An Evaluation of Options for Managing Greater-Than-Class-C Low-Level Radioactive Waste

October 1988

NTIS order #PB89-114250

AN EVALUATION OF OPTIONS FOR MANAGING
GREATER-THAN-CLASS-C LOW-LEVEL RADIOACTIVE WASTE

Background Paper

October 1988

Congress of the United States
Office of Technology Assessment
Washington, D.C. 20510-8025

Recommended Citation:

U.S. Congress, Office of Technology Assessment, An Evaluation of Options for Managing Greater-Than-Class-C Low-Level Radioactive Waste, OTA-BP-O-50, October 1988.

Library of Congress Catalog Card Number 88-600589

Foreword

This evaluation of management options for greater-than-Class C (GTCC) low-level radioactive waste was undertaken at the request of the Senate Committee on Environment and Public Works. The Committee asked that OTA evaluate existing Federal and non-Federal options for GTCC waste storage and disposal. From its analysis, OTA was to develop an integrated management approach to protect public health and safety in the short- and long-term.

The most significant finding of this study deals with the storage of GTCC waste. Since a disposal facility for GTCC waste will not be available for at least fifteen to twenty years, GTCC waste will have to remain in storage in the meantime. This period of extended storage could be extremely difficult for many GTCC material users and waste generators. OTA has developed a possible approach for addressing these problems.

Other OTA documents covering radioactive waste issues are the reports, Mana~in~ the Nation's Commercial High-Level Radioactive Waste (1985), Transportation of Hazardous Materials, (1986), and a staff paper, Subseabed Disposal of High-Level Radioactive Waste, (1986).

This Background Paper on GTCC waste was prepared as part of a broader study on the disposal of Class A, B, and C low-level radioactive waste that will be completed next year. This latter report will also deal with the disposal of mixed wastes that contain both low-level radioactive and hazardous wastes. The management of hazardous wastes has been addressed in several OTA reports, including Technologies and Management Strategies for Hazardous Waste Control, (1983) and Serious Reduction of Hazardous Waste, (1986).

OTA is grateful for the input from the many reviewers of this report; their comments were invaluable. As with all OTA studies, the content of this report is the sole responsibility of OTA.

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by all the reviewers of this Background Paper. The reviewers do not, however, necessarily approve, disapprove, or endorse this Background Paper. OTA assumes full responsibility for the Background Paper and the accuracy of its contents.

Contents

Page

Chapter 1: Summary of Findings 1

Background 1

Step 1 - Extended Storage 1

Step 2 - Limited-Access Storage 2

Step 3- Disposal 2

Issues Requiring Federal Consideration 3

Chapter 2: Background 4

Purpose of the Study 4

What is GTCC Low-Level Radioactive Waste? 4

GTCC Waste Types and Generators 5

Nuclear utilities 5

Fuel manufacture and test facilities 5

GTCC sealed source manufacturers and distributors 5

GTCC sealed source users 6

Other generators 6

GTCC Waste Volumes and Radioactivity 6

Risks Associated with GTCC Waste 8

Present Problems Associated with GTCC Waste Management 15

Chapter 3: Management Options 16

An Evaluation of Storage Options for GTCC Waste 17

Description of storage technologies 17

Optional storage sites 18

An Evaluation of Disposal Options for GTCC Waste 22

Description of disposal technologies 22

Technical comparison of disposal technologies 24

Preliminary economic comparison of disposal options 25

Institutional considerations in choosing a disposal option 28

Summary 29

Chapter 4: A Management Approach for GTCC Waste 31

Limited-Access Storage 32

Extended Storage 32

Disposal 32

Funding Mechanisms 32

References 34

Appendix A. Types of Radioactive Waste 38

Appendix B. Definitions 39

Appendix C. Decommissioning of Nuclear Power Plants 40

Appendix D. Possible Schedule for Managing GTCC Waste 41

Tables and Figures

Tables

Table 1. Approximate Limits for Radionuclides in GTCC Waste 9
Table 2. Qualitative Description of Protective Measures for Managing Low-Level Radioactive Waste 11
Table 3. Relative Risks from Different Types of Radioactive Waste 13
Table 4. Primary Factors for Comparing Waste Management Options 17
Table 5. Preliminary Estimates of GTCC Waste Disposal Costs 28
Table 6. Effects of Delayed Decommissioningon the LLW Generated by Commercial Nuclear Power Plants 40

Figures

Figure 1. Qualitative Comparison of Risks from Different Types of Radioactive Waste 14
Figure 2. Near-Surface Disposal Costs for a Range of LLW Volumes 27
Figure 3. A Management Approach for GTCC Waste 31

CHAPTER 1

SUMMARY OF FINDINGS

BACKGROUND

Most commercial low-level radioactive waste (LLW) in the United States is classified as A, B, or C, with Class C being the most radioactive. Universities, hospitals, nuclear utilities, and various industries generate a small amount of LLW that is more radioactive than Class C waste, termed greater-than-Class-C (GTCC) waste. **Several thousand GTCC material users and waste generators, most of which are small, such as academic laboratories and small radiography firms, are currently forced to store this waste on-site because no options are available for off-site storage or disposal.** Many generators argue that their on-site storage capacity is shrinking and that over the next decade or so they will have no capacity remaining. Although no deaths have been reported from accidents involving GTCC waste in this country, the relatively high levels of its radioactivity demand **that management options be made available to ensure that public health and safety are protected.**

In the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA), the Federal Government (presumably the Department of Energy (DOE)) is directed to develop a disposal plan for GTCC waste. No such plan, however, has been developed. In response to this legislative mandate, DOE issued a report in 1987 focusing primarily on GTCC waste characteristics, including present and projected volumes. **DOE** decided to defer proposing a disposal plan until it had completed analyzing various disposal options.

The Office of Technology Assessment (OTA) has evaluated options for managing GTCC waste and concludes that no disposal facility, regardless of the technology **used, is expected to be available for GTCC waste for at least fifteen to twenty years. During this time, problems could arise if an off-site storage option is not made available for some GTCC waste generators that have limited on-site storage capacity.**

In its 1987 report, DOE tentatively committed the Federal Government to accept GTCC waste for storage by 1989, presumably at an existing DOE facility. There are questions, however, about the propriety of storing commercial GTCC waste at an unlicensed DOE facility used primarily for defense waste. With few exceptions, commercial radioactive waste has been stored at facilities that are licensed by the Nuclear Regulatory Commission (NRC) or Agreement States. Legally, commercial GTCC waste must also be disposed of in an NRC-licensed facility. DOE is presently awaiting guidance from Congress on this licensing issue.

Congress has drafted some legislation dealing with the management of GTCC waste, but no hearings have been held. The following 3-step management approach was developed by OTA to supplement these efforts.

STEP 1 - EXTENDED STORAGE

Since a disposal facility for GTCC waste will require at least 15 to 20 years to develop, GTCC waste will have to remain in storage until at least 2010 and potentially much longer. The NRC **may need to update its packaging and storage guidance for GTCC waste considering the likelihood of a few decades of extended storage.**

It is likely that off-site storage capacity will be needed, especially for small and/or financially unstable GTCC waste generators. Given the open-ended period during which GTCC waste will have to be stored, it is unlikely that States (which under the LLRWPAA of 1985 are not responsible for GTCC waste disposal) or private companies would be anxious to independently accept the liabilities associated with storing this waste. They would have to charge sufficiently high storage fees which may not be affordable to many generators. Therefore, the Federal Government (presumably DOE) will probably need to provide this off-site storage capacity for GTCC waste generators.

During the next three decades, between 10,000 and 20,000 cubic feet of packaged waste -- a volume equivalent to four to eight tractor trailers -- is projected to need off-site storage. OTA estimates that **several years would be required to develop a storage facility for this waste, assuming that it would be NRC-licensed.**

STEP 2-- LIMITED-ACCESS STORAGE

Some generators of GTCC waste, especially small companies, **may need access to a small amount of off-site storage capacity before an extended-storage facility could be available.** Sufficient capacity may need to be only a few thousand cubic feet.

GTCC radioactive sealed sources pose a particular concern. Sealed sources are small radiation sources containing granules of radioactive material that are sealed inside capsules ranging from 0.3 inches to 20 inches long. several thousand GTCC sealed **sources are now being used** in a wide variety of tools (e.g., gauges used to check pipe welds) and machines (e.g., cancer therapy machines) **throughout the United States. Over the last 25 years the theft and improper handling of sealed sources has been responsible for about 15 deaths in foreign countries and several serious radiation burns in the United States.**

Once a sealed source becomes obsolete, a user may try and return it to the manufacturer. The manufacturer will generally refuse to accept the sealed source unless it can be recycled economically. Many sealed source users, however, may not have appropriate facilities for extended, on-site storage. Furthermore, some companies possessing GTCC material and/or waste may go out of business before an extended storage or a disposal facility is available.

To reduce the potential for GTCC accidents in the United States, the Federal Government could provide limited access to existing storage capacity such as an unlicensed, DOE storage facility. Some accidents could also be avoided by adding a deposit-return fee to the price of sealed sources. For example, some portion of this fee would be returned to a user when it returned its obsolete sealed source to the manufacturer. The remainder of the fee would be kept by the manufacturer to fund its recycling or storage and eventual disposal of the sealed source.

Although it is impossible to predict whether a GTCC waste accident might occur in this country, the political repercussions of such an accident for the Federal Government could be especially significant if the accident were linked to the Government's inability to accept GTCC waste for storage or disposal.

STEP 3- DISPOSAL

The longevity of risk and the radioactivity associated with most GTCC waste is similar to that of defense high-level waste (HLW). Furthermore, once utilities begin to refurbish or decommission their nuclear plants, more than half of GTCC wastes' activity will be contributed by radionuclides (primarily nickel-63) with half-lives 100 years or longer. **The Federal Government is currently planning to use a deep-geologic repository for the disposal of defense HLW.**

If a decision about the disposal of GTCC waste were required today, **a conservative approach would be to permanently isolate the** waste **in a deep-geologic repository, as has been**

proposed for commercial spent fuel and defense HLW. It is possible, however, that further research and analysis could demonstrate that other disposal alternatives would be acceptable, such as deep-augered holes or an intermediate-depth repository. Near-surface disposal alternatives, such as buried concrete vaults, would probably provide waste isolation for periods of a few hundred years but probably not for the few thousand years needed for much GTCC waste.

The volume of GTCC waste is probably not large enough to justify the economic or institutional costs associated with developing a separate disposal facility, regardless of the technology used. The projected volume of GTCC waste that will be generated through the year 2020 would probably occupy much less than 1 percent of the proposed repository for commercial spent fuel and defense HLW. Preliminary calculations also indicate that the costs associated with using this large repository for GTCC waste would be comparable to, or perhaps even less than, costs associated with developing a small disposal facility only for GTCC waste.

The proposed repository for commercial spent fuel and defense HLW could be operational in fifteen to twenty years if the site now being investigated at Yucca Mountain, Nevada, is found suitable and no unforeseen legal or procedural delays are encountered. This time estimate could be extended by another two decades if the Yucca Mountain site is found unsuitable and another repository site must be located. Even if another technology were chosen for GTCC waste disposal, history indicates that it would still require about five years to select that technology, and another ten to fifteen years to design, site, and license a separate facility.

Although a decision to use the Yucca Mountain repository for GTCC waste disposal could be made now, DOE must still determine whether such use of the repository would have unacceptable environmental or institutional impacts on the repository's overall operation and performance. DOE could concentrate its efforts on this analysis over the next year or two. If it appears that no such impacts would occur, DOE could decide to use the repository for GTCC waste. In contrast, if it appears that unacceptable impacts would occur or repository disposal would be more expensive than other disposal alternatives, DOE could then evaluate other disposal options for GTCC waste disposal. In weighing the advantages and disadvantages associated with using the **Yucca** Mountain repository, it is important to consider the institutional and political difficulties associated with siting a separate GTCC waste disposal facility, regardless of its size or type.

