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Rob P. Rechard, Janis R. Trone, Elena A. Kalinina,
Yifeng Wang, Teklu Hadgu, Lawrence C. Sanchez
Sandia National Laboratories

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Rob P. Rechard, Janis R. Trone, Elena A. Kalinina,
Yifeng Wang, Teklu Hadgu, Lawrence C. Sanchez
Nuclear Energy & Fuel Cycle Programs Center 8840
Sandia National Laboratories
Albuquerque, NM 87185-0747

Abstract

The experimental breeder reactor (EBR-II) used fuel with a layer of sodium surrounding the uranium-zirconium fuel to improve heat transfer. Disposing of EBR-II fuel in a geologic repository without treatment is not prudent because of the potentially energetic reaction of the sodium with water. In 2000, the US Department of Energy (DOE) decided to treat the sodium-bonded fuel with an electrorefiner (ER), which produces metallic uranium product, a metallic waste, mostly from the cladding, and the salt waste in the ER, which contains most of the actinides and fission products. Two waste forms were proposed for disposal in a mined repository; the metallic waste, which was to be cast into ingots, and the ER salt waste, which was to be further treated to produce a ceramic waste form. However, alternative disposal pathways for metallic and salt waste streams may reduce the complexity. For example, performance assessments show that geologic repositories can easily accommodate the ER salt waste without treating it to form a ceramic waste form. Because EBR-II was used for atomic energy defense activities, the treated waste likely meets the definition of transuranic waste. Hence, disposal at the Waste Isolation Pilot Plant (WIPP) in southern New Mexico, may be feasible. This report reviews the direct disposal pathway for ER salt waste and describes eleven tasks necessary for implementing disposal at WIPP, provided space is available, DOE decides to use this alternative disposal pathway in an updated environmental impact statement, and the State of New Mexico grants permission.

Acknowledgements

Safely managing and radioactive waste is the priority, yet this management is expensive. The direct disposal of electrorefiner salt a transuranic waste is a possible path to reduce costs and maintain or even increase safety when treating sodium bonded reactor used fuel; however, much work must be done before this pathway can be considered as an alternative to the current pathway of disposing electorefiner salt waste as a ceramic waste form. This report lists the major tasks to complete to help understand whether the pathway is viable. Developing a task roadmap is not meant to imply that the alternative has been chosen. This work was guided by Michael Patterson and Steve Frank at the Idaho National Laboratory.

Executive Summary

Several experimental reactors, including the experimental breeder reactor (EBR-II), operated with fuel that use a layer of metallic sodium and layer of cladding surrounding the uranium-zirconium metallic fuel to improve heat transfer. Directly disposing of the used fuel from these reactors without treatment in a geologic repository is not prudent because of the potentially energetic reaction of the sodium metal with water to produce hydrogen gas and sodium hydroxide. Hence, the US Department of Energy (DOE) decided in 2000 to treat the EBR-II sodium-bonded using an electrorefiner (ER), which produces metallic uranium. The two waste forms are a metallic waste, mostly from the cladding, and the salt in the ER, which contains most of the transuranic elements and fission products. For disposal in a mined repository, the metallic waste was to be cast into ingots and the salt waste further treated to produce a ceramic waste form. However, examining the direct disposal of ER salt waste (without treating it to form a glass ceramic) is desirable because of the large increase in the volume of ER salt waste when producing a ceramic waste form, the complexity of creating the ceramic waste form, the limited space in the hot cell to accommodate the equipment, the inability to use the hot cell for other experiments while treating the waste over many years, and the *de facto* stoppage of the nation's first proposed mined repository in volcanic tuff at Yucca Mountain, Nevada.

Assessments of the performance of the ER salt waste in a salt repository or deep borehole in crystalline rock show that the ER waste can easily be accommodated without additional treatment. Because of this demonstrated feasibility of direct disposal, the primary focus is now on the feasibility of transporting this ER salt waste to a repository.

Three pathways exist for directly disposing the ER salt waste: (1) disposal at a commercial or defense-only mined repository, (2) disposal at the Waste Isolation Pilot Plant (WIPP) as defense related transuranic (TRU) waste, and (3) disposal in a deep borehole. The currently proposed size of the handling container offers the flexibility to be disposed via any of the three pathways.

This document reports on the feasibility of the second disposal option using WIPP. Eleven primary tasks to complete before disposal at WIPP can be implemented are

1. Document that the waste is TRU and of defense origin
2. Request NMED modify the WIPP Hazardous Waste Facility Permit to approve EBR-II ER salt waste disposal
3. Document packaging schemes for shipping ER salt waste to WIPP
4. Update the environmental impact statement (EIS) on EBR-II salt waste disposition
5. Develop overall quality assurance (QA) program for EBR-II ER salt waste and obtain Carlsbad Field Office (CBFO) approval
6. Develop waste characterization program to meet requirements of WIPP waste acceptance criteria (WAC) and obtain CBFO approval
7. Develop and obtain CBFO approval of transportation program for EBR-II ER waste that includes QA plan, packaging plan, and modification of either contact-handled (CH) or remote-handled (RH) TRU waste authorized methods for payload control (TRAMPAC)
8. Update performance assessment (PA) to show no material changes
9. Certify the characterization, QA, and transportation programs through CBFO Certification Audit
10. Implement program by assembling acceptable knowledge document and waste stream profile form, and obtain CBFO approval of documents
11. Package EBR-II ER salt, obtain CBFO approval, and ship.

The first task involves describing the ER waste form, documenting its defense origin, and documenting that it meets the definition of TRU waste to the satisfaction of CBFO.

The second task is for CBFO to ask for and receive disposal approval from the New Mexico Environment Department (NMED) through a modification to the WIPP Hazardous Waste Facilities Permit. Even though ER salt waste is of defense origin, meets the definition of TRU waste, and has a TRUCON code assigned, it has been managed as high-level waste, and thus requires NMED approval.

The third task is to document packaging schemes for shipping ER salt waste to WIPP. Two different shipping options are possible. One option is to ship using the TRUPACT-II truck cask. A second option is to ship using the RH-TRU 72-B truck cask.

The fourth task is to update the EIS supporting the record of decision to treat the EBR-II used fuel. This task could be concurrent with the first three tasks. The purpose of update is to (1) designate the EBR-II ER salt waste as defense TRU waste, (2) discuss the advantages of the WIPP disposal pathway versus other disposal pathways, and (3) discuss environmental impacts of options for shipping waste to WIPP.

The next two tasks are to develop a QA program and characterization program. These two tasks can build upon the QA and waste characterization program already existing at INL for mixed TRU waste currently shipping CH-TRU and RH-TRU waste to WIPP (i.e., Advanced Mixed-Waste Treatment Program—AMWTP and Idaho Nuclear Technology and Engineering Center—INTEC, respectively).

The seventh task is to develop and obtain approval of a transportation program for EBR-II salt waste. Shipping using the TRUPACT-II truck cask would require either diluting the ER contaminated salt prior to placement in the currently proposed primary salt contain (PSC) or develop a small PSC that will hold between 4 and 8 kg of ER salt waste. Between 200 and 400 PSCs would be produced. This option would also require developing an overpack for use in 55-gallon drums and amending the certificate of compliance issued by the US Nuclear Regulatory Commission (NRC) for the TRUPACT-II cask.

