern to the EPA, namely that the tremendous costs being committed for the management of radioactive wastes may not be recognized during the planning stages and may result in the foreclosure of options which incorporate the greatest protection for the environment. Tables I and II show the annual and cumulative cost commitments of radioactive waste management for the years 1980, 1990, and 2000 for the six types of wastes described. (A 5% annual inflation rate is included in these costs.)

There are two major points to be made. First, the USAEC has generated a large volume of radioactive waste that it is committed to manage for the foreseeable future. Inescapably associated with this management responsibility is a large commitment of government funds. The nuclear energy production industry is currently embarking on a program of rapid growth in which it must be recognized *now* that there is a similar and even-

TABLE I

Radioactive Waste Management Costs Committed Cumulatively Through the Indicated Year (Millions of Dollars) with 5% Inflation from 1974

	1980		1990		2000	
	USAEC	Commercial	USAEC	Commercial	USAEC	Commercial
High-level	35	30	120	1200	260	6 800
Low-level[a]	15	6	50	200	100	1 900
Alpha	30	3	100	300	200	1 800
Total	80	39	270	1700	560	10 500

[a]Disposal cost only.

TABLE II

Radioactive Waste Management Costs Committed Annually During the Indicated Year (Millions of Dollars) with 5% Inflation from 1974

	1980		1990		2000	
	USAEC	Commercial	USAEC	Commercial	USAEC	Commercial
High level	7	30	11	230	18	1000
Low level[a]	3	6	4	30	7	400
Alpha	5	3	5	60	5	300
Total	15	39	20	320	30	1700

[a]Disposal cost only.

TABLE III

Additions to Power Costs for Waste Management for the Year 2000

	(mill/kWh)[a]
High-level waste	0.03
Alpha waste	0.01
Low-level waste	0.01
Total	0.05

[a]In 1974 dollars.

tually a much larger commitment of both government and private funds to properly manage the radioactive wastes that will result. This long-range fiscal commitment and its potential impact on this nation must be examined by those recommending these actions, and it should be made clear to the people who will ultimately either directly or indirectly have to pay the costs—the general public.

Second, in consideration of the planning for the interim engineered storage facility and the development of a permanent waste management system, the USAEC should specifically examine the costs involved in moving from an operating interim engineered facility to the permanent solution. Explicit attention should be given to the possibility that the interim facility may become permanent, solely due to the economic costs involved in reprocessing and repackaging the interim stored wastes (if this becomes necessary), their transportation to the ultimate disposal site, and the decommissioning of the interim storage facilities.

To further demonstrate the cost of managing the three categories of commercially generated nuclear wastes (high-level, low-level, and alpha), estimates were made to determine the impact of their addition to the total fuel-cycle cost. These estimated costs are shown in Table III (without an inflation factor). The high-level waste costs are within the range, exclusive of the ultimate disposal cost, estimated by numerous USAEC reports.[16]

Although these costs are a small fraction of the total fuel-cycle cost (~15 mill/kWh) of nuclear electric energy, the costs are sufficient to require serious consideration, development, and planning for the future.

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