ISSUES REQUIRING CONGRESSIONAL CONSIDERATION

There are several issues that will need to be addressed by Congress. The first five issues may best be addressed through hearings and oversight the last may require legislation. These issues involve:

- Ensuring institutional control over sealed sources.
- Ensuring the adequacy of packaging and storage guidance for extended storage at GTCC waste generation sites.
- Verifying and reviewing the need for limited access to Federal storage capacity for GTCC waste, and clarifying DOE's role in providing such storage.
- Verifying and reviewing the need for extended Federal storage for GTCC waste, and clarifying DOE's role in providing such storage.
- Developing technical and non-technical criteria and specifications on the use of Federal storage capacity for GTCC waste.
- Determining the need for NRC-licensing of any Federal facilities used to store commercial GTCC waste.

The sequence and possible activities involving GTCC waste management are presented in Appendix D.

Chapter 2

BACKGROUND

PURPOSE OF THE STUDY

No disposal facility is presently available for greater-than-Class-C (GTCC) low-level radioactive waste (LLW) and some waste generators claim to be running out of on-site storage capacity. Through the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA), the Federal Government (i.e., the U.S. Department of Energy (DOE)) was made responsible for disposing of GTCC waste. In accordance with this legislation, DOE published a report in February 1987 entitled Recommendations for Management of Greater-Than-Class-C Low-Level Radioactive Waste. This report focused primarily on the types and quantities of GTCC waste and regulatory needs; there was little analysis of disposal options for this waste. DOE plans to select a disposal technology within the next several years after evaluating disposal alternatives.

Without knowing disposal requirements or when a disposal facility will be available, GTCC waste generators have difficulty estimating their storage needs and designing waste packages for both storage and disposal. Congress therefore asked **OTA to analyze different management options and to develop an integrated management approach for** GTCC waste. Before presenting this analysis, we provide some background information on GTCC waste and the factors that are most important in safely managing it. Finally, we present an analysis of different management options by comparing them to technologies that are or will be used to store and dispose of other types of radioactive waste.

Since concerns about managing GTCC waste have been raised only within the last few years,[1] very little information on this type of LLW has been published. DOE's February 1987 report, cited above, is the only report published on the subject. A few papers on GTCC waste have also been presented at conferences on radioactive waste management. Additional information used in this analysis was obtained from reports and papers that deal with all types of radioactive waste, letters and memos from Federal agencies, and communications with personnel working in this and other related areas of radioactive waste management.

WHAT IS GTCC LOW-LEVEL RADIOACTIVE WASTE?

Low-level radioactive waste is defined in the LLRWPAA of 1985 by what it is not, rather than by what it is. LLW includes radioactive waste not classified as spent fuel, high-level waste (HLW) from reprocessing spent fuel or uranium mill tailings. These types of radioactive waste are defined generally in Appendix A; special terms relating to radioactive waste are defined generally in Appendix B.

The NRC has developed a classification system for commercial LLW based on its relative danger to human health and safety. This system establishes three classes of LLW -- A, B, and C -- with Class C being generally the most radioactive and/or long-lived of these three classes. Tables and procedures for classifying LLW are provided in Title 10 of the Code of Federal

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[1] GTCC waste has only existed since 1983 when the U.S. Nuclear Regulatory Commission's classification system was established (10 CFR 61).

Regulations Part 61 (10 CFR 61).[2] LLW that is more radioactive and/or long-lived than Class C is called greater-than-class C (GTCC) waste.

GTCC WASTE TYPES AND GENERATORS

GTCC waste comes from the full range of typical LLW generators including: nuclear utilities, hospitals, universities, and various industries (e.g., pharmaceutical manufacturers and radiography firms). The GTCC waste produced by these generators is briefly described below.

A [illegible]

GTCC waste can be generated during reactor operations and during reactor dismantling, called decommissioning. Operational waste can include non-fuel reactor core components (e.g., control rods), neutron sources required for reactor start-up, fission chambers, and spent ion-exchange resins and sludges containing high levels of radioactivity from coolant and fuel pool cleanup activities. When nuclear power plants wear out or become uneconomical to operate, they will be refurbished or shut down and eventually decommissioned. Most GTCC waste from refurbishing and decommissioning will be activated metals, such as stainless steel core shrouds that separate the reactor core from the reactor vessel (Knecht, 1988 and NRC, 1984a).

B. Fuel Manufacture and Test Facilities

In the past, fuel fabrication facilities used plutonium in advanced fuel research and development. All of these facilities have either been decommissioned or are in the process of being decommissioned. Since the Federal Government frequently sponsors the activities at these facilities, most facility operators have contractual arrangements to transfer much of their GTCC wastes to DOE for storage and disposal (NRC, 1984a).

Three companies currently operate test facilities that sample and examine reactor fuels. The wastes from these facilities consist of solidified aqueous waste; activated metals in the form of contaminated equipment, cladding, and metal cuttings; and other solid wastes such as glassware and resins (Knecht, 1988). Much of these wastes contain enough transuranic radionuclides to exceed Class C limits and, therefore, would be classified as GTCC. In addition, some GTCC wastes are likely to contain hazardous chemicals (NRC, 1984a; DOE, 1987a).

C. GTCC Sealed Source Manufactures and Distributors

GTCC sealed sources are small radiation sources containing granules of radioactive material that are sealed inside capsules. Sealed sources are physically small; they range from 0.3 inches to 20 inches long. These sources are used in density and moisture gauges, well-logging equipment, radiography devices, X-ray fluorescence tubes, and static eliminators. For example, radiography firms check the integrity of pipe welds using instruments containing sealed sources. The activity of GTCC sealed sources can range from a few curies to several thousand curies. Common radionuclides used in GTCC sealed sources are americium-241, cesium- 137, strontium-90, plutonium-238, and plutonium-239 (Knecht, 1988 and NRC 1984a).[3]

Some GTCC sealed sources can be recycled by their original manufacturer, especially if the user is willing to purchase a replacement source. **A** whole sealed source that was of high-activity can sometimes be reused in an instrument requiring a lower-activity source, or the material inside a sealed source can sometimes be recycled by repackaging it in a new source.

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[2] See 47 Federal **Register** 248 (Dec. 27, 1982).

[3] **Sealed** sources can also contain radium-226 -- a **radionuclide** that is not regulated by the Federal Government.

Lower-activity sources are generally more difficult to recycle. The 40 or so manufacturers of sealed sources in this country are unlikely to accept obsolete sealed sources from their customers if recycling is uneconomical (DOE, 1987a).

Manufacturers of sealed sources often possess contaminated equipment resulting from processing sealed sources. This equipment, which can exceed Class C limits, is often bulky and difficult for manufacturers to store.[4]

D. GTCC Sealed Source Users

GTCC sealed sources are used by industries, universities, colleges, hospitals, and other medical institutions conducting research and development. For example, GTCC sealed sources are used both to diagnose and to treat certain diseases, such as cancer. A NRC or Agreement State license[5] is required to manufacture, distribute, possess, and use GTCC sealed sources, but individual sources are not licensed.

The NRC estimates that there may be 25,000 to 30,000 GTCC sealed sources now in use in the United States (NRC, 1988 b). Most of these sealed sources will be recycled rather than disposed. The NRC estimates that by the year 2020 there may be about 4,000 GTCC sealed sources being held for disposal by as many as 3,000 licensees (NRC, 1988b).[6]

E. Other Generators

Some companies use carbon-14 as a tracer in manufacturing specialty chemicals for biological and chemical research. Some waste from these processes is GTCC waste. GTCC waste can also result from decontaminating out-dated facilities from other commercial operations. Such clean-up activities can generate contaminated soil, trash, and ion-exchange resins.

GTCC WASTE VOLUMES AND RADIOACTIVITY

At the end of 1985, about 14,000 cubic feet of packaged GTCC waste had been generated; this waste is now in on-site storage.[7] For comparison, this volume is equivalent to about 6 tractor trailers. The present rate of GTCC waste production is about 1,400 cubic feet of packaged GTCC waste per year.[8] For comparison, about 1.8 million cubic feet of Class A, B, and CLLW was shipped for disposal to Barnwell, South Carolina; Richland, Washington; and Beatty, Nevada in 1987. This annual volume of A, B, and C waste is over 100 times greater than GTCC waste's annual volume.

By 2020, the total volume of packaged, untreated GTCC waste is projected to be about 170,000 cubic feet.[9] About 60 percent of this volume -- 105,000 cubic feet, which is equivalent to 40 tractor trailers -- is projected to be produced when nuclear power plants are

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[4] K. Amiauer, President of Isotope Products Laboratories (a small radioisotope producer in Burbank, California), personal communication, Sept. 1988.

[5] A State that wishes to regulate the radioactive material licensees in its state can apply to the NRC for Agreement State status. Such States have to demonstrate that their regulations are equivalent to or more restrictive than the NRC'S regulations. There are 29 States that have received Agreement State status.

About one-third are NRC licensees; about two-thirds are licensed by Agreement States.

[7] These are the most recent data on waste volumes from M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

[8] M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

[9] M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

shut down and decommissioned or refurbished for use beyond their licensed operation period.[10] Reactor refurbishing will probably generate about the same amount of GTCC waste as decommissioning. The remaining 40 percent of the total volume -- about 65,000 cubic feet, which is equivalent to 25 tractor trailers -- will be generated by all activities other than the refurbishing or decommissioning of nuclear reactors.

According to DOE's 1987 GTCC report, decommissioning or refurbishing of reactors will begin around 2000 and increase significantly within the following decade (DOE, 1987a). For those reactors that are shut down, rather than refurbished, decommissioning may be delayed, perhaps until the middle of the 21st century (see Appendix C). Putting a reactor in storage for 30 to 50 years -- commonly referred to as SAFESTOR -- will significantly decrease both the volume and the radioactivity of LLW produced. GTCC waste generation, therefore, may peak around 2015, but the peak may not be as large as predicted by DOE (1987a). Furthermore, the GTCC waste volumes from decommissioning and/or refurbishing may be spread over a considerable period after 2015 (EPRI, 1987).

There is some uncertainty associated with GTCC waste volume projections. Due to packaging and treatment procedures, waste volumes can both increase and decrease. Waste generators, for example, could decide to melt down certain contaminated metals which would decrease voids in packaging containers and reduce volumes. Furthermore, some generators (e.g., utilities) may package a small volume of GTCC waste with very low-activity LLW, thus reducing the average activity of a package's volume to Class C, Class B, or even Class A limits. This technique greatly increases waste volumes, but may make it possible to generate very little GTCC waste during decommissioning or refurbishing of some nuclear power plants.

Given the expected long-term storage period, GTCC waste may need to be repackaged for further storage and/or disposal. Such repackaging may increase waste volumes significantly, but it is not clear. It is assumed in this report that packaging will generally increase waste volumes by about 7 for wastes generated by decommissioning or refurbishing nuclear power plants and by about 5 times for all other GTCC waste.

Even though the volume of GTCC waste that will be generated in the United States is small, its radioactivity is very high relative to other classes of LLW. By the end of 1985, the radioactivity of all GTCC waste in storage was about 4.5 million curies.11 For comparison, this is more than three times the radioactivity of all other commercial LLW that was disposed of by the end of 1985.

Much radioactivity in GTCC waste is contributed by cobalt-60 which has a 5.3 year half-life. Cobalt-60, by itself, is never GTCC because of its short half-life. When cobalt-60 is associated with enough longer-lived radionuclides, the waste has to be classified as GTCC. Cobalt-60 cannot normally be separated out of this waste. The overall radioactivity of GTCC waste containing significant quantities of cobalt-60 will decay substantially in about 50-60 years.

The cumulative radioactivity of all GTCC waste generated by 2020 is projected to rise to 80 million curies. Over 99 percent of this activity (and the heat output from the waste) will be produced by nuclear power plants.1[2]

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10 M. Knecht, EG&G Idaho, Inc. (DOE contractor), personal Communication, September 1988.
11 M. Knecht, EG&G Idaho, Inc. (DOE contractor), personnal communication, September 1988.
12 M.. Knecht, EG&G (DOE contractor), personal communication, September 1988,,

RISKS ASSOCIATED WITH GTCC WASTE

To safely manage GTCC waste, it is essential to understand the risks associated with the waste. These risks can be significant because of the thousands of potential GTCC waste generators and the waste's high concentrations of radioactivity. In determining whether a particular type of radioactive waste will pose significant risks to humans and the environment, a variety of interrelated factors can be considered: the overall concentration of the radionuclides per unit of waste relative to their concentration in the environment, the half-lives of the radionuclides in the waste, the types of radiation emitted, the heat generated by the waste, and potential pathways to human exposure.