Shipping ER salt waste using the RH-TRU 72-B truck cask, would require amending the NRC Certificate of Compliance for the RH-TRU 72-B cask to allow (a) higher fissile amounts in a payload container, and (b) ~90 W heat loads for the 36 payload canisters containing the Mark IV ER salt waste for disposal in 2023 (Figure 1). The ER salt waste can easily be shown to be far below any criticality concern because of the chlorine based salt regardless of the dimensions.

The current heat limits in the WIPP WAC and CH and RH TRAMPACs are to avoid producing gases from organics that may be in the waste. However, ER salt waste is noncombustible without organics; hence, the heat limits could be safely revised for transporting ER salt waste.

Also, the payload canister for the RH-TRU 72-B cask would easily accommodate ER salt waste provided additional radiation protection is added to the proposed packaging using dunnage and possibly metallic shielding.

The eighth task is to update the PA supporting the WIPP Certificate of Compliance with regulations of the US Environmental Protection Agency (EPA). PA analysis conducted in previous years has shown the ability of a salt repository to accommodate the moderately warm ER salt waste. However, WIPP specific PA codes must be run to provide the basis that ER salt waste does not materially alter the safety case for WIPP after closure.

The exact heat load would depend upon how long the ER salt waste cooled prior to shipment, but the total heat could be as large as 3 kW if shipped soon after ER treatment (originally projected to conclude in 2023). The 3 kW in ER salt waste represents an increase of only 2%, above the ~136 kW originally projected for disposal of CH and RH-TRU waste. A 2% increase in heat would be difficult to detect in a performance assessment of the behavior of the waste at WIPP.

The final three tasks are to certify and implement the program.

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Nomenclature

AMWTP Advance Mixed Waste Treatment Program

CBFO DOE Carlsbad Field Office at WIPP

CFR Code of Federal Regulations

CH Contact Handled (TRU)

CWF Ceramic Waste Form

DOE US Department of Energy

EBR-II Experimental Breeder Reactor at INL second generation

EBS Engineered Barrier System

EIS Environmental Impact Statement

EPA US Environmental Protection Agency

ER Electrorefiner

FCF Fuels Conditioning Facility

FFTF Fast Flux Test Reactor

FGE Fissile Gram Equivalent

HEU Highly Enriched Uranium

HFEF Hot Fuels Examination Facility

HLW High-Level (radioactive) Waste

HWFP Hazardous Waste Facility Permit issued by State of New Mexico

INL Idaho National Laboratory

INTEC Idaho Nuclear Technology and Engineering Center

MTHM Metric Ton Heavy Metal

MWF Metal Waste Form

NBS Natural Barrier System

NMED State of New Mexico Department of the Environment

NRC US Nuclear Regulatory Commission

PA Performance Assessment

PSC Primary Salt Container

QA Quality Assurance

RH Remote Handled (TRU)

RH-TRUCON – RH-TRU Content (code)

RH-TRU 72-B Remote-Handled TRU Transport Cask Model 72-B

SAR Safety Analysis Report

SNF Spent Nuclear Fuel

TRAMPAC TRU Waste Authorized Methods for Payload Control

TRU Transuranic (waste)

t Metric Ton

TRUPACT-II Transuranic Package Transport Cask Model 2

WAC Waste Acceptance Criteria

WIPP Waste Isolation Pilot Plant in southern New Mexico

Roadmap for Disposal of Electrorefiner Salt Waste as Transuranic Waste

1 Introduction

The US Department of Energy (DOE) currently stores 60 metric tons of heavy metal (MTHM) of used fuel with a layer of metallic sodium (Na) and a layer of cladding (usually stainless steel) surrounding a uranium-zirconium metallic fuel. In 2000, DOE decided to treat 26 MTHM of the Na-bonded used fuel with an electrorefiner (ER), which forms a metallic uranium product. The two waste forms are a metallic waste, mostly from the cladding, and the salt in the ER, which contains most of the actinides and fission products.[1; 2] For disposal in a mined repository, the metallic waste was to be cast into ingots and the salt waste further treated to form a ceramic waste form. However, examining the direct disposal of the ER salt waste is prudent because of the substantial increase in volume of ER salt waste caused by treatment, the complexity of creating the ceramic waste form, the limited space in the hot cell to accommodate the equipment, the inability to use the hot cell for experiments during treatment, and the *de facto* stoppage of the nation's first repository at Yucca Mountain, Nevada.

The following discussion provides background on previous studies. Chapter 2 provides background on the various pathways to disposal of ER salt waste. Chapter 3 presents a roadmap for direct disposal.

1.1 Past Direct Disposal Studies

Evaluation of the direct disposal of ER salt in a salt repository was initiated in FY10. In FY11 and FY12, work focused on laboratory studies of salt waste dissolution in simulated salt repository brines.[3] In FY13, a performance assessment (PA) was performed for ER salt waste disposal in a salt repository without any other waste. In FY14, the PA of the salt repository included a detailed thermal analysis, and disposal of ER salt waste with commercial spent nuclear fuel (SNF) and DOE-managed HLW. Also, in FY14, a criticality analysis related to transportation and disposal was initiated.[4] In FY15, the analysis shifted to the feasibility of deep borehole disposal and corresponding criticality analysis.

Specific analysis for disposal in a mined repository in clay/shale or crystalline rock has not occurred, but it can be surmised that the disposal clay/shale would be similar to that in salt. Provided a sufficiently robust package was used, direct disposal of ER salt waste in crystalline rock would also likely be viable but subject to verification.

These performance assessments verify the usual adage that if SNF, high-level radioactive waste (HLW), and transuranic (TRU) waste can be transported, it can be disposed in a repository under US regulations, provided social-political limitations on the type and amount of waste are met.

1.2 Current Focus

Because ER salt waste performance has been shown to be generally acceptable, at least in a generic salt repository and deep borehole, the focus of the direct disposal in FY16 and FY17 shifted to the feasibility of transporting ER salt waste to a repository.

Thus, the more important question is what distinguishes ER waste from other SNF, HLW, and TRU waste. In general, no known distinguishing characteristics of ER waste would make transportation difficult. The thermal load is like most other DOE-managed HLW canisters and less than commercial SNF. The plutonium content is higher than typical TRU waste drums, and DOE-managed HLW canisters (i.e., ~5 kg ^{239}Pu) but Pu would be uniformly dispersed in chloride salt in an ER waste package).

A more practical question, then, is the feasibility of placing the ER salt waste in containers that are sized such that they can be easily filled and moved out of the hot cell using current hardware, yet, are containers likely to be directly transportable and disposable sometime in the future.

1.3 Implications of Direct Disposal

Electro-chemical processing was developed for treating the Na-bonded EBR-II used fuel in the current once-through, open nuclear fuel cycle.[2] But its use is far more general and could have great promise for treating other DOE-managed SNF. It could also be used for recycling actinides for use in either thermal or fast neutron spectrum reactors in order to develop a closed nuclear fuel cycle in the US.[3]

Yet, for this technology to succeed in the US, a path forward for disposition of the resulting ER salt waste must be developed. Encapsulating the ER salt waste in a ceramic waste form has certainly been demonstrated, but the complexity of the treatment, which must be executed remotely in a hot cell, and the substantial volume increase, diminishes the simplicity of the electro-chemical treatment. Direct disposal of the ER salt waste provides a simple deposition pathway.[3]

2 Disposal Pathways for ER Salt Waste

2.1 ER Salt Waste

DOE has 3.0 MTHM of driver used fuel, 0.22 MTHM of experimental driver used fuel, and 22.6 MTHM of blanket used fuel from the experimental breeder reactor (EBR-II) at Idaho National Laboratory (INL). DOE also has 0.25 MTHM driver used fuel from the experimental Fast Flux Test Reactor (FFTF) at Hanford, for a total of 25.89 MTHM.[2]

Both the highly enriched uranium (HEU) metal-zirconium alloy driver and blanket fuel is surrounded by metallic Na for heat transfer and stainless-steel cladding. The breeder experiments mostly ended by the end of the 1960s. Thereafter, the reactors were used for other atomic energy defense activities.

In 2000, DOE decided to treat the Na-bonded fuel using two electrorefiners (ER),[1; 2] located in the Fuel Conditioning Facility (FCF) hot cell at INL, prior to disposal because of the energetic reaction of the Na metal with water to produce hydrogen gas and sodium hydroxide. The Mark-IV ER treats the driver used fuel. The Mark-V ER treats the blanket used fuel.

In ER treatment, a batch of chopped used fuel is placed in anode metal baskets and immersed in a 500 ^{o}C molten LiCl-KCl salt near its eutectic concentration. When current is passed through the ER, active metal fission products and TRU elements dissolve as chlorides. Uranium is reduced to its metallic form and accumulates on the cathode. The ~24.8 MTHM of uranium is to be recovered, diluted to ~19% enrichment, and cast into 30-kg ingots.

The irradiated cladding and most of the zirconium in the driver U-Zr used fuel remains in the anode basket. The noble fission products also remain with the anode basket such as ^{93}Nb, ^{99}Tc, ^{107}Pd, ^{126}Sb, ^{126}Sn, and Rh, Ru, Te, and Ag. Existing metallic waste has been cast into 3 circular ingots in the furnace currently operating since 2012. This metal waste form (MWF) is to be placed in HLW canisters for disposal (~5.85 metric tons—t or 145 40-kg ingots from processing 25.89 MTHM of Na-bonded used fuel) (Figure 1).

The active metal fission products and TRU elements (except most of the uranium), remains in the molten LiCl and KCl eutectic salt in each ER as per DOE operation requirements. It is feasible to recover TRU elements using a secondary cathode, if found to be advantageous. However, separation of the Pu raises storage and safeguard issues.

The ER salt must be removed when operations are completed. The salt will also be replenished at other times. For the Mark V, which treats the blanket fuel, the salt in the ER would be replenished after 39.77 kg of Pu accumulates in the ER to avoid criticality concerns from ^{239}Pu.[5] Based on an estimate of 250 kg of Pu,[1, Table D-3] Mark V salt will be replenished 6.3 times. Replenishing the Mark IV salt, which treats the driver fuel, is unnecessary unless it is found that the added Na greatly increases the melting point of the ER salt above 500 ^{o}C, or decay heat from actinides products prevents solidification once it is removed from the ER.

2.2 Baseline Pathway

Because of the chloride salts, vitrification of the ER salt waste to form borosilicate glass is not feasible. The current disposal pathway is to form a glass-bonded sodalite composite ceramic (referred to as a ceramic waste form or CWF).[6] The CWF process greatly increases the mass of the waste to dispose. For example, further treatment of 5.4 t of salt waste (1.017 t from Driver and 4.4 t Blanket) would eventually produce ~70 t CWF and require 88 HLW canisters (Figure 1).[7]

If treatment of the blanket EBR-II is never completed beyond the 3.68 MTHM already processed, then disposing of the 0.699 t of salt waste in the Mark V ER along with the 1.017 t of salt waste in the Mark IV ER would require 29 HLW canisters (Figure 1).

The waste treatment equipment is to be located in Hot Fuels Examination Facility (HFEF), similar to the existing furnace for forming the metallic waste ingots. The equipment to treat the ER salt waste is large and would occupy a significant portion of the space available in the HFEF hot cell, which would greatly limit using HFEF for experimental purposes for the 5 years or more necessary to complete treatment.[6]

2.3 Direct Disposal Pathways

The direct disposal option involves sending the ER salt waste directly to a repository without further treatment. Three direct disposal pathways exist for ER salt waste. The first pathway is to send ER salt waste by rail to a mined repository for commercial and/or defense waste in 32 HLW canisters (or 11 HLW canisters if blanket fuel treatment is never completed). Until the proposed repository at Yucca Mountain, Nevada, came to a *de facto* stop in 2010, this was the anticipated pathway, but with treatment of the ER salt waste to produce 88 HLW canisters of CWF. This pathway depends upon renewed Administrative and Congressional support for a commercial repository.[8] A second pathway is to send the waste to a future deep borehole repository.

The third pathway is to send 62 truck shipments (or 41 shipments) of ER salt waste, which meets the definition of defense related remote handled transuranic (RH-TRU) waste, to the Waste Isolation Pilot Plant (WIPP) located in bedded salt in southern New Mexico. This report focuses on this pathway (Figure 1).