Exposure pathways can be short-term or long-term; each affects humans differently. There is a great deal of uncertainty about the biological damage caused by a particular exposure to radiation, especially from long-term, low-level exposures (National Research Council, 1980). Short-term exposure of workers can occur during waste generation, processing, transportation, or disposal. Short-term exposure of the public can occur if there is an accident during any one of these management stages. Long-term exposure of the public can occur if there is any release and off-site migration of radionuclides from buried radioactive waste by ground water to a drinking water source. Inadvertent intruders of a disposal site could also suffer from short- or long-term exposure.

The NRC weighed all the interrelated factors mentioned above in establishing three classes of LLW (A, B, and C). Because of the different risks posed by various radionuclides, each of the three classes of LLW has different concentration limits for different radionuclides. Generally speaking, if the concentrations of radionuclides in a commercial generator's waste exceed the limits listed in Table 1 and the waste is not spent fuel, the waste is considered GTCC.[13] If waste contains alpha-emitting transuranic radionuclides that have half-lives exceeding 5 years and are in concentrations exceeding 100 nanocuries per gram, the waste is also considered GTCC.[14] There are no defined upper limits on the concentration of radionuclides for GTCC waste.

13 If there are two or more radionuclides in a waste, the sum of fraction rule [10 CFR 61.55(a)(7)] must be used to determine the class of the waste.

14 Transuranic radionuclides with concentrations less than 100 nanocuries per gram are considered Class A or Class C LLW, depending on the radionuclide's concentration.

Table 1. Approximate Limits for Radionuclides in GTCC Waste

Radionuclide	Minimum Concentration (curies per cubic foot)	Half-Life (years)
Short-lived		
Strontium-90	200	30
Cesium-137	130	30
Nickel-63	20	100
Nickel-63 in activated metal	200	100
Long-lived		
Carbon-14	0.2	5,800
Carbon-14 in activated metal	2	5,800
Nickel-59 in activated metal	6	75,000
Niobium-94 in activated metal	0.006	20,000
Technetium-99	0.08	210,000
Iodine-129	0.002	16,000,000
Alpha emitting transuranic nuclides with half-life greater than 5 years	100 nanocuries per gram	
Plutonium-241	3,500 nanocuries per gram	
Curium-242	20,000 nanocuries per gram	

Source: Adapted from Tables 1 and 2 from 10 CFR 61.55

GTCC waste can be extremely dangerous, even lethal, if not handled properly. Although low radiation doses usually produce few if any short-term effects, the following examples illustrate the potential danger associated with higher radiation doses from radioactive material.

(1) In 1987, a sealed source -- the size of a paint can and containing 1400 curies of cesium-137 -- was stolen from a cancer therapy machine located in an abandoned clinic in Brazil. Within one month, four people had died and 54 others were hospitalized for varying lengths of time. People known to be contaminated were shunned by their communities. Contaminated buildings, vehicles, and furniture had to be decontaminated or taken into custody (Anderson, 1987 and Roberts, 1987).

(2) In 1962, a boy living in Mexico found an abandoned, pencil-sized radiography gauge containing a highly radioactive, broken, sealed source. The boy played with the gauge and took it home. The boy's mother then found the gauge and placed it on the kitchen shelf for several more weeks. The boy died shortly thereafter and over the next few months three other members of his family also died (Marshall, 1984 and West, 1984).

(3) A California man unknowingly exposed himself to excessive levels of radiation in 1979 when he placed a 29-curie sealed source in his back pocket for about 45 minutes. An initial

reddening of the skin under the pocket eventually became an open wound about 4 inches in diameter and almost an inch deep. Despite two subsequent skin grafts, the wound had still not healed completely nineteen months after the accident. In a similar accident in the 1970s, both legs of an Argentine man had to be amputated after receiving excessive doses of radiation from a sealed source he had been carrying in his front pant's pocket (NRC, 1986a).

In this country, protective measures (listed in Table 2), required to prevent such exposure to radioactive material over the short- and long-term are established by the EPA, NRC, and the U.S. Department of Transportation (DOT) in the form of standards, regulations, and guidance. Short-term risks are addressed through standards and regulations for worker exposure, packaging, storage, and transportation. For example, it is estimated that about 60 to 75 percent of all GTCC waste emits levels of radiation that warrant remote rather than contact handling by workers (Knecht, 1988).

Long-term risks are addressed through EPA standards and NRC disposal facility regulations that address environmental considerations, waste stability, and facility design. Table 2 lists some of these protective measures. Due to the magnitude and longevity of the risks associated with most GTCC waste, near-surface disposal used for Class A, B, and C LLW is generally not acceptable for GTCC waste.[15]

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15 10 CFR 61.55(@(4)(iv)

Table 2. Qualitative Description of Protective Measures for Managing Low-Level Radioactive Waste

Against short-term risk prior to disposal	Against long-term risks after disposal
1. Worker regulations and standards - limited exposure - film badges for measuring exposure	1. Environmental considerations: - minimize water infiltration (ground water depth & flow, amount of rainfall) - geologic stability
2. Packaging regulations - labels - protective shielding if needed 3. Storage guidelines 4. Transportation regulations and standards - packaging design (e.g.,labeling and stability and shielding if needed) - manifest forms for tracking waste packages - trucking and train transport regulations and standards (e.g., for routing and driver training)	2. Waste stability & facility design - packaging requirements - barriers to environment (e.g., depth of disposal, an intruder barrier, and a stable cap on the facility) - environmental monitoring program - buffer zone 3. Institutional control factors (e.g., fences, signs, and a site closure plan) - Government ownership of sites

Sources: Adapted from:

10 CRF 20 (Standards for Protection Against Radiation)
10 CFR 61 (Licensing Requirements for Land Disposal of Radioactive Waste)
49 CFR 171,172,173,177 (Radioactive Materials; Routing and Driver Training Requirements)

To evaluate the management of GTCC waste, as compared to other types of radioactive waste, two primary factors were used 1) the concentration of radioactivity in the waste, and 2) the length of time that the waste poses a significant risk to **humans, or the longevity** of risk. These two factors help policy makers to qualitatively understand the relationships between the various types of radioactive waste. Table 3 and Figure 1 are based on this analysis.

Table 3 illustrates that the average concentration of radioactivity in GTCC waste is closest to that of defense HLW and higher than any type of commercial radioactive waste except spent fuel. As of 1985, the average concentration of radioactivity in GTCC waste was 300 curies per cubic foot. If the activity from all short-lived radionuclides (e.g., cobalt-60) was ignored, this concentration would drop to about 50 curies per cubic foot. By 2020, GTCC waste's average concentration is projected to increase significantly to about 2500 curies per cubic foot. If all short-lived radionuclides were again ignored, this concentration would drop to about 1500 curies. This concentration of radioactivity will be much higher than it is today because by 2020 more than half of GTCC waste activity will be contributed by radionuclides (primarily nickel-63) with half-lives of 100 years or longer.

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[16] M Knecht EG&G Idaho, Inc. (DOE contractor), personal communication, September 1988-

Table 3. Relative Risks from Different Types of Radioactive Waste

Waste type	Average Concentration [a] (Ci/tcubic foot) End of 1985	2020	Relative longevitv of risk
Spent fuel	200,000(1)	100,000(1)	Ten thousand years[b]
High-level waste (defense)	100(1)”	100(1)	Hundreds to few thousand years[b]
Transuranic waste (defense)	02(l)	~(l)	Few to several thousand years[c]
Greater-than-C1ass-C waste*	300(2)	2,500(²)	Hundreds to few thousand years[c]
Low-level waste			
Total commercial	01(0	01(1)	
class c	7 (l&9)		Few 100 to 500 years[d]
Class B	2 (l&3)		Few 100 years[d]
Class A	O J (w		Less than 100 years[d]

Much of the initial radioactivity associated with GTCC waste is due to short-lived radionuclides (e.g., cobalt-60). By 2020, more than half of its radioactivity will be contributed by long-lived radionuclides (e.g., nickel-63).

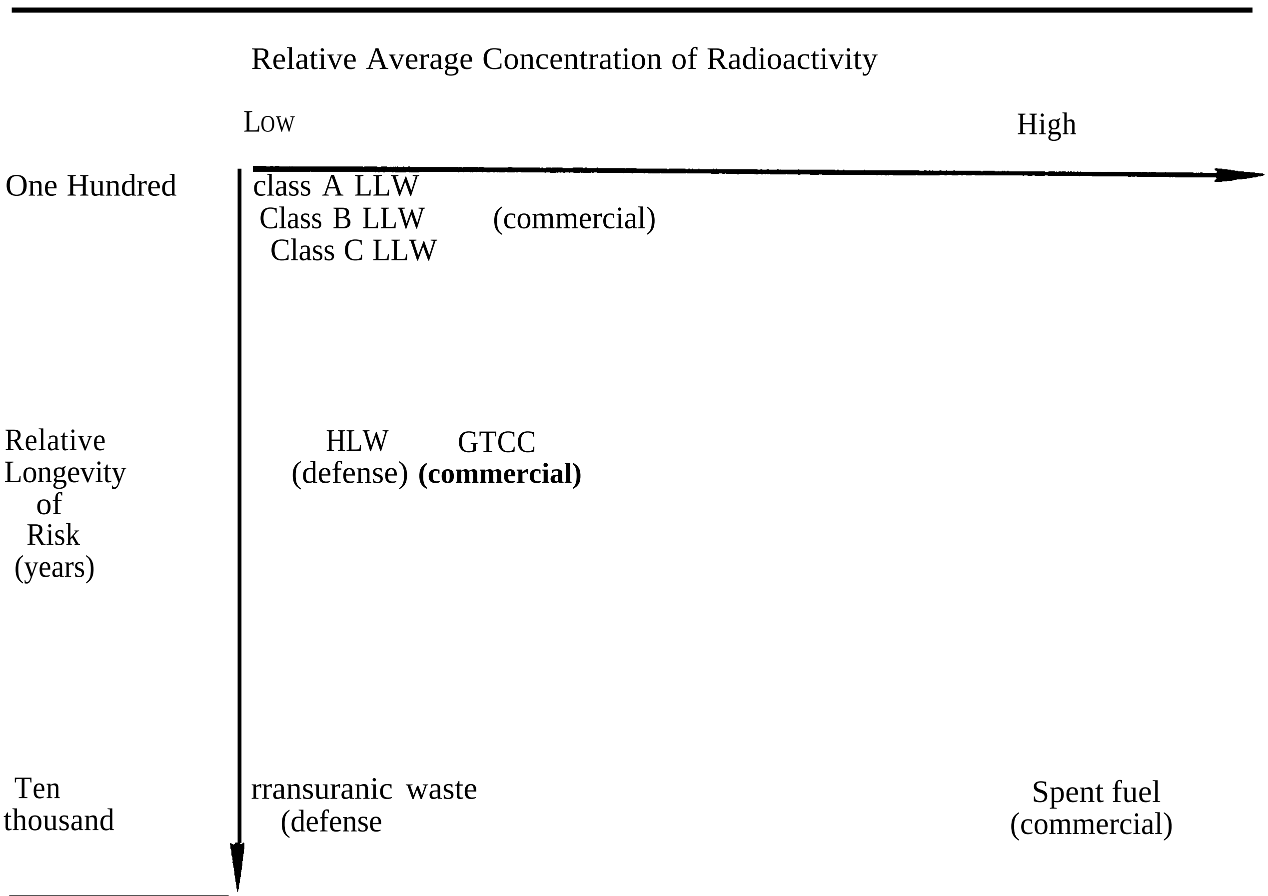
[a] **Average concentrations for waste in storage or shipped for** disposal.
[b] Semi-quantitative approximation of longevity of risk based on the half-life of the radionuclides in the waste, and EPA standards for radioactive waste disposal.
[c] Semi-quantitative approximation of longevity of risk based on the half-life of radionuclides in the waste relative to EPA standards for radioactive waste disposal.
[d] Semi-qualitative approximation of longevity of risk based on NRC 10 CFR 61 regulations for LLW.