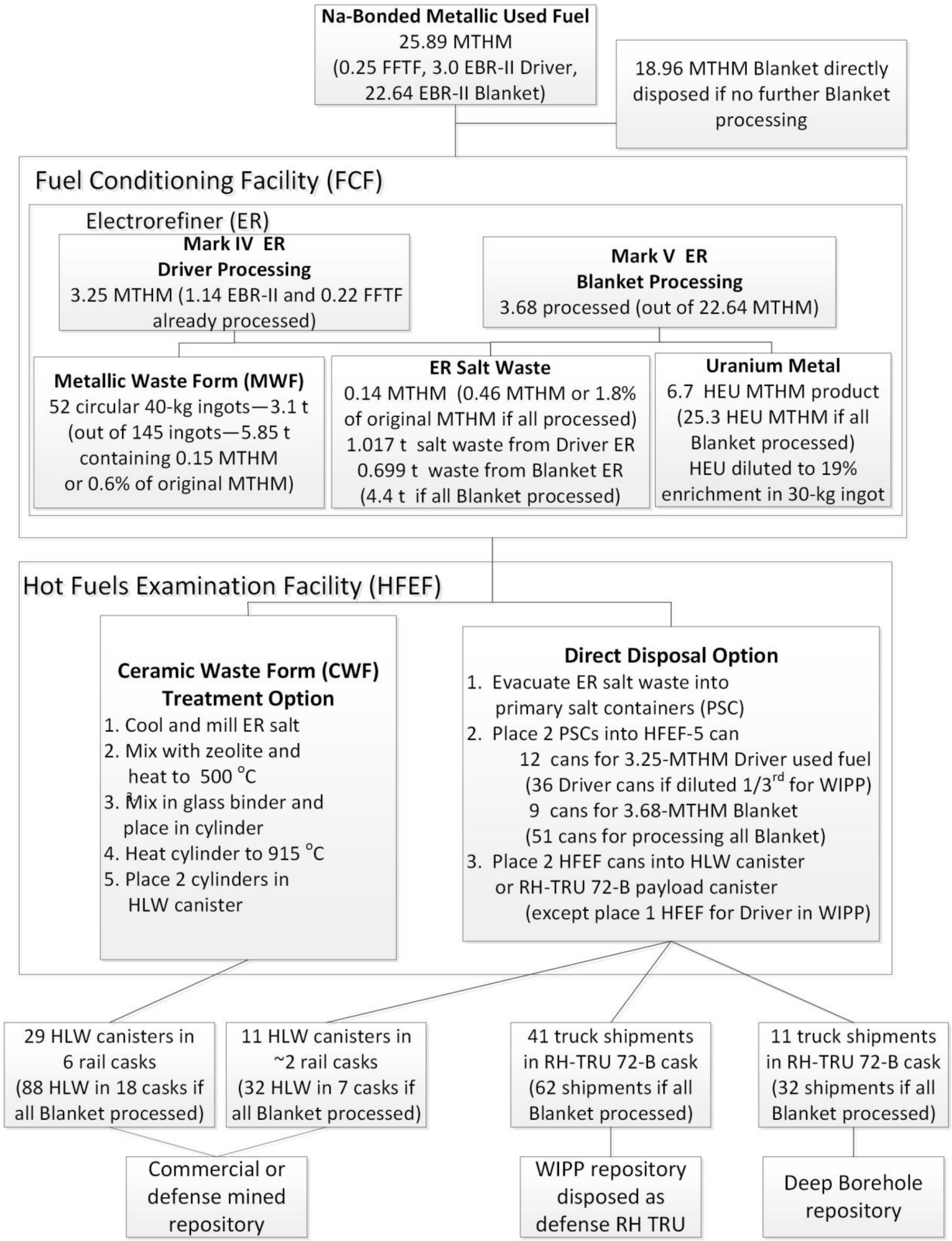

Figure 1. Various pathways for disposal of Na-bonded used fuel from EBR-II and FFTF, where for each pathway all the driver fuel is processed but the option exists to process either a portion or all of the blanket fuel with the latter option shown in parentheses and where shipment to WIPP requires one-third dilution of the driver fuel and placing only 1 HFEF can in a truck cask.[5, Figure 1]

3 Roadmap for Direct Disposal of ER Salt Waste at WIPP

3.1 Eleven Tasks to Complete

Eleven tasks to complete before disposal of salt waste produced from electro-chemically treating Na-bonded used fuel can be implemented at WIPP are as follows (Table 1):

1. Document that EBR-II ER salt waste meets definition of TRU waste and is of defense origin
2. Request NMED modify the WIPP Hazardous Waste Facility Permit to approve EBR-II ER salt waste disposal
3. Document packaging schemes for shipping ER salt waste to WIPP
4. Update the environmental impact statement (EIS) on EBR-II salt waste disposition
5. Develop overall quality assurance (QA) program for EBR-II ER salt waste and obtain CBFO approval
6. Develop waste characterization program to meet requirements of WIPP waste acceptance criteria (WAC) and obtain CBFO approval
7. Develop and obtain CBFO approval of a transportation program for EBR-II ER waste that includes QA plan, packaging plan, and modification of either contact-handled (CH) or RH TRU authorized methods for payload control (TRAMPAC)
8. Update performance assessment (PA) to show no material changes
9. Certify the characterization, QA, and transportation programs through CBFO Certification Audit
10. Implement program by assembling acceptable knowledge document and waste stream profile form, and obtain CBFO approval of documents
11. Package EBR-II ER salt, obtain CBFO approval, and ship.

The first task involves describing the ER waste form, documenting its defense origin, and documenting that it meets the definition of TRU waste to the satisfaction of CBFO. Presumably, the first task can be met. In fact, a RH-TRU content code (RH-TRUCON) has already been assigned for "used chloride salts from pyrochemical processes such as electrorefining, molten salt extraction, or direct oxide reduction.[9, Table 2]

The second task is for CBFO to ask and receive disposal approval from the New Mexico Environment Department (NMED) through a modification to the WIPP Hazardous Waste Facilities Permit.

The third task is to document packaging schemes for shipping ER salt waste to WIPP. Two different shipping options are possible. One option is to ship using the TRUPACT-II truck cask. A second option is to ship using the RH-TRU 72-B truck cask.

The fourth task is to update the EIS supporting the record of decision to treat the EBR-II used fuel.[1] This task could be concurrent with the first three tasks.

The next two tasks are to develop a QA program and characterization program. These two tasks can build upon the QA and waste characterization program already existing at INL for shipping CH-TRU or RH-TRU waste to WIPP (i.e., Advanced Mixed-Waste Treatment Program—AMWTP or Idaho Nuclear Technology and Engineering Center—INTEC, respectively).

The seventh task is to develop a program and obtain approval to transport EBR-II salt waste. Shipping using the TRUPACT-II truck cask would require either diluting the ER contaminated salt prior to placement in the currently proposed primary salt container (PSC) or developing a small PSC. This option would also require developing an overpack for use in 55-gallon drums and amending the US Nuclear Regulatory Commission (NRC) Certificate of Compliance for the TRUPACT-II cask.

Shipping ER salt waste using the RH-TRU 72-B truck cask, would require amending the RH-TRAMPAC, WIPP WAC, and NRC Certificate of Compliance to allow (a) higher fissile amounts in a container, and (b) ~90 W heat loads (in 2023) for the 36 payload canisters containing the Mark IV ER salt waste (Figure 1).

The eighth task is to update the PA supporting the WIPP Certificate of Compliance with regulations by US Environmental Protection Agency (EPA). Even though previous PA analysis has shown the ability of a salt repository to accommodate ER salt waste, WIPP specific PA codes must to be run to provide the basis that the moderately warm ER salt waste does not materially alter the safety case for WIPP after closure.

The final three tasks are to certify and implement the program. Most of the savings in costs to the US occur in the eleventh task

Table 1. Tasks for disposal of EBR-II ER salt waste at WIPP

Task	Project Elapsed Time (months)	Project Costs ($1000)	Time for Ruling (months)	Program Risk	Comments
1. Document EBR-II ER salt waste is TRU and of defense origin	1.5	$60	3		Document supports the Task 2 in requesting a modification to WIPP facility permit. Costs to CBFO might be similar ($60k)
a. Describe ER salt waste form				Low	
b. Document defense origin of ER salt waste to satisfaction of CBFO at WIPP				Low	
c. Document that ER salt waste meets definition of TRU to satisfaction of CBFO				Moderate	
2. CBFO requests NMED modify WIPP Hazardous Waste Facility Permit	3	$100	24	High	ER salt waste previously managed as HLW; thus, disposal requires approval of NMED. Risk to project is high if a CBFO request for general Class 3 modification is unsuccessful; otherwise, risk is moderate and time for ruling 6 months; direct costs to INL are minor ($10k)
3. Document packaging schemes for storage and transportation including RH-TRU 72-B and TRUPAC-II casks	2	$80		Low	Document supports Task 4 EIS. The advantage of using 72-B cask is reduced disposal volume at WIPP; the advantage of using TRUPACT-II cask is possibly earlier disposal and less disruption of WIPP operations. Other disposal pathways may need a similar scoping document.
4. Update the EIS on disposition of EBR-II ER salt waste				Low	Purpose of EIS update is to (1) designate EBR-II ER salt waste as defense TRU, (2) discuss advantages of WIPP disposal, and (3) discuss impacts of shipping options developed in Task 3. Task 4 could occur simultaneously with Tasks 1, 2, and 3. Direct costs to INL could be minor (0.5 months, $20k).
a. Draft EIS	18	$1500			
b. Comments period			3		
c. Final EIS	9	$750			
d. DOE Record of Decision			3		
5. Develop QA program for EBR-II ER salt waste disposition and obtain CBFO approval a. Write waste certification plan b. Write certification QA plan	3	*$80**	3	Low	QA program will be based on AMWTP or INTEC at INL, which are already WIPP compliant. Costs may be somewhat less than other disposal pathways since building upon existing program.
6. Develop waste characterization program and obtain CBFO approval a. Write QA project plan b. Write implementing procedures c. Train and qualify staff d. Participate in Performance Demonstration Program	5	*$100**	3	Low	Characterization program will be based on AMWTP or INTEC. Costs may be somewhat less than other disposal pathways since building upon existing program at INL.
7. Develop program and obtain CBFO approval to transport EBR-II ER salt waste				Low	This task builds upon Task 3 and any decisions made in relation to the updated EIS in Task 4
a. Develop QA transportation plan	2	*$100**			Subtasks 7a and 7d would be similar for any disposal pathway; however remaining subtasks are unique to WIPP disposal
b. Contract to either					Contract could be made with cask vendor
i. Select shielding for RH-TRU 72-B payload canister ii. Amend RH TRAMPAC	12	$500			One driver for shielding and developing/ amending site-specific RH TRAMPAC is to allow ~90 W payloads (in 2030) for 36 canisters containing driver ER salt; second driver is high Pu content uniformly dispersed in salt for 9 (or 51) canisters of blanket ER (Figure 1)

Task	Project Elapsed Time (months)	Project Costs ($1000)	Time for Ruling (months)	Program Risk	Comments
or					
i. Develop scheme for diluting salt or develop small PSC	24	*$1000**			
ii. Develop inner shielded assembly for 55-gallon drum					
iii. Amend CH TRAMPAC					
c. Amend NRC Certificate of Compliance for shipping cask	4	$500	3		An amendment would likely be required if fissile limits of the payload were changed. Contract with cask vendor could include Step 7b, which might save time and money. Costs likely paid by CBFO as part of 5-year renewal
d. Develop packaging plan	4	*$300*			
i. Write QA packaging plan per NRC 10 CFR 71					
ii. Write implementing procedure					
iii. Train and qualify staff					
e. CBFO updates WIPP WAC		*$50*	2		CBFO updates the WAC with no costs to INL; Update costs should be low since the WIPP WAC references the CH or RH TRAMPAC.
8. Update WIPP PA including disposal of ER salt waste	6	*$500**	6	Low	Demonstrate that small amount of warmer ER salt waste does not materially change safety case. A similar task required for other disposal pathways. Costs would be difficult to discern from other costs incurred when updating the PA
9. CBFO conducts Certification Audit of QA, waste characterization, transportation programs		*$75k*	3		Audit occurs several months after implementation of the program in Task 10. Review costs might be $75k paid by CBFO.
10. Implement waste characterization program as defined in QA program plans				Low	Steps 9a and 9b are unique to disposal at WIPP, but a similar task with similar costs would be required for any disposal pathway
a. Assemble acceptable knowledge document	1.5	*$60**			
b. Complete waste stream profile	1.5	*$60**			
Subtotal (omitted italic costs)		$3490			
11. Package EBR-II ER salt waste, obtain approval, and ship				Low	Shipping costs dominate costs and are incurred regardless of pathway; however, the costs differ by pathway because the volume moved and transportation mode changes; except for loading costs, most transportation costs to WIPP paid by CBFO (41 shipments for partial treatment of blanket fuel—Figure 1).
a. 41 truck casks to WIPP	24	$50500	2		
b. 62 truck casks to WIPP	36	*$72200**	2		
Disposal Cost (omitted italic costs)		$54040			

The following sections elaborate upon the task and give a rough estimate of the costs, the period necessary to complete the task, and the period necessary for review. Not all the conceivable costs and resources would necessarily be charged to or be unique for the WIPP disposal pathway. Furthermore, costs to INL can vary from overall costs to the DOE. The general purpose is to give a sense of the costs that can be considered unique to this pathway, costs that would have similar counterparts in other pathways, and costs that might be considered part of the general operation of the DOE Complex. Hence, comments related to tabulated values convey what the major source of the costs and mention specific costs to INL. For example, the final two tasks would be required regardless of the disposal pathway. The costs, however, can dramatically differ because of the volume of waste and mode of transportation. More importantly, all these costs would not necessarily be borne by INL. Costs to ship waste to WIPP are born entirely by the WIPP Project as part of its annual budget.

3.2 Description of EBR-II Electrorefiner Salt Waste

The *Waste Isolation Pilot Plant Land Withdrawal Act* (WIPP LWA) allows disposal of only transuranic (TRU) waste that was generated by atomic energy defense activities. [10]

Specifically in WIPP LWA,

> *SEC. 12. BAN ON HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL.*
>
> *The Secretary shall not transport high-level radioactive waste or spent nuclear fuel to WIPP or emplace or dispose of such waste or fuel at WIPP*

Where the meanings of high-level radioactive waste and spent nuclear fuel are as defined in NWPA:

> *The term "high-level radioactive waste" means—*
>
> > *(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and*
> >
> > *(B) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.*
>
> *The term 'spent nuclear fuel" means fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.*

3.2.1 Documenting Defense Origin of EBR-II ER Salt Waste

In the WIPP LWA, "atomic energy defense activity" is as defined in NWPA.[11]

> *(3) The term "atomic energy defense activity" means any activity of the Secretary performed in whole or in part in carrying out any of the following functions:*
>
> > *(A) naval reactors development;*
> >
> > *(B) weapons activities including defense inertial confinement fusion;*
> >
> > *(C) verification and control technology;*
> >
> > *(D) defense nuclear materials production;*
> >
> > *(E) defense nuclear waste and materials by-products management;*
> >
> > *(F) defense nuclear materials security and safeguards and security investigations; and*
> >
> > *(G) defense research and development.*

Before a waste site ships TRU waste to WIPP, the waste site provides CBFO justification that the waste originated from an atomic energy defense activity. Generally, sufficient justification consists of a description of the waste, the treatment that produced the waste, the related defense activity, and documents that support the defense activity origin of the waste. In the case of ER salt waste, EBR-II operated between 1964 and 1994 on general atomic energy defense activities, with the breeder experiments ending in 1967.

Once CBFO technical personnel and counsel are satisfied with justification, CBFO counsel recommends the CBFO Manager approve the Defense Determination. Environmental Management (EM-10) and General Counsel (GC-51) at Headquarters, Department of Energy (HQ-DOE) are notified of the decision.

If after coordination with the TRU waste site, CBFO questions the justification or if the Defense Determination raises unique issues, CBFO forwards the Defense Determination to HQ DOE to make the final decision.

3.2.2 TRU Waste Determination and Limitations

The justification that the waste meets the definition of TRU is conducted simultaneously with the justification that the waste is of defense origin, but it is listed as a separate task here (Table 2) because EBR-II raises a unique challenge since it has been previously identified as HLW in the EIS on the disposition pathway and, thus, represents a moderate risk to the program.[1]

The following terms are pertinent to the TRU waste justification. As defined in WIPP LWA, *TRANSURANIC WASTE—The term 'transuranic waste' mean waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for—*

(A) high-level radioactive waste;

(B) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations; or

(C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations.

CONTACT-HANDLED TRANSURANIC WASTE.—The term 'contact-handled transuranic waste" means transuranic waste with a surface dose rate not greater than 200 millirem per hour

REMOTE-HANDLED TRANSURANIC WASTE.—The term "remote-handled transuranic waste" means transuranic waste with a surface dose rate of 200 millirem per hour or greater

According to the WIPP LWA, the RH-TRU waste is limited as follows:

(1) REM LIMITS FOR REMOTE-HANDLED TRANSURANIC WASTE.—

(A) 1,000 REMS PER HOUR.—No transuranic waste received at WIPP may have a surface dose rate in excess of 1,000 rems per hour.