Sources:

1) U.S. Department of Energy, Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories. Projections. and Characteristics, DOE/RW-0006, Rev. 3 (Washington, D. C.: September 1987).
2) Knecht, M., EG&G (DOE contractor), personal communication, September 1988.
3) U.S. Department of Energy, The 1986 State-bv-State Assessment of the Low-Level Radioactive Waste Received at Commercial Disposal Sites, National Low-Level Radioactive Waste Management Program, DOE/LLW 66T, December 1987.

Figure 1 shows a qualitative plot of Table 3. The average concentration of radioactivity is plotted against the average longevity of risk associated with different categories of radioactive **waste.** With regards to these two factors, GTCC waste shares characteristics that are most similar to defense HLW. One important difference between these two wastes is that much of GTCC waste activity will be from long-lived nickel-63, which is slow to migrate because it will be contained in activated metals, while defense HLW activity is from shorter-lived radionuclides (e.g., cesium- 137 and strontium-90), which are generally more mobile.

Figure 1. Qualitative Comparison of Relative Risks from Different Types of Radioactive Waste



Source: OTA

PRESENT PROBLEMS ASSOCIATED WITH GTCC WASTE MANAGEMENT

The DOE has deferred a decision about GTCC waste disposal pending further analysis of various disposal technologies. The NRC staff has published a proposed amendment to 10 CFR 61 that would require the disposal of GTCC waste in **a** deep-geologic repository, unless the DOE develops another licensable option (Federal Regisrer **May** 1988). The deep-geologic repository for commercial spent fuel and defense HLW will not be available, however, for fifteen to twenty years. If another disposal technology were chosen, it would require a similar length of time to develop a separate facility for GTCC waste disposal.

The major concern is the storage of this waste **until a disposal facility can be made available. Specifically, potential storage problems include: 1) the management of sealed sources, 2)** GTCC material users phasing out operations that use this material and needing off-site storage capacity, 3) the increasing number of GTCC waste generators that expect to exhaust their on-site storage capacity during this period, 4) the potential for waste packages to degrade during this period.

In its 1987 report on GTCC waste, DOE tentatively committed the Federal Government to accept GTCC waste within the next two years for storage at an as yet unspecified facility. Considering this time frame, this facility would presumably be an existing, DOE storage facility, all of which are unlicensed to ensure national security of defense operations. There is some question in Congress whether an unlicensed facility would be appropriate for commercial GTCC waste.

These problems and options for managing GTCC waste are discussed in the following section.

Chapter 3

MANAGEMENT OPTIONS

Since some GTCC waste remains potentially dangerous for a few thousand years, it must be safely disposed of in a manner that protects future populations and the environment. The analysis provided in this section indicates that an appropriate disposal facility for GTCC waste will not be available for at least 15 to 20 years. Furthermore, GTCC waste generators cannot prepare their waste for disposal because no disposal technology has been chosen. Instead, they must prepare their waste for storage, and may have to repackage it later for disposal. Until a disposal facility is available, GTCC waste must be safely stored to avoid unnecessary worker exposure and handling accidents that could subsequently contaminate the environment and harm the general population.

Since GTCC waste storage is the most immediate problem now facing waste generators and policy makers, several storage options are analyzed to determine their ability to accommodate GTCC waste over the next two decades. Disposal options for GTCC waste are then analyzed by comparing them with the disposal technologies chosen for other types of radioactive waste. Finally, an integrated approach for managing GTCC waste over the short- and long-term is presented.

The technical and institutional factors listed in Table 4 are used to compare various storage and disposal options in a qualitative manner. The factors within each of the two categories are generally ranked according to their relative importance, but no attempt was made to weight them. These factors are used in somewhat different ways for storage and disposal.

STORAGE: The analysis in the storage discussion indicates that GTCC waste can be safely stored for several decades if it is safely packaged and stored under appropriate conditions. Thus, the major issue for the Federal Government does not involve determining what technologies to use, but <u>which</u> sites to use: a facility constructed and maintained on-site by the waste generator or some other off-site facility. The technical and institutional factors listed in Table 4 are used to qualitatively compare on- and off-site storage facilities.

DISPOSAL: Since the long-term safety associated with GTCC waste disposal depends largely on the disposal technology chosen, technical factors are given primary emphasis and used to evaluate three generic disposal technologies: near-surface disposal, intermediate-depth disposal, and disposal in a deep-geologic repository. Economic and institutional factors are then used to evaluate disposal of GTCC waste either at a separate facility for GTCC waste or at a currently proposed facility (e.g., the deep-geologic repository for spent fuel and defense HLW).

Table 4. Primary Factors for Comparing Waste Management Options

TECHNICAL FACTORS:

- **Public health and safety risks**
- **Worker** Safety risks
- Environmental risks
- Transportation risks

INSTITUTIONAL FACTORS

- Timeliness in meeting the general intent of LLRWPAA -- having the Federal Government responsible for finding a safe disposal option for all GTCC waste
- Availability of adequate funding and institutional stability to ensure safe storage and disposal
- Ease of facility siting (e.g., acquiring land and finding local support)
- cost

Source: OTA

A n N ~

There is a rather wide spectrum of facilities having varying levels of protection that can be used to store GTCC waste. The most appropriate storage technology depends primarily on the type and radioactivity of GTCC waste, and the expected storage time.

A. Description of Storage Technologies

The most basic storage facilities for radioactive waste are unshielded prefabricated-fabricated structures or fenced-in outdoor concrete or asphalt pads, which are sometimes covered to shed precipitation. Some companies simply store their GTCC material and waste in the basements of their buildings. Shielded concrete storage modules or bunkers with removable covers may also be located on company property at a distance from workers. The most elaborate storage facilities are permanent steel frame buildings or reinforced concrete structures. To prevent corrosion of the waste containers, some of these facilities are equipped to monitor and strictly control the indoor storage conditions, such as temperature and humidity (Siskind, 1985; Siskind, 1986).

To ensure public health and safety, GTCC waste must be properly prepared for extended storage. In choosing packaging materials, for example, a generator needs to assume that the waste may remain in storage for at least two decades. Like other types of packaged LLW, GTCC waste containers may corrode externally if indoor climatic conditions are not controlled during extended storage. Chemical reactions within the waste can produce liquids that could internally corrode containers; degrading organic wastes can generate pressurized gases, and cause unvented containers to breech or explode. If individual unvented containers are breached, stacked containers could collapse (Siskind, 1985; Siskind, 1986).

While GTCC waste is in extended storage, an adequate monitoring system will be needed to detect packages that may be deteriorating. Once degradation occurs, the GTCC waste will need to be repackaged, which could elevate worker exposures and contaminate the environment.

Inadequate administrative practices during extended storage can also result in contamination problems. For example, a combination of poor record keeping, illegible packaging labels and personnel changes, can result in loss of control over GTCC waste.

Since the controls required for radiation protection and accident prevention tend to increase as the intended storage periods increase, the storage conditions, and monitoring and administrative procedures **now used for most GTCC waste may have to be upgraded to accommodate extended storage. To ensure public health and safety in light of current uncertainties over the availability of a disposal facility the NRC and Agreement States may need to update their packaging guidance and storage regulations assuming several decades of extended storage.**

B. Optional Storage Sites

Options for providing on-site extended storage, off-site extended storage, and limited-access to off-site storage are analyzed in the following discussion. The technical and institutional factors listed in Table 4 are used in this analysis.

1. GTCC waste storage at its generation sites.

At present, GTCC materials **and wastes are being stored on-site by a few thousand users and generators, the majority of which are small companies.** On-site storage places the financial burden and liability for waste storage on the users and waste generators. The main concerns about on-site storage involve human health and safety and the potential for environmental contamination if storage is not conducted properly. This is especially true for the small GTCC material users and waste generators that possess sealed sources.

Surveys mailed to some 14,000 potential GTCC waste generators by a DOE-contractor and an informal telephone survey by OTA indicate that GTCC waste generators will have increasing problems developing on-site storage capacity over the next few decades. Some generators, especially small companies, argue that their present on-site storage capacity cannot be expanded because of costs and limitations on the physical size of their property. Although such claims by waste generators seem reasonable, they are difficult to verify. Some generators may have overestimated their storage problems with the hope that more attention would be focused on their need for a disposal facility. Nonetheless, the availability of unused on-site storage capacity for GTCC waste will decrease as the length of time required to develop a disposal facility increases.

The problem of diminishing on-site storage capacity for GTCC waste may also be much worse than it now appears for several reasons. First, thousands of users of GTCC material and sealed-source were not included in the DOE-contractor survey. Second, some generators that may be nearing the limits of their material licenses may have underreported their projected inventories. Third, some generators, especially small companies, may go out of business over the next few decades before a disposal facility is available to accept their waste. In such a situation, the Federal Government could be left responsible for storing the waste and protecting public health and safety and the environment.

2. Off-site extended storage

Over the next 30 years about 65,000 cubic feet -- equivalent to about 25 tractor trailers -- of GTCC waste is projected to be generated.[17] The DOE-contractor survey indicated that by 2020 generators will posses about 14,000 cubic feet -- equivalent to about 5 tractor trailers -- of packaged GTCC waste that cannot be stored on-site.[18] Since not all generators responded to the survey, and the survey did not include sealed source users, this figure may be low. OTA estimates that the volume of waste that may require off-site storage could be as much as 20,000

17 M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

18 M. Knecht, EG&G (DOE contractor), personal communication, September 1988.

cubic feet of packaged waste.

For several reasons, it is unlikely that a State or private company would be willing to independently develop an extended-storage facility for GTCC waste. First, given the uncertainty about the availability and timing of the Yucca Mountain repository or an alternative disposal facility for GTCC waste, it is unlikely that any State or private company would be willing to accept the open-ended liability associated with GTCC waste storage. Second, because no decision has been made on which disposal option will be chosen or how much it will cost, no State or private company would know what to charge for storage and the eventual disposal of the waste. Third, if a State or private company decides to wait and charge a second fee when a disposal decision is made, a company whose waste it is holding may go out of business in the meantime, placing all liability on the State or private company hosting the storage facility. Fourth, siting a storage facility for GTCC waste would undoubtedly involve many political difficulties, in addition to current State problems siting facilities for Class A, B, and C wastes. Fifth, the large uncertainties about the needed amount of storage capacity may make such a storage facility a risky investment. Through a notice in the Federal Register, DOE plans to solicit comments on the willingness of any non-Federal entity to provide storage capacity for GTCC waste.

Considering the situation described above, it may be necessary to provide extended storage capacity for some GTCC waste at a Federal facility.[21] In its GTCC waste report (1987a), DOE tentatively committed the Federal Government to accept GTCC waste for storage by 1989. Centrally storing GTCC waste at a well-designed facility would likely enable a more effective and efficient monitoring and enforcement program and minimize the potential for accidents and container failure at scattered GTCC waste generating sites. In the absence of political or legal intervention, the Federal Government, in particular DOE, could quickly expand an existing facility or construct a new facility at one of. its national laboratories.

Political resistance toward a Federal extended-storage facility is likely to come from any State in which the DOE storage facility is located. States have consistently expressed concerns about the added risk of any new radioactive waste management activity to its citizens and the environment. States would be worried that if activities to develop the Yucca Mountain repository or an alternative disposal option were to stall, any storage facility could evolve into a de facto disposal facility. Public trust in DOE programs has been severely eroded during past Federal efforts to site a deep-geologic repository. These State concerns may be tempered by appropriate Federal legislation (e.g., mandating that the facility only be used for GTCC storage and limiting the volume and duration of stored waste).

There is some question as to whether a Federal extended-storage facility would have to be

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[19] This figure assumes that most decommissioned nuclear power plants will be placed in storage for 30 to 50 years. Under this scenario, decommissioning waste will not be generated until the middle of the 21st century. (See Appendix C.)

[20] A commercial waste service company accepts GTCC sealed sources for extended storage. If it accepts the responsibility of eventually disposing of the waste, the company charges rates generally above those for Class C waste disposal. For example, one-half curie of americium-241 would cost $23,000 for storage and disposal. This company receives many inquiries about GTCC waste disposal, but few customers because of the high costs.