(B) 100 REMS PER HOUR.—No more than five percent by volume of the remote-handles transuranic waste received at WIPP may have a surface dose rate in excess of 100 rems per hour

(2) CURIE LIMITS FOR REMOTE-HANDLED TRANSURANIC WASTE.—

(A) CURIES PER LITER.—Remoted-handled transuranic waste received at WIPP shall not exceed 23 curies per liter maximum activity level (averaged over the volume of the canister).

(B) TOTAL CURIES.—The total curies of the remote-handled transuranic waste received at WIPP shall not exceed 5,100,000 curies

(3) CAPACITY OF WIPP.—The total capacity of WIPP by volume is 6.2 million cubic feet of transuranic waste.

Developing the justification for designating EBR-II ER salt waste as TRU waste of defense origin should not be difficult. About 1.5 months should be sufficient to document the justification and ~3 months for CBFO review. The CBFO costs for the 3-month review are assumed to be part of general costs of operating the DOE Complex. The costs to INL would be roughly $60k.

3.3 State of New Mexico Disposal Approval

Because EBR-II ER salt waste has been previously identified at HLW (e.g., in the EIS supporting the Record of Decision to electro-chemically treat the EBR-II used fuel [1]), CBFO must request, from NMED, a Class 3 modification to the WIPP Hazardous Waste Facility Permit (WIPP HWFP), under the authority granted by EPA in accordance with the *Resource Conservation, and Recovery Act* (RCRA). That is, in the WIPP HWFP (https://www.env.nm.gov/hazardous-waste/wipp-permit-page/),

2.3.3. <u>Treatment, Storage, and Disposal Facility Waste Acceptance Criteria (TSDF-WAC)</u> The Permittees shall not accept TRU mixed wastes at WIPP for storage, management, or disposal which fail to meet the treatment, storage, and disposal facility waste acceptance criteria as presented in Permit Sections 2.3.3.1 through 2.3.3.10 of this Permit…

2.3.3.8. <u>Excluded Waste</u> TRU mixed waste that has ever been managed as high-level waste and waste from tanks specified in Permit Attachment C are not acceptable at WIPP unless specifically approved through a Class 3 permit modification.

CBFO may submit a general Class 3 modification to generically cover several types of TRU waste previously managed as HLW sometime in the future. If this general Class 3 modification is approved, the request for ER salt waste may involve a less onerous administrative process. Possibly a ruling could be made within 6 months versus 24 months (Table 1).

Without a general Class 3 modification, working with CBFO in preparing a full request and responding to NMED questions may take ~1.5 month. Receiving approval from NMED may take between 18 and 24 months. Simultaneously working on the update to the EIS during this time would by prudent. Perhaps the successful completion of the EIS update would facilitate the decision at NMED.

As noted in Table 1, this task presents the highest risk to the project if the general Class 3 modification to the facility permit was not successful. Thus, attention to the process would be important. The greatest costs would be borne by CBFO. The direct costs and resources to INL would not likely be great (~0.5 months and $20k)

3.4 Packaging Schemes for Shipping ER Salt Waste

In the third task, INL must develop a document describing packaging schemes for shipping ER salt waste to WIPP. Preliminary work necessary to support this document was started in FY16.[5] About 2 months would be sufficient to document packaging schemes.

The primary purpose of the third task is to support the fourth task of updating to the EIS on the disposition pathways for ER salt waste. It is designated as a separate task since INL would be responsible, rather than the contractor producing the EIS. The third task also provides the foundation for the seventh task where INL must develop a transportation QA plan.

3.4.1 Proposed Handling Vessel

In the proposed scheme for direct disposal of ER salt waste, the contaminated molten salt from the ER would be placed into a primary salt container (PSC) and allowed to cool.

In concept, 3 sizes were considered for the PSC, but not all 3 sizes would make sense for the 3 disposal pathways of Figure 1. Specifically, the 3 PSC considered were (1) PSC container 43 kg ER salt for use in standard truck cask for shipment of RH-TRU to WIPP, (2) a smaller PSC for use in shipping contact handled transuranic (CH-TRU) waste to WIPP, and (3) a larger PSC for shipping via rail to a future mined repository for commercial SNF and/or DOE-managed SNF.

PSCs would then be placed in some type of handling container. For the shipment to WIPP, two PSC could be stacked in an inner container. The inner container would then be placed in an outer container (called a HFEF-5 can) such that the proposed handling vessel consists of 3 nested cylinders around the ER salt waste, with 86 kg ER salt/HFEF-5 can.

3.4.2 Proposed Type B Shipping Casks

NRC has certified many Type B casks for shipment of TRU, SNF, and HLW and new casks will be developed in the future. Each Type B shipping cask has a maximum fissile gram equivalent (FGE), maximum radiation dose rate, a maximum heat generation rate, and a maximum amount of gas generation possible during transportation for approved payloads.

For the pathway involving shipments to WIPP (Figure 1), currently five NRC-approved Type B truck casks exist for shipping TRU waste: TRUPACT-II (Transuranic Package Transporter Model 2), HalfPACT, TRUPACT-III, RH-TRU 72-B, and 10-160B. This roadmap discusses the general tasks necessary for transporting ER salt waste in the RH-TRU 72-B and TRUPACT-II, which are readily available.

The advantage of using the RH-TRU 72-B cask is reduced disposal volume at WIPP (e.g., disposal of only 41 payload canisters—Figure 1). The advantage of using TRUPACT-II cask is possibly earlier disposal and less disruption of WIPP operations since the drum waste would be placed in the disposal rooms rather than in boreholes in the walls or floor.

3.4.3 RH-TRU 72-B Cask for Shipping to WIPP

The RH-TRU 72-B transportation cask, (NRC Certification 9212, Docket Number 71-9212, and package identification USA/9212/B(M)F-96) was designed to transport RH-TRU waste in a payload canister (Figure 3).[12] One RH-TRU 72-B cask is transported on a truck at a time (Figure 2).

The cask can transport a payload (including the payload canister) weighing 3628 kg. The current payload canister has an internal volume of 0.94 m^3 (Table 2),[13] which could easily accommodate one or two HFEF-5 cans.

Figure 2. RH-TRU 72-B truck for remote-handled TRU waste.

Table 2. Current limits on payload canister for RH-TRU 72-B.

Unit	Limit
Mass of payload and payload canister	3628 kg
Diameter, outside	66 cm
Height, total	306 cm
Height, lid	21 cm
Thickness	0.635 cm
Volume	0.94 m^3
Material	Carbon or Stainless Steel
Heat limit	300 W
Pu FGE for $\geq$25 g of ^{240}Pu	370 g
Activity	1800 PE-Ci

One or two HFEF-5 cans can be centrally suspended in dunnage within the payload canister RH-TRU 72-B transportation cask. Any necessary lead or uranium shielding would be a circular envelop surrounding the HFEF-5 cans and dunnage. Several options for dunnage are possible: (1) Celotex or redwood cellulose, (2) sand, (3) salt, and (4) a commercial product, polysiloxane with bismuth.