[21] To ensure that such a facility would be used by generators with on-site storage problems, the Federal Government may need to decide whether such storage should be in some way subsidized.

licensed by the NRC.[22] All storage and disposal facilities for commercial LLW are today licensed by NRC or Agreement States. Furthermore, the LLRWPAA of 1985 already requires licensing of any **disposal** (not storage) facility for GTCC waste. The Senate passed a bill during the IOOth Congress -- that would require any storage facility for GTCC waste to be NRC-licensed. as To allay some State concerns and to bolster public Confidence, Congress may decide to require **that any Federal extended-storage facility for commercial GTCC waste be** licensed **by NRC.**

To ease potential problems associated with developing a licensed storage facility, DOE could parcel off a site adjacent to or within one of its national laboratories, such that the activities occurring at the licensed facility would not interfere with unlicensed defense-related activities. Two of the three commercial LLW disposal facilities are located in such a fashion.[24] Even if this made siting easier, it would still require probably several years to select a site, to conduct the required environmental assessments, and to construct a licensed storage facility for GTCC waste.

Due to economics, it is unlikely that all GTCC waste generators would choose to use the extended-storage facility. Generators who have adequate on-site storage capacity (e.g., utilities) would likely not want to pay for off-site storage. Some generators may wish to defer paying disposal costs for their GTCC waste as long as possible. This facility would, therefore, have to be designed in a modular fashion with a great deal of flexibility in its capacity and use storage technologies that would provide several decades of safe isolation. This facility would also have to accommodate a wide variety of GTCC wastes -- 60 to 75 percent of which must be handled remotely even after packaging (Knecht, 1988).

3. Limited access to an off-site storage facility

Before an extended-storage facility is available, some generators of GTCC waste may need limited access to an existing commercial or Federal storage facility. Of particular concern is the fate of the several thousand sealed sources now being used in a wide variety of tools and machines throughout the United States. Some portion of these will become obsolete and will not be returnable to their manufacturers during the period before an extended-storage facility

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22 DOE can legally accept and store commercial radioactive material generated by health and safety emergencies (e.g., accidents) at its unlicensed facilities. In addition, DOE can accept sealed sources containing plutonium, if the plutonium concentrations are economically recoverable. Users of such sources (e.g., universities and the military) pay for packaging and transportation (but not disposal) of the sources, which are donated to DOE. DOE also has accepted transuranic waste from the decommissioning of facilities operated by Monsanto (Dayton, Ohio), Nuclear Fuel Services (Erwin, Tennessee), and Babcox and Wilcox (Lynchberg, Virginia) under research and development contracts. Negotiations have stalled on a fourth contract with Exxon on a fuel fabrication facility in Richland, Washington. It has not been decided where this transuranic waste will be disposed.

23 See Section 303, Title III, entitled the Nuclear Regulation Reorganization and Reform Act of 1988 (H.R. 1315), reported by the Senate Committee on Environment and Public Works' Subcommittee on Nuclear Regulation on February 22, 1988. The Committee feels that this requirement is a logical extension from the LLRWPAA language that requires any GTCC disposal facility to be NRC-licensed. As of September 1988, The House of Representatives had not acted on this amended bill.

24 The commercial facility at Barnwell, South Carolina is adjacent to the DOE Savannah River Laboratory. The commercial site near Richland, Washington, is <u>inside</u> the DOE Hanford Reservation.

would become available.

The theft and improper handling of sealed sources have been responsible for four major accidents and 14 deaths in foreign countries over the last 25 years. In the **United States** the 40 **or so sealed source manufacturers and the thousands of sealed sources users are regulated, but individual sealed sources are not registered. Institutional controls tend to diminish as equipment containing sealed sources is transferred to other users over time.**

The impacts associated with sealed source accidents often go well beyond any immediate deaths and can be difficult to detect. For example, in 1983, a stored radiotherapy machine containing a large sealed source was illegally sold as scrap to a junkyard in Juarez, Mexico. Contaminated scrap metal was subsequently sold to two Mexican foundries, where it was melted down, made into table legs and reinforcing steel, and shipped to the United States. This accident was discovered five weeks later when a truck carrying contaminated reinforcing steel made a wrong turn at the Los Alamos Laboratory in New Mexico and tripped a radiation sensor. By this time, contaminated steel had been shipped to 40 states throughout the United States, and about 200 Mexicans were exposed to very high levels of radiation (West, 1984; Marshall, 1984; Stengel, 1984).

The International Atomic Energy Agency (IAEA) held a meeting in June 1988 on the problems associated with regulating sealed sources. The IAEA acknowledges the potential for accidents occurring if sealed sources are poorly regulated (IAEA, 1988).

Although fatal accidents involving sealed sources have not been recorded in the United States, they would be more likely to occur if tight regulatory control of licensed material and sealed sources is not maintained, especially when on-site storage is unfeasible. Even though the amount of radioactive material in many sealed sources is small, some are highly radioactive. Moreover, there are several thousands in use or in storage. In response to recent accidents involving sealed sources and mishandling of radioactive materials, the NRC issued a Notice in March 1988 to material licensees, alerting them of the need to control the handling and transfer of their licensed material to reduce the risk of an accident or its loss. Specifically, licensees are to periodically inventory and test for leaks in their sealed sources. Furthermore, the NRC encourages licensees to avoid long-term storage of surplus radioactive material.

Until an off-site storage option is available, generators have no choice but to store their GTCC waste on site. **The political repercussions for the Federal Government if a GTCC waste accident were to occur could be especially significant if the accident were linked to the Federal Government's inability to accept this waste for disposal or long-term storage.**

It is possible that a private company would be interested in storing a limited amount of GTCC waste at an existing commercial facility until a Federal extended-storage facility or disposal facility is available. Such a company would most likely only store GTCC waste if acceptance fees were sufficiently high to cover its potential liabilities, which are several. First, the period that GTCC waste would need to remain in storage is presently open-ended. There is no assurance when or if an extended-storage facility will be developed. Second, the availability of a disposal facility for GTCC waste is far from guaranteed. Third, it is unclear who would pay for extended-storage and disposal if a company were to go out of business while its waste was being held at private company's limited-access storage facility. DOE's planned Federal Register notice on the availability of non-Federal storage facility may also solicit comments on limited access to such a facility.

It appears that the most effective option for reducing the potential for GTCC accidents and ensuring adequate storage capacity for GTCC waste is to provide limited access to an

existing, unlicensed DOE storage facility. To ensure that such a facility were used only when necessary, acceptance criteria may need to be developed. Determinations of need would probably be made on a case-by-case basis by the DOE or NRC. OTA estimates that the total storage capacity needed would probably be a few thousand cubic feet -- less than 2 tractor trailers. **Any GTCC waste in limited access storage could be transferred to the licensed, extended-storage facility, once it is available.**[25]

To minimize the amount of GTCC waste requiring limited-access storage, manufacturers of new sealed sources could be required to repossess obsolete sources. Several mechanisms could be emplaced to further help the management of sealed sources. (See section on Funding Mechanisms beginning on page 32.)

AN EVALUATION OF DISPOSAL OPTIONS FOR GTCC WASTE

The goal of disposal is to isolate GTCC waste during the few hundred to few thousand years when its radioactivity poses a risk to humans and the environment. The technology chosen for GTCC waste disposal is critical to ensure long-term safety. The technical factors listed in Table 4 are used to qualitatively evaluate the acceptability of the following disposal technologies:

- near-surface disposal
- intermediate-depth disposal
- disposal in a deep-geologic repository

After this analysis, the economic and institutional factors listed in Table 4 are used to qualitatively evaluate GTCC waste disposal.

A. Description of Disposal Technologies

1. Near-surface disposal

Near-surface disposal is the technology that is presently used for the disposal of Classes A, B, and C LLW. Waste packages are disposed of in near-surface earthen trenches that are generally 20 to 30 feet deep, 20 to 100 feet wide, and several hundred to 1,000 feet long. As the waste is emplaced, the trench is backfilled with dirt and then covered with a compressed earthen cap. To reduce subsidence of the cap, Class B and C LLW must be packaged to remain structurally stable for at least 300 years. Class B and Class C waste are segregated from structurally unstable Class A waste. In addition, Class C waste must be disposed of at least 16 feet below ground or covered with a barrier (usually made of concrete) that will last at least 500 years.[26] The purpose of this barrier ‘ called an intruder barrier -- is to prevent people from digging into the waste once the site is closed and the institutional period has ended. During the institutional period, monitoring and surveillance of the site must be maintained for at least 100 years. This period begins after a site has closed and its license has been transferred to the State or a Federal Custodial agency.

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25 According to Knecht (1988), the unpackaged volume Of obsolete sealed sources that ‘s expected to accumulate by the year 2020 is less than 35 cubic feet. In the several years or so before an extended-storage facility could become available, there will likely be significantly less than 35 cubic feet. How these sources are packaged will determine how much storage capacity will be needed. It is also likely that during the period before an extended-storage facility could become available, some small companies that possess GTCC material could go out of business, requiring their facilities to be decontaminated and decommissioned. This waste could also require limited storage.

26 10 CFR 61.52(a)(2)

Three near-surface disposal sites which were used in the 1960s and 1970s experienced significant problems with subsidence and failure of overlying caps, infiltration of water, and the subsequent migration of radionuclides from the trenches. These sites have subsequently been closed. Although the more stringent 1983 NRC regulations (10 CFR 61) on near-surface disposal have thus far eliminated these kinds of problems, many States and Compact regions are very interested in using structurally enhanced near-surface disposal alternatives for their future LLW disposal sites (DOE, 1987c and NRC, 1984b).

Among the most discussed enhanced disposal alternatives are: concrete-lined trenches, above- and below-ground concrete vaults, and earth-mounded concrete bunkers (which combine several LLW disposal technologies). Concrete would be used in the construction of all of these enhanced facilities. Many other features (e.g., waterproof coatings, internal and external drainage, etc.) can be incorporated into facility designs to minimize the infiltration of surface water and to keep the waste as dry as possible.

It is possible to increase the degree to which GTCC waste can be isolated beyond that provided by near-surface facilities, by disposing of the waste at an intermediate depth of a few hundred feet. At sucha depth, there is greater assurance that humans will not inadvertently come into contact with the waste. If concrete were used at this depth it would have to withstand the pressures of deep burial over the long-term and resist degradation due to the disposal environment. The primary risk of radionuclide migration at this depth would stem from unforeseen ground water movement. Such risks would be minimized if waste were far removed from potential ground water.

2. Intermediate-depth disposal

Several different technologies could be used to place waste at an intermediate depth of between 100 and 500 feet below the earth's surface. The use of augered holes is one such technology. It involves boring a hole, typically measuring 8 or more feet in diameter, into the ground and pouring a concrete foundation in the bottom of the hole. A smaller diameter steel or fiberglass liner is then lowered into the hole until it rests on the concrete foundation. This liner is then surrounded on the outside with a layer of concrete or cement grout, typically measuring about one-foot thick. After the liner has been filled with waste, grout is poured around the waste to form a solid cement-waste matrix inside the liner. A concrete cap is then placed on top of the hole, and any remaining part of the hole is backfilled with soil (Cook, 1987).

Augered holes with depths of 20 to over 100 feet have been used over the last several years at DOE's national laboratories for the disposal of some defense LLW similar in radioactivity to Class B, C, and some GTCC waste. For example, unpackaged reactor fuel cladding and well-packaged tritium have been disposed of at the Nevada Test Site in a few unlined augered holes measuring about 120 feet deep.[27] These holes are unlined because the yearly precipitation is low and ground water is about 800 feet deep.

Another technology that could be used at an intermediate depth (100 to 500 feet deep) is a geologic repository. Repositories are described in the following section, with respect to deep disposal, but could also be constructed at an intermediate depth. Sweden has developed an intermediate-depth repository under the Baltic Sea, about half a mile offshore and 200 feet below the sea floor. The facility, which has been operating since April 1988, is excavated into

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[27] R. Dodge, Reynolds Electric Company (DOE contractor at the Nevada Test Site), Personal communication, June 1988.

granite. It is designed with 4 large rooms to hold LLW and a concrete silo, about 200 feet high and 100 feet in diameter, to contain intermediate-level waste.