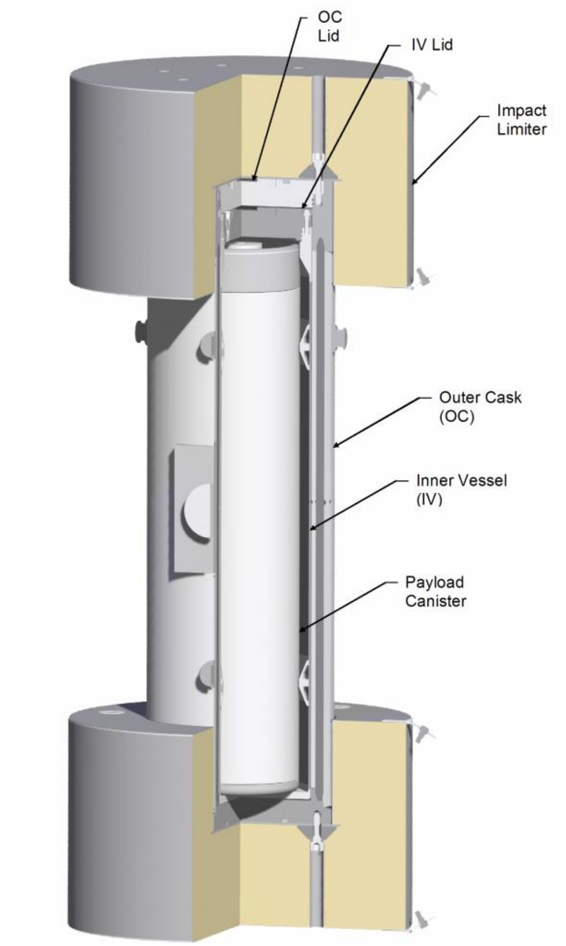

Figure 3. RH-TRU 72-B cask (outer container and inner vessel) with payload canister and impact limiters.[13, Figure 1.1.1]

The WIPP LWA contains a provision that influences packaging schemes: the RH-TRU activity concentration cannot exceed 23 kCi/m^3 (23 Ci/L in Section 3.2.2), averaged over the volume of the payload canister of 0.94 m^3 for the RH-TRU 72-B cask (Table 2). To meet the statutory limit, several packaging schemes are possible. If disposal is planned in 2023, then the ER salt from the driver used fuel must be diluted with pure salt by 1/3rd and only one HFEF-5 can placed in the payload canister to obtain a concentration < 23 kCi/m^3 (Table 3) (or, alternatively, diluted by 1/6th and two HFEF-5 cans placed in a payload canister).

The ER salt waste from blanket fuel could also be used to dilute the ER salt waste from the driver fuel. This option would be particularly useful if all the blanket used fuel was treated. If disposal can be delayed until 2043, then placing one undiluted PSC in a HFEF-5 can and one HFEF-5 can in a payload canister would be another option.

Table 3. Activity and thermal power in 2013 for 86 kg of driver and blanket ER salt waste in 0.94-m^{3}payload canister

Duration beyond 2013	Driver				Blanket	
	Activity (kCi/m^3)	Dilute Factor of 3	Power (W)	Dilute Factor of 3	Activity (kCi/m^3)	Power (W)
0	170.8	57.0	327.2	109.1	51.7	24.9
1	127.2	42.4	322.0	107.3	5.1	24.6
10	67.8	22.6	261.8	87.3	3.5	21.9
30	46.4	15.5	166.1	55.4	2.4	17.5
100	8.3	2.8	26.2	8.7	0.6	12.0

3.4.4 TRUPACT-II Cask for Transport

The TRUPACT-II represents an alternative transportation cask currently available for shipping waste. The TRUPACT-II transportation cask is not designed to provide gamma or neutron shielding. Hence, the payload contents must be sufficiently shielded. The approved payloads are the thin-walled 55-gallon drum, 85-gallon drum, 100-gallon drum, standard waste box, and 10-drum overpack. The 55-gallon drum is the basis of several payloads with additional internal components to provide either criticality control or additional shielding such as the S200 pipe overpack used inside a 55-gallon drum, but with additional gamma shielding. Each TRUPACT-II cask can transport fourteen 55-gallon drums. A truck can carry 3 TRUPACT-II casks (Figure 4).

Figure 4. TRUPACT-II casks for contact-handled TRU waste.

The primary advantage of using a smaller PSC would be make use of the readily available TRUPACT-II transportation cask and avoid having to dilute the driver ER salt waste to dispose at WIPP.

3.5 Updating EIS on Managing ER Salt Waste

The fourth task is to update the EIS supporting the record of decision to treat the EBR-II used fuel. This task could be concurrent with the first three tasks. The purpose of update is to (1) designate the EBR-II ER salt waste as defense TRU waste, (2) discuss the advantages of the WIPP disposal pathway versus other disposal pathways, and (3) discuss environmental impacts of options for shipping waste to WIPP.

Although the direct costs to INL would be minor (0.5 months, $20k), updating the EIS is a major task (~$2.25 million to complete for the WIPP disposal pathway.

3.6 Developing QA Program and Characterization Program.

The fifth and sixth tasks are to develop a QA program and characterization program, respectively. These two tasks can occur concurrently and build upon the QA and waste characterization program already existing at INL for shipping CH-TRU and RH-TRU waste to WIPP (i.e., Advanced Mixed-Waste Treatment Program—AMWTP and Idaho Nuclear Technology and Engineering Center—INTEC, respectively). Costs to INL may be somewhat less than other disposal pathways since building upon existing program. Review/oversight costs to CBFO might be $50k but other pathways would have similar review and oversight costs (i.e., the review and oversight costs are not unique to the WIPP disposal path).

3.7 Developing Program to Transport ER Salt Waste

The seventh task is to develop and obtain approval of a transportation program for EBR-II salt waste. The most cost-effective method for developing and implementing the transportation program would be by using the Central Characterization Program (CCP), which is available through the CBFO contract with the WIPP Managing and Operating Contractor (M&O). CCP provides TRU transportation services and resources to sites possessing TRU waste. CCP is currently the only WIPP certified Transportation Program and most implementing costs would be paid by CBFO.

Shipping ER salt waste using RH-TRU 72-B truck cask, would require amending the RH-TRAMPAC for the RH-TRU 72-B cask to allow (a) higher fissile amounts in a container, and (b) 87.6 W thermal power (Table 2) for the 36 payload canisters containing the driver ER salt waste for disposal in 2023 (Figure 1).

The ER salt waste can easily be shown to be far below any criticality concern. The current heat limits in the RH TRAMPAC (and by reference, the WIPP WAC) are to avoid producing gases from organics that may be in the waste. Yet, ER salt waste is noncombustible without organics.

Shipping using the TRUPACT-II truck cask would require setting up a program to either dilute the ER contaminated salt in the currently proposed PSC or develop a small PSC that will hold between 4 and 8 kg of ER salt waste. Between 200 and 400 PSCs would be produced. However, existing inner containers for the standard 55-gallon drum payload have insufficient shielding for ER salt waste. Adding additional shielding to an existing shielded inner container, the S200 pipe overpack, is not feasible because it leaves too little space for the ER salt waste. The time and costs are significant: 24 months and ~$1 million would be required to develop and certify an inner container for the 55-gallon drum payload.

Each choice would involve amending the WIPP WAC and NRC Certificate of Compliance for cask (Table 1). CBFO is responsible for updating the WIPP WAC. Their costs should be minor since it mostly references the CH or RH TRAMPAC. Amending the NRC Certificate of Compliance for the cask would likely be required if the fissile limits were changed.

3.8 Updating PA Analysis

The eighth task is to update the PA supporting the WIPP Certificate of Compliance with EPA regulations. Even though previous PA analysis has shown the ability of a salt repository to accommodate ER salt waste, WIPP specific PA codes must to be run to provide the basis that the moderately warm ER salt waste does not materially alter the safety case for WIPP after closure.