3. **Disposal** in a deep-geologic repositorv

Deep-geologic repositories, located at depths of 2,000 to 3,000 feet, are viewed by the scientific community worldwide as generally the most favored technology for disposing of highly radioactive waste. The geologic formations surrounding a repository will provide major natural barriers to the migration of radionuclides by ground water over the long-term. Engineered barriers, such as the waste form and surrounding package, enhance the isolation of the waste during the first few thousand years. During this time, heat from the waste could increase the migration of radionucides if the waste were to contact with any flowing water (OTA, 1985).

According to the Nuclear Waste Policy Act of 1982 and subsequent studies by DOE (1985d and b, 1987d, and 1988), all spent fuel and defense HLW will be permanently isolated in one deep-geologic repository. Yucca Mountain in Nevada is now being evaluated to determine its suitability for such a facility. If this site found to be suitable, waste canisters will be emplaced along a widely spaced grid within the repository beginning in about 20 years. Waste emplacement will continue for about 50 years (DOE, 1987d). The repository may remain accessible for a few decades after the waste has been emplaced to allow for monitoring and continued cooling of the waste. The repository will then be backfilled. About 67 percent of the repository's volume is projected to be used for commercial spent fuel and 33 percent for defense HLW.[28]

Another deep-geologic repository will be used for the disposal of transuranic waste generated by defense activities. Over the last decade DOE has been developing such a facility, called the Waste Isolation Pilot Plant (WIPP). This repository is situated at a depth of about 2,200 feet in a bedded salt formation near Carlsbad, New Mexico. DOE plans to dispose of some defense transuranic waste in WIPP on a demonstration basis in late 1988.[29] If this 5-year demonstration is successful, much of DOE's remaining transuranic waste will be disposed of in this repository over the next 20 years.

Although there are as yet no licensed deep-geologic repositories for radioactive waste in the United States, or elsewhere in the world, decades of extensive scientific study have revealed no insurmountable technical obstacles for developing such repositories, provided suitable sites are found (OTA, 1985).

B. Technical Comparison of Disposal Technologies

Near-surface disposal facilities, which **are licensed by** NRC (under 10 CFR 61) or by Agreement States, can be used for the disposal of Class C LLW which requires isolation for periods of about 500 years. Since the longevity of risk for GTCC waste greatly exceeds this time period, near-surface disposal technologies would generally not be appropriate. Such a position is stated in NRC's Part 61 regulation.

Reinforced concrete is widely used in enhanced near-surface disposal technologies for long-term structural integrity. To evaluate the suitability of concrete for near-surface enhancements, DOE's Brookhaven National Laboratory conducted an in-depth analysis for the

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28 M.Komar, DOE, personal communication, June 1988.

29 C. Fankey, DOE, Personal communication, May 1988. As of September 1988, it appeared that this demonstration phase would not begin until 1989.

NRC on historical and recent experience with concretes throughout the world (NRC, 1986 b). This study found that some ancient concretes have performed adequately for 2,000 years or more. Although modern concretes have not been in use for much more than a century, there are many examples of excellent performance for periods of several decades and a few for periods on the order of 100 years (MacKenzie, 1987).

Considering the lack of deterioration of ancient concretes that have been subjected to harsh conditions and the relatively benign conditions expected at near-surface LLW disposal facilities, it should be possible to formulate concrete with enough durability to perform satisfactorily as a structural material for a few hundred years (MacKenzie, 1987). It is unclear, however, that enhanced near-surface disposal alternatives using concrete would prove adequate for the few thousand years necessary to isolate most GTCC waste.

As mentioned in the background section of this report, GTCC waste characteristics are most similar to defense HLW. Furthermore, by the year 2020 more than half of the activity of GTCC waste will be contributed by radionuclides (primarily nickel-63) with half-lives of 100 years or longer. In accordance with the Nuclear Waste Policy Act of 1982 and its 1987 amendments, defense HLW is planned for disposal in the Yucca Mountain repository; defense transuranic waste is planned for disposal in WIPP. If a decision about the disposal of GTCC waste were required today, its permanent isolation in a deep-geologic repository would be technically acceptable.

The NRC staff, in a letter response to DOE's report to Congress on GTCC waste (NRC, 1987), recommended that GTCC waste be disposed of ina deep-geologic repository. In this letter the NRC estimated that roughly 85 percent of GTCC waste had enough long-lived radionuclides to require permanent isolation in a deep-geologic repository (NRC, 1987). As mentioned earlier, the NRC has also published a proposed amendment to 10 CFR 61 in the Federal Register (May 18, 1988) that would require all GTCC waste to be disposed of in a deep-geologic repository, "unless disposal elsewhere has been approved by the Commission."

It is possible that further research and analysis over the next several years could demonstrate the acceptability of non-repository disposal alternatives, such as intermediate-depth augered holes or an intermediate-depth repository. These technologies, if used in areas of low rainfall and deep ground water, might be found acceptable for some GTCC waste, especially the portion of waste composed of short-lived radionuclides. It is unclear, however, whether any disposal alternatives other than a deep-geologic repository would be acceptable for isolating the long-lived radionuclide portion of GTCC waste.

C. Preliminary Economic Comparison of Disposal Options

Due to significant economies of scale associated with constructing large facilities, it is possible that waste disposal in a large repository may be less expensive than using a smaller facility only for GTCC waste. In the following discussion, the costs of GTCC waste disposal in the Yucca Mountain repository are analyzed, to the extent possible, before examining possible costs for a smaller, separate disposal facility for GTCC waste only. It must be emphasized that these calculations are preliminary and will have to be verified when more accurate estimates become available.

Disposal costs are calculated below in terms of the volume of disposed waste rather than considering the various factors used for commercial near-surface disposal facilities. Among others, these factors include: concentration of radioactivity (i.e., curie content per unit volume), the half-life of the waste's radionuclides, and the type of radiation emitted by the waste. Site operators use these factors to determine the waste package's longevity of risk and whether it must be handled remotely. Since repository disposal costs will probably be based on waste volumes, **the following analysis uses only waste volumes to estimate disposal costs.**

1. Large, deep-geologic repository

The approximate cost of GTCC waste disposal in a repository is highly dependent on the mode of waste emplacement. One potential mode involves stacking the packaged waste from floor to ceiling in **dedicated rooms excavated specifically for** GTCC waste. If waste packages could be packed tightly together, the total volume of GTCC waste generated by 2020 would fill a room approximately 15 feet wide, 20 feet high, and 570 feet long. This volume -- about 170,000 cubic feet -- would occupy about 0.1 percent of the 115 miles of tunnels and waste emplacement rooms now planned for the Yucca Mountain repository. According to very preliminary DOE estimates, constructing the Yucca Mountain repository is now projected to cost about $15 billion. Constructing ().1 percent of the repository for GTCC waste would cost about $15 million (not including waste repackaging and loading costs), or about $90 per cubic foot of GTCC waste.

A potentially less expensive disposal mode involves using GTCC waste as **backfill material when the repository rooms and/or connecting tunnels are sealed off and the repository is closed. This mode would eliminate the cost of excavating dedicated** rooms. If this second mode were used, GTCC waste disposal would probably not begin for at least a decade after the first (and presumably the coolest) spent fuel was emplaced. In other words, the emplacement of some GTCC waste could begin around 2020.

Although the backfill option is likely to be less expensive than GTCC waste disposal in dedicated rooms, the backfill option has a couple disadvantages. First, if the small section of repository containing GTCC waste were ever reexcavated, the waste in the backfill material could make this operation significantly more difficult due to worker exposure. Second, if the entire repository were left open for about 50 years to allow further cooling and continued monitoring of the spent fuel, disposal of GTCC waste as backfill could not begin until after the middle of the 21st century.

2. Separate GTCC waste disposal facility

The costs associated with developing a separate facility for GTCC waste using intermediate-depth disposal facilities have not been calculated. Cost estimates, however, have been made by DOE for several near-surface disposal technologies for LLW, with near-surface disposal being the least expensive and earth-mounded concrete bunkers being the most (DOE,

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The majority of non-utility GTCC waste and a great deal of utility GTCC waste could be tightly packed into repository rooms. Some utility waste (e.g., core shrouds) may have to be emplaced along a widely spaced grid, like spent fuel, or further cooled by storing the waste for two or three more decades. NRC staff believe that the overall packaging requirements for most GTCC waste need not be more stringent than those provided in 10 CFR Section 61.55 for 300-year stability of Class B and C LLW (NRC, 1988 b).

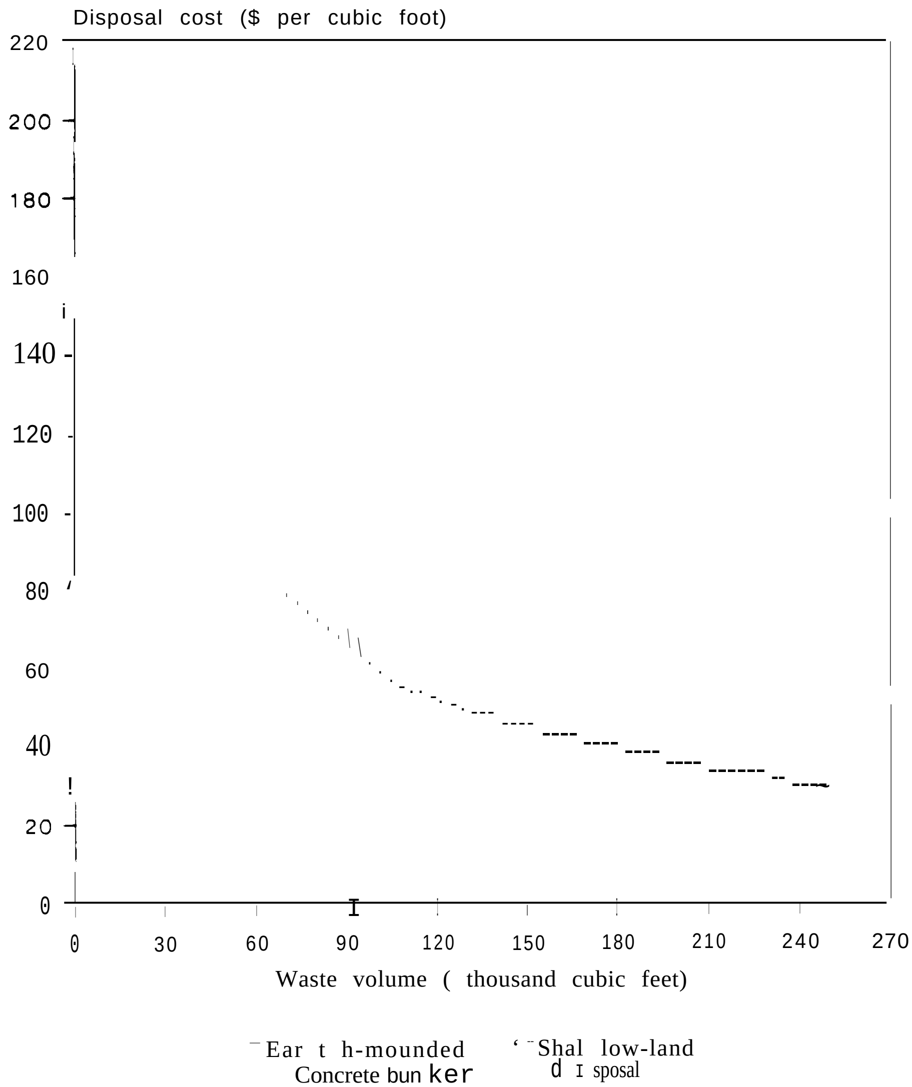
31 M Komar DOE personal communication, June 1988.

32 C. " Conner: DOE: personal communication, May 1988. DOE has already spent several tens of millions of dollars screening sites for a HLW repository and an additional $1 to $2 billion will be required to characterize the presently proposed site at Yucca Mountain in Nevada.

~ This assumes that the cost of space occupied by GTCC waste would include a Proportion of the overall cost of siting and developing the repository. Some people would argue that the repository must be developed anyway, under the Nuclear Waste Policy Act of 1982, and that GTCC costs should be based only on the incremental cost of adding the space used for GTCC waste disposal.