The exact heat load would depend upon how long the ER salt waste cooled prior to shipment, but the total heat load could be as large as 3 kW if shipped soon after ER treatment (originally projected to conclude in 2023). In 1998, WIPP was projected to dispose of CH and RH-TRU waste that generated ~136 kW. The 3 kW in ER salt waste represents an increase of only 2%, which would be difficult to detect in a performance assessment of the behavior of the waste at WIPP.

The eighth task is explicit for WIPP disposal, but the costs of $500k would not necessarily be borne by INL and the costs may be difficult to discern from other costs incurred with updating the WIPP PA every 5 years.

A similar task would be part of other disposal pathways and not incur any direct costs. For example, disposal of ER salt waste as CWF was not explicitly modeled in the existing PA conducted in 2008 to apply for a construction license from the NRC for the proposed Yucca Mountain repository. Also, direct disposal of ER salt waste at Yucca Mountain repository was not modeled in the PA. But like the WIPP disposal pathway, the costs to include these two types of waste would not necessarily be borne by INL and the costs may be difficult to discern from other costs for the necessary update to the PA when applying for a license to operate the Yucca Mountain repository after it had been constructed. Therefore, the cost to update the PA is not included in the added costs of direct disposal of ER salt waste at WIPP.

3.9 CBFO Conducts Certification Audit

As part of the WIPP HWFP, CBFO is to certify that the INL site, which processes the TRU ER salt waste, complies with the QA plan, characterization program, and the transportation program (§C5a):

> *DOE will perform an initial audit at each generator/ storage site performing waste characterization activities prior to the formal acceptance of the WSPFs and/or any waste characterization data supplied by the generator/storage sites.*

The audit occurs several months after implementing the program in Task 10 so that objective evidence exists to review. Review costs might be $75k but review costs are part of CBFO annual budget.

3.10 Package ER Salt Waste and Ship

The overall savings of direct disposal of ER salt waste is realized when the cost of implementing the program are included. The savings occurs because (1) no lengthy processing time is required to produce CWF and (2) a reduce volume of waste is shipped.

The cost to complete ER treatment of EBR-II used fuel and produce/ dispose of CWF has been estimated to be between $405 and $526 million.[14, Table 7] Of this amount, disposal/shipping costs only represent ~20% of the costs). Yet, the savings from the reduce volume of waste shipped and disposed can be substantial.

For planning purposes, the unit shipping/disposal cost estimated for CWF processing was ~$1.75 million per HLW canister, which included the cost to buy the canister, load the canister, qualify, certify, load/unload the cask, ship, and pay a disposal fee. The unit cost also included a 40% contingency fee.[14, Table 7]

Reducing the number of canisters shipped to a commercial mined repository from 29 to 11 (Figure 1) results in saving $31.5 million in shipping costs (or if all the blanket fuel is processed then the number of canisters shipped is reduced from 88 to 32 HLW canisters for a savings of $98 million).

It is beyond the scope of this report to estimate total preparation and disposal costs for WIPP, but it is possible to quickly estimate a portion of the shipping costs. From this estimate, one can make a rough estimate of disposal costs when all the blanket fuel is processed. Just the costs for shipping 62 truck casts to WIPP is $2.63 million (Table 4). The costs for shipping 18 rail casks (containing 88 HLW canisters) is $5.61 million (Table 4). Hence, the shipping costs to WIPP are less than half the cost to ship to a commercial repository such as the proposed Yucca Mountain repository. Keep in mind, however, that INL would not bear most of the costs of shipping waste to WIPP. Actual shipping costs are paid by CBFO. Only the costs to load ER waste into casks would be borne by INL (and CBFO mobile loading service could help, if desired.)

The total disposal costs for 88 HLW canisters is $154 million (88 HLW canisters × 1.75 million/canister). Assuming a ratio of $2.63 million to $5.61 million for the $154 million, yields $72.2 million to ship to WIPP (Table 1). Hence, the savings from directly shipping ER salt at WIPP is $82 million if all the blanket fuel is processed. This savings easily covers the $3.54 million in added costs to prepare documentation to change to direct disposal of ER salt waste at WIPP.

These savings to the taxpayer and the direct savings to INL are large. Furthermore, the savings in costs to move equipment into the HFEF hot cell, test the equipment, and personnel necessary for producing CWF over ~5 years have not been quantified. Some costs would be incurred in filling PSCs and loading the HFEF cans but these costs are far less than the $325 to $480 million to produce the CWF (e.g., 405 million minus 20% disposal/shipping costs). Furthermore, the lost opportunity costs to use the HFEF hot cell for other experiments for ~5 years not been quantified.

Table 4. Costs of transporting EBR-II and FFTF driver and blanket used fuel to repository from INL as estimated by Transportation Operations Model [15]

Repository	Waste Form Shipments		Cost ($ 1000s)
WIPP	ER salt waste		
	41 Truck Casks		
	Load/unload	660	
	Shipping	700	
	Maintenance/lease	410	1770
	62 Truck Casks (blanket)		
	Load/unload	990	
	Shipping	1020	
	Maintenance/lease	620	2630
Yucca Mt.	ER salt waste		
	2 Rail Casks		
	Load/unload	320	
	Shipping	225	
	Maintenance/lease	100	645
	7 Rail Casks (all blanket)		
	Load/unload	1120	
	Shipping	700	
	Maintenance/lease	350	2170
Yucca Mt.	Ceramic Waste Form		
	6 Rail Casks		
	Load/unload	960	
	Shipping	510	
	Maintenance/lease	300	1770
	18 Rail Casks (all blanket)		
	Load/unload	2880	
	Shipping	1830	
	Maintenance/lease	900	5610

4 Concluding Remarks

The roadmap layouts the work ahead. Crucial tasks for WIPP disposal include (1) modifying the WIPP Hazardous Waste Facility Permit, (2) updating the EIS on disposition of EBR-II and FFTF ER salt waste, (3) developing cask inserts (either selecting shielding/dunnage for the payload canister of the RH-TRU 72-B cask or developing shielded inner assembly for 55-gallon drums of TRUPACT-II cask), and (4) amending the TRAMPAC and possibly NRC Certificate of Compliance for the shipping cask.

The additional documentation and development costs to the project to prepare for shipping ER salt waste to WIPP above those costs anticipated to prepare documentation for CWF (but not produce or ship CWF to a commercial mined repository) is \$3.54 million (Table 1). Of this \$3.54 million, updating the EIS represents 64% (\$2.25 million).

The additional cost to prepare for shipping ER waste to a commercial mined repository is \$3.05 million. (Table 1). The cost to ship ER salt waste to a commercial mined repository is primarily the cost of the updating the EIS, since it is not necessary to request modification to WIPP Hazardous Waste Facility Permit or modify/develop a truck shipping payload. The EIS update would likely be less costly also because the EIS update would only involve switching the waste form from CWF to ER salt but that cost savings is not quantified here.

The overall savings of direct disposal of ER salt waste is realized when the cost of implementing the program are included. The savings occurs because (1) no lengthy processing time is required to produce CWF and (2) a reduced volume of waste is shipped.

Several avenues exist for future analyses in the near term. One set of analysis could examine the feasibility of direct disposal of ER salt waste at a tuff repository. This analysis would be useful if Congress and the Administration show renewed interest in the Yucca Mountain repository. Another set of analyses would continue to lay the groundwork for disposal at WIPP. Task 3, documenting packaging schemes for storage and transportation, and Task 8, updating PA to include disposal of ER salt waste specifically at WIPP, are two tasks that could be started and do not depend upon formally initiating Task 1.

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