1987c). **Disposal costs fora near-surface facility accepting** about 60,000 cubic feet of waste per year, which was the smallest facility evaluated, were estimated to average $120 per cubic foot (DOE, 1987c). The projected annual rate of GTCC waste generation around the year 2020 is only about 6,000 cubic feet per year. As suggested in Figure 2, the disposal costs for a near-surface facility with a capacity of only 6,000 cubic feet per year could be significantly more than $120 per cubic foot due to its smaller size. These preliminary cost figures are summarized in Table 5.

Figure 2.-Near-Surface Disposal Coats for a Range of LLR Volumes (calculated using the EG&G economic model for a 30-year facility)



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[34] **This figure is substantially higher than** the generation **rate today because** of **waste** 'hat 'iii come from decommissioning and refurbishing of nuclear power reactors.

Table 5. Preliminary Estimates of GTCC Waste Disposal Costs

Disposal technology	Estimated cost *
Yucca Mountain repository (assuming tight packing of waste)	$ 90/ft^3 [a]
Separate near-surface facility	$ 120/ft^3 [b]

* The disposal costs for both of these options will probably be higher than those indicated above. Repository disposal costs, which are still being developed by DOE, probably do not include the full range of operating costs. Unit disposal costs for using a separate facility for GTCC waste could be significantly higher due to its intermediate depth, its small size, and other additional operational costs for handling highly radioactive GTCC waste.

Source:
[a] C. Conner, DOE, personal communication, May 1988.
[b] EG&G Idaho, Inc., "Costs and Consequences of Site proliferation: per Unit Disposal Costs," Low-Level Radioactive Waste Forum, Toronto, July 1988, unpublished conference notes;

The preliminary calculations provided above indicate that the costs of GTCC waste disposal in the Yucca Mountain repository could be comparable to, or perhaps even less than, costs associated with developing a smaller, separate disposal facility only for GTCC waste. The level of long-term isolation provided by the Yucca Mountain repository would also presumably be as great or greater than the isolation provided by an "intermediate-depth facility.

D. Institutional Considerations in Choosing a Disposal Option

A disposal facility for GTCC waste could, theoretically, either be developed and operated by a non-Federal entity or by the Federal Government. For several reasons, it does not appear likely that a non-Federal entity would be interested in developing and operating such a facility. As mentioned earlier, DOE plans to issue a notice in the Federal Register to determine whether any such non-Federal interest exists.

It is possible, though unlikely, that a State or regional Compact would accept GTCC waste for disposal. During the Presage of the LLRWpAA, States argued that the Federal Government should take responsibility for GTCC waste because of the long-term risks associated with much of the waste. In fact, one State opposed taking responsibility for Class C LLW.[36] Thus, States would probably not be interested in developing a separate disposal facility

35 The Low-Level Radioactive Waste policy Act of 1980 and the Low-Level Radioactive Wrote Policy Amendments Act of 1985 encouraged States to form multi-state Compacts with each Compact region hosting one disposal facility. States that have not joined a Compact may be planning to host a facility only for waste generated in their State. Economically, some States and Compacts may have difficulty supporting their facilities, given the 50 percent decrease in volume of LLW shipped for disposal over the last 7 years. It is, however, unclear whether the economic gain from disposing of such a small amount of waste would outweigh the added risks.

36 Representative Kostmeyer from Pennsylvania introduced an amendment to the Low-Level Radioactive Waste Policy Amendments Act of 1985 to transfer the responsibility of Class C

for GTCC waste. It is unlikely that they would be interested in accepting GTCC waste at an existing or planned near-surface LLW disposal facility, which would probably not provide adequate long-term isolation for much GTCC waste.

Private companies are also unlikely to be interested in independently developing and operating a GTCC waste disposal facility without Federal sponsorship. In addition to the inevitable political difficulties associated with siting and potential delays with licensing such a facility, private industry may have considerable concerns about potential long-term liability of holding title to waste that remains hazardous for a few thousand years. The fact that a commercial waste disposal facility for GTCC waste has never been constructed or licensed would make such a business venture extremely risky.

Given the increasing difficulty in siting nuclear waste facilities, it is unlikely that the Federal Government, presumably DOE, would choose to develop a new, separate facility for GTCC waste. **At this time, the most likely disposal option appears to be the Yucca Mountain repository. Congress, the DOE, and the State of New Mexico have agreed that** the WIPP facility will be only for defense waste, and defense facilities are not licensed by the NRC. The LLRWPAA of 1985 explicitly requires GTCC waste, which is commercial waste, to be disposed of in a NRC-licensed facility.

If DOE decides to dispose of GTCC waste in the Yucca Mountain repository, the State of Nevada will likely object to GTCC waste being funneled into this disposal facility. Furthermore, if fees for GTCC waste disposal in the Yucca Mountain repository are comparable to, or less than, disposal fees for Class C waste at commercial near-surface disposal sites, waste generators would have an incentive to compact Class C waste such that its radioactivity were increased to GTCC levels. In addition, it is still unclear how the country will dispose of GTCC defense waste that is not transuranic. “

It could be argued that the National Environmental Policy Act of 1970 (NEPA) would require an evaluation and comparison of alternatives prior to selecting a disposal option. Such a process normally involves balancing costs and benefits associated with a particular project or a major Federal action. In most cases, environmental and public health and safety risks associated with projects can be decreased by adding features to the project that would increase its development costs. The situation involving GTCC waste disposal, however, appears to be quite different. From a public health and safety standpoint, it is highly unlikely that any disposal alternative would provide more isolation than the Yucca Mountain repository. It also appears unlikely that a small, separate GTCC waste disposal facility of any type would be as economical as the repository.

E. Summary

From a public health and safety standpoint, deep-geologic repositories are likely to provide the greatest isolation of GTCC waste based on information available today. In fact, repository disposal is believed to be sufficient for isolating spent fuel which is many times more dangerous than GTCC waste. Since the projected volume of GTCC waste would probably occupy much less than 1 percent of the planned Yucca Mountain repository, this option would

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waste to the Federal Government.

[37] prior to May 1986, DOE had plans to develop a second repository in the East. DOE Secretary, Herrington, postponed these plans, arguing that volumes of spent fuel and defense HLW were insufficient to justify two repositories. This decision also defused a great deal of political opposition associated with this siting program.

likely be less expensive than developing a small, separate facility for only GTCC waste using ~ technology. Institutionally, using the Yucca Mountain repository would eliminate having to site, develop, and license a new separate disposal facility for GTCC waste.

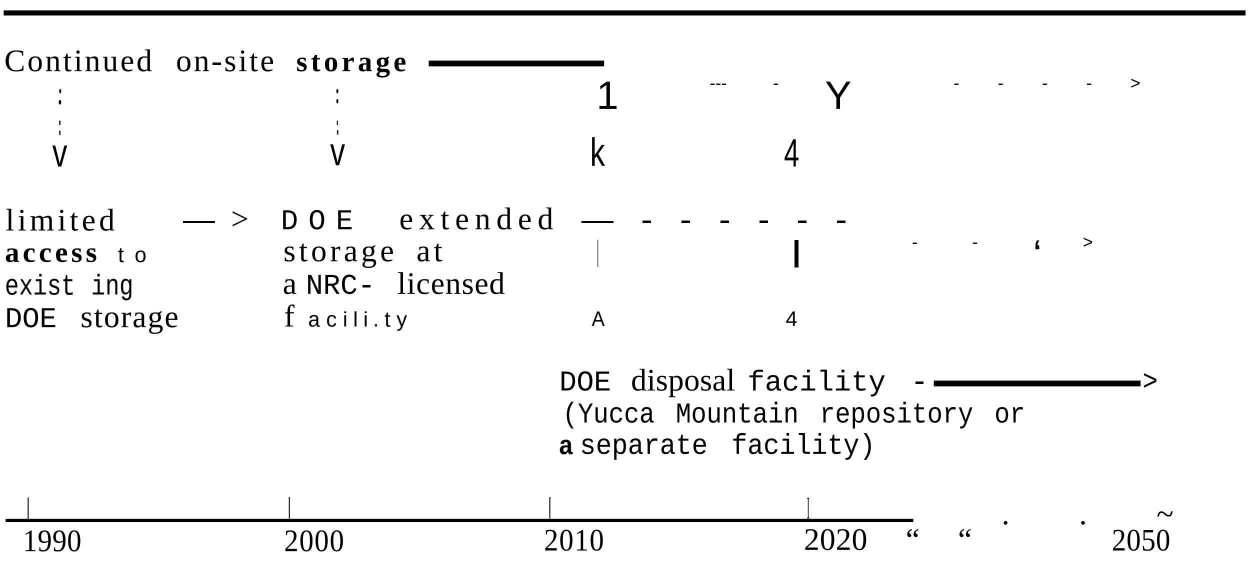
If a decision about the GTCC waste disposal were required today, permanently isolating GTCC waste in a deep-geologic repository would be an acceptable option. It is possible, however, that further research of alternative disposal technologies could indicate that an intermediate-depth disposal facility used only for GTCC waste (e.g., augered holes) would provide an acceptable level of isolation. DOE could spend the next couple of years evaluating the impacts associated with disposing of GTCC waste in the Yucca Mountain repository on the repository's overall operation and performance. If this disposal option proved to be acceptable from an environmental, economical, and institutional standpoint, DOE could use the Yucca Mountain repository asaba,sis in designing its GTCC waste management approach. If this option proved to be unacceptable, DOE could then evaluate other disposal technologies. Making a disposal decision will help resolve many storage uncertainties and enable necessary guidance and regulations to be developed.

Chapter 4

A MANAGEMENT APPROACH FOR GTCC WASTE

As indicated in the previous chapters, GTCC waste **will have to be stored for at least 15 to 20 years while a** disposal facility is being developed. **Many large generators will probably store GTCC waste on-site; some generators, especially small ones, claim that they will exhaust their on-site storage capacity and that this capacity cannot be expanded. Off-site storage for an extended period** could be available in several years at an NRC-licensed, DOE storage facility. While such a facility is being developed, GTCC waste generators could be given limited access to an existing unlicensed DOE storage facility on a case-by-case basis, determined by DOE or NRC. Once the extended-storage facility is available, all GTCC waste in limited-access storage could be transferred to it. Figure 3 portrays this integrated management approach.

Figure 3. A Management Approach for GTCC Waste



Source: OTA

If the above approach for managing GTCC waste over the next two decades is implemented, then the Federal Government needs to make several decisions and undertake many activities regarding storage, disposal, and funding. These decisions and activities are summarized in the following discussion. The sequence and minimum timing of these activities are further developed in Appendix D.

Limited-Access Storage

During the next several years while an extended storage facility is being developed, DOE could provide limited access to an existing, unlicensed, storage facility at one of its national laboratories. This would reduce the potential for GTCC accidents, especially those involving sealed sources, and ensure adequate storage capacity for those generators who do not have adequate on-site storage capacity for their GTCC waste. DOE and/or NRC could determine technical criteria for accepting GTCC waste; DOE, NRC, and possibly Congress could establish additional technical and non-technical specifications (e.g., waste volume limits, generator eligibility, and a decision on fee subsidization). DOE could then estimate the required storage capacity as well as storage costs prior to adapting one of its existing facilities.

State concerns about the permanence of such a facility could be allayed by requiring that any GTCC waste in limited-access storage be moved to the extended storage facility when it becomes available.

Extended Storage

DOE's estimate of the time required to develop an acceptable disposal facility for GTCC waste will indicate the time that this waste will have to remain in storage. NRC and/or DOE could then determine performance objectives and technical criteria for waste packaging and extended storage. DOE, NRC, and possibly Congress could establish non-technical specifications on use of this facility, as were made for the limited-access storage facility. With this information, DOE could better design the extended-storage facility and determine storage costs. Considering the probable uncertainties in waste volumes that will require off-site storage, a modular storage facility could be incrementally developed as storage needs become more apparent.

Disposal

If a decision about the disposal of GTCC waste were required today, permanently isolating GTCC waste in a deep-geologic repository would be an acceptable option. It is possible, however, that further research of alternative disposal technologies could indicate that an intermediate-depth disposal facility used only for GTCC waste would provide an acceptable level of isolation. Such research could commence in a couple of years if DOE determines that GTCC waste disposal in the repository would produce unacceptable environmental or institutional impacts or would be more expensive than other disposal alternatives.

Funding Mechanisms

The LLRWPAA of 1985 states that the beneficiaries of the activities generating GTCC waste should bear all reasonable costs associated with its disposal. Since GTCC waste cannot be disposed of immediately, it could be argued that the beneficiaries should also bear the cost of pre-disposal management. However, there are some who argue that the delays in selecting a disposal option, which make GTCC waste storage necessary, are the fault of the Federal Government even though the Federal Government was made responsible for GTCC waste disposal only in 1985. When, how, and how much money is collected from generators for the disposal of their GTCC waste may depend in part on when the waste is accepted for storage and/or disposal. Funding mechanisms are discussed below for several groups of GTCC waste generators.

For waste accepted for limited-access storage, estimated costs for extended storage and disposal could be collected at the time of waste acceptance. Given the current uncertainties about disposal costs, however, acceptance fees could be quite high if full-cost recovery is a primary goal. Unreasonably high costs would discourage the use of the limited-access facility, yet some waste generators may need use of it to protect public health and safety; unrealistically low costs would leave the Federal Government with an obligation to pay the balance of future disposal costs.

Alternatively, an initial fee for limited-access storage could be collected when GTCC waste is accepted for storage. Once a disposal option is chosen and the costs of extended storage and disposal are better known, a second fee could be calculated. This second fee could be collected when GTCC waste in limited-access storage is transferred to the extended storage-facility.

Utilities, which generate about 60 percent of all GTCC waste, will probably be able to develop sufficient on-site storage capacity for this waste to last until a disposal facility is available. If the Yucca Mountain repository were chosen as the disposal facility for GTCC waste, utility fees paid into the Nuclear Waste Trust Fund could be increased to cover GTCC **waste disposal costs.**

Due to the problems associated with controlling the fate of many thousand sealed sources, it may be desirable to add a materials management fee into the initial cost of all sealed sources. This type of arrangement could be used for sealed sources sold after disposal costs have been estimated (within the next several years). When the user is finished with a source, this fee could be partially or entirely refunded depending on the costs that would be required to subsequently manage the source. If the source could be recycled, the user would receive a larger refund. This type of “deposit-return” funding arrangement would encourage the proper management and disposal of sealed sources.

For all other non-utility GTCC waste or GTCC material now in use, including sealed sources, waste management fees could most easily be collected in one lump sum or in periodic installments when the waste is accepted for extended storage and/or disposal by the Federal Government. Collecting “deposit-return” management fees prior to waste acceptance may be more difficult, but not impossible, due to the large number of present generators. As with limited-access storage, unless extended-storage and disposal fees are reasonable, waste generators may delay transferring their waste to a waste management facility, which could jeopardize public health and safety. Furthermore, if a waste generator goes out of business before its GTCC waste has been stored or disposed, the Federal Government may have to accept the waste and pay for its storage and subsequent disposal in order to maintain public health and safety.

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APPENDICES

Appendix A. Types of Radioactive Waste

The following types of radioactive waste are differentiated by the nature and intensity of the emitted radiation, as well as their physical and chemical form. They are listed roughly in order of decreasing risk to humans.

Spent fuel consists of fuel rods that have been "burned" (irradiated) uncommercial, defense, or research nuclear reactors to the point where they no longer contribute efficiently to the nuclear chain reaction. Spent fuel is thermally hot, highly radioactive, and requires heavy shielding. Commercial spent fuel is being stored at nuclear power plants pending the availability of a Federal monitored retrievable storage facility or a deep-geologic repository for disposal

High-level waste (HLW), as the term is used in this report, is generated when spent fuel is reprocessed to recover plutonium and unused uranium. The vast majority of HLW in this country has been generated in support of national defense programs. HLW is highly radioactive, generates some heat, and requires heavy shielding. Most HLW is now stored at Richland, Washington; Aiken, South Carolina; and Idaho Falls, Idaho pending availability of a deep-geologic repository.

Transuranic (TRU) waste is produced from the production of plutonium for nuclear weapons, from the manufacturing of sealed radioactive sources, and from the refurbishing or decommissioning of nuclear power plants. Transuranic waste contains radionuclides that have atomic numbers greater than 92, which is uranium. Defense TRU wastes are currently being stored at seven DOE national laboratories pending disposal in a deep-geologic repository called the Waste Isolation Pilot Project (WIPP), located near Carlsbad, New Mexico. Commercial transuranic waste is defined as low-level radioactive waste. If the concentration of transuranic radionuclides is greater than 100 nanocuries per gram, the waste is greater- than-Class-C low-level radioactive waste.

Low-level radioactive waste (LLW) includes radioactive waste not classified as uranium mill tailings, high-level waste, or spent fuel. About 95 percent of all LLW -- Class A -- has relatively low levels of radioactivity. Class A waste remains hazardous for about 100 years, Class B and C waste remains hazardous for a few hundred years, while GTCC waste remains hazardous for a few hundred to a few thousand years.

Uranium mill tailings are the earthen residues -- coarse sand and a "slime" of clay-like particles -- that remain after extracting uranium from mined uranium ore. These tailings contain low concentrations of radioactive material, but tailing volumes are very large.

Byproduct Material is material contaminated or made radioactive during the **production or use of special nuclear material.**

Source: Adapted from the League of Women Voters Education Fund, 1985

Appendix B. Definitions

Curie: A measure of the rate of radioactive decay essentially equal to the radioactivity of one gram of radium. A microcurie is one millionth (or 10^{-0}) of a curie. A nanocurie is one billionth (or $1O^{-g}$) of a curie.

Half-life: Time required for a radioactive substance to lose 50 percent of its radioactivity by decay. For example the radioactivity of cobalt-60 with a half-life of 5.3 years will drop by one-half in 5.3 years.

Ion-exchange resins: Sand-like materials that chemically remove radionuclides from wastewater and concentrate them in a solid form.

Isotope: Isotopes are different forms of the same chemical element, having different numbers of neutrons but the same number of protons in the nucleus of their atoms. A single element may have many isotopes. For example, umnium naturally appears in three forms: uranium-234 (142 neutrons), uranium-235 (143 neutrons), and uranium-=238 (146 neutrons); each uranium isotope has 92 protons.

Radiation: Radiation is emitted in the form of alpha particles, beta particles, gamma rays, or x-rays -- each affecting human health differently. For example, alpha particles cannot penetrate a person's skin, therefore can only harm a person if inhaled or ingested. Gamma rays, in contrast, can pass through a person's body.

Radioactivity: The spontaneous emission of radiation from the nucleus of an atom.

Radionuclide: Any species of atom whose nucleus emits radiation. Transuranic radionuclides have an atomic number greater than 92 (uranium).

Sealed sources: Sealed sources are sources of radiation that contain granules of radioactive material typically sealed inside double-walled, stainless steel capsules. Large sources can measure up to 20 inches long and 2 inches in diameter, but generally are about 3 inches long and 0.5 inch in diameter. Sealed sources are primarily used in industrial and medical applications (e.g., density and moisture gauges, well logging sources, and radiotherapy machines).

Waste form: Waste form is the matrix in or on which radionuclides are contained. The waste from of GTCC waste maybe metal, ceramic, paper, etc.

Source: Adapted from the League of Women Voters Education Fund, 1985

Appendix C. Decommissioning of Nuclear Power Plants

Although most nuclear power plants are licensed by NRC to operate for 40 years, there is no absolute age at which they become unsafe or uneconomical to operate. In fact, it may be possible to economically refurbish and extend the operating lifetime of many reactors by replacing aging internal components (EPRI, 1987). Once a plant has been shut down, it can be decommissioned (e.g., dismantled) within a few years, placed in safe storage for 30 to 50 years prior to decommissioning, or permanently entombed (NRC, 1981). Reactor refurbishing will probably generate about the same amount of GTCC waste as "plant decommissioning.

There are two reasons for delaying decommissioning once a reactor has been shut down. First, the overall radioactivity of the LLW from decommissioning (at least 95 percent of which is contributed by GTCC waste) will decrease by 30 to 45 times, if decommissioning is deferred five decades (see Table 6). Deferral could therefore reduce worker risks and decrease dismantling costs. **Second,** the volumes of Class **A,** B, and C LLW generated from immediate decommissioning (97% of which is Class **A** waste) can be reduced by about 10 times if decommissioning is deferred five decades, thereby significantly decreasing LLW disposal costs unless these costs rise dramatically over this time (See Table 6).

Table 6. Effects of Delayed Decommissioning on the LLW
Generated by Commercial Nuclear Power Plants

Plant type [1.175 GW(e)]	Radioactivity of all LLW in thousands of curies		
	No delay	30-year delay	50-year delay
Boiling-water	6,600	180	140
Pressurized- water	4,900	210	160
	Volume of all LLW in thousands of cubic feet		
	No delay	30-year delay	50-year delay
Boiling-water	670	670 *	60 ●
Pressurized- water	630	630 *	65 *

* Includes wastes from both preparation for SAFESTOR and decommissioning.

Source: U.S. Department of Energy, "Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics," DOE/RW-0006, Rev. 3, September 1987, p. 279.

For these reasons, many of the existing 110 nuclear plants, especially the 71 plants that are co-located with other units, could likely be placed in "SAFESTOR" for 5 decades prior to decommissioning. It is not clear, however, that decommissioning of all nuclear plants will be deferred. If costs for LLW disposal continue to rise as they have over the last 15 years, it may be more economical to immediately decommission some plants. Older plants (i.e., constructed prior to 1970) without well-documented designs and plants that are not co-located with multiple units may require decommissioning before plant engineers are reassigned or retired.

The NRC issued its final rule on decommissioning nuclear facilities in June 1988 (53 Federal Register 123).

Appendix D. Possible Schedule for Managing GTCC Waste

The following tight schedule lists possible activities that may be needed to manage GTCC waste. These activities are listed generally in the sequence in which they would occur. Even if the activities actually take longer than indicated here, the relationship among them should generally remain the same. If any activity requires additional time to complete, the remaining activities will have to be delayed the same amount of time.

	Minimum time in years
	0 1 2 3 4
Disposal	
DOE evaluates the technical, economic, and institutional advantages and disadvantages associated with: 1) disposing of GTCC waste in the Yucca Mtn. repository, or 2) developing a separate intermediate-depth facility.	
DOE **decides either to use the Yucca Mtn. repository, or to further evaluate intermediate-depth disposal options.**	
DOE estimates disposal fee.	
DOE finalizes disposal fee.	year **7**

Storage continued on the following pages.

	Minimum time in years 0 1 2 3 4
Extended-storage regulatory guidance: (regardless of disposal option chosen)	
NRC reviews storage technologies and analyzes its storage guidance.	
DOE develops estimates of storage time until disposal.	
NRC drafts preliminary revisions of added guidance for GTCC waste packaging and storage.	
NRC finalizes guidance.	**year 3**
DOE extended-storage facility: (assuming NRC licensing)	
Congress mandates development of NRC-licensed facility.	
DOE/NRC determine general technical criteria for accepting GTCC waste.	
DOE estimates storage fee and facility capacity.	
DOE, NRC, and possibly Congress determine non-technical specifications for facility use (e.g., waste volume limits, generator eligibility, and a decision on fee subsidization).	
DOE designs facility.	
DOE sites facility.	
DOE constructs facility.	years 4 and 5
NRC grants operating license.	year 6
DOE finalizes storage/repackaging/disposal fee.	year 7
DOE begins accepting waste and extended storage/disposal fee.	year 7 to year 20

Minimum time in years

	0 1 2 3 4
Limited-access storage at **existing DOE facility:**	
Congress mandates DOE to provide limited-access storage, and expresses intention to transfer waste in limited-access storage to an extended-storage facility.	
DOE/NRC determine technical criteria for accepting GTCC waste.	
DOE estimates required storage capacity.	
DOE estimates fee for limited-access storage.	
DOE, NRC and possibly Congress determine non-technical specifications for facility use (e.g., waste volume limits, generator eligibility, and a decision on fee subsidization).	
DOE adapts existing facility.	
DOE finalizes limited-access storage fee.	
DOE accepts waste and collects fee for limited-access storage	**year 2 to year** 7
Waste is transferred to extended-storage facility and an additional fee is collected for extended storage/repackaging/disposal.	year **7**
Other:	
Congress considers additional controls on the distribution and/or use of sealed sources	