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Transportation of Transuranic Nuclear Waste to WIPP: A Reconsideration of Truck versus Rail for Two Sites

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP) is a repository for the permanent disposal of radioactive transuranic (TRU) waste generated from the United States' defense programs. In March 1999, the U.S. Department of Energy (DOE) began shipping TRU waste to WIPP by truck while reserving the future option to use rail. This article compares advantages and disadvantages of shipment by truck and by rail and recommends that DOE reconsider the use of rail for the two major generators of TRU waste, the Hanford, Washington, site and the Idaho National Engineering and Environmental Laboratory, in view of the potentially large savings in costs and slight reduction in risks.

I. INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), located 26 miles east of Carlsbad, New Mexico, is a deep geological repository for the permanent disposal of transuranic (TRU) waste, including fission products, generated as a consequence of the nation's defense programs. Transuranics are long-lived radionuclides heavier than uranium. The WIPP Land Withdrawal Act[1] required the U.S. Department of Energy (DOE) to compare the shipment of TRU waste to the WIPP facility by truck and by rail, including the use of dedicated trains,[2] and to submit a report to Congress.[3] The Act required "(A) a consideration of occupational and public risks and exposures, and other environmental impacts; (B) a consideration of emergency response capabilities, and (C) an estimation of comparative costs."[4] The DOE examined these issues as well as others related to

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1. Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, § 16(f), 106 Stat. 4777, 4793-94 (1992), *amended by* Waste Isolation Pilot Plant Land Withdrawal Amendment Act, Pub. L. No. 104-201, §§ 3181-91, 110 Stat. 2422, 2851-54 (1996).
2. Dedicated trains are used solely to transport radioactive waste.
3. *See* Waste Isolation Pilot Plant Land Withdrawal Act, § 16(f), 106 Stat. at 4793-94.
4. *Id.* § at 4793.

radioactive waste disposal in several studies.[5] In the Record of Decision, DOE announced its intent to transport TRU waste to WIPP initially by truck while reserving the option to use commercial rail transportation in the future.[6] According to DOE, the decision was based on four primary factors: (1) rail carriers had a limited interest in handling shipments of TRU waste; (2) dedicated trains are more expensive than trucks; (3) rail requires three times as many shipping containers; and (4) rail carriers could not guarantee that shipments would be delivered within 60-days from sealing the shipping container.[7] DOE stated that it will require 38,300 truck shipments, totaling 106 million truck miles, over a 35-year period to transport the radioactive waste at a cost of approximately $1.6 billion.[8]

There are several issues to consider with respect to the four factors listed by DOE. First, none of the DOE reports provides evidence of "limited interest" by the rail carriers. It is not clear if the rail companies were made aware that the cumulative trucking contracts are estimated to be worth $1.6 billion. Second, while DOE generally reports that TRU shipments by dedicated rail are significantly more expensive than both truck and regular rail, in one environmental impact statement the agency stated that regular rail is one-third the cost of truck.[9] This suggests potential savings approaching $1 billion. Third, at a cost of $0.3 million[10] for each Contact Handled (CH)-TRU waste shipping container, the additional number of containers required for rail transport would increase costs by $36 million or only three

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5. *See* U.S. DEP'T OF ENERGY, DOC. NO. DOE/WIPP 93-058, COMPARATIVE STUDY OF WASTE ISOLATION PILOT PLANT (WIPP) TRANSPORTATION ALTERNATIVES (1994) [hereinafter COMPARATIVE TRANSPORTATION ALTERNATIVES]; U.S. DEP'T OF ENERGY, DOC. NO. DOE/WIPP 95-2135 REV. 0, ENGINEERED ALTERNATIVES COST/BENEFIT STUDY FINAL REPORT (1995) [hereinafter ENGINEERED ALTERNATIVES]; U.S. DEP'T OF ENERGY, DOC. NO. DOE/CAO-95-1121 REV. 3, TRANSURANIC WASTE BASELINE INVENTORY REPORT (1996) [hereinafter TRU BASELINE INVENTORY REPORT]; U.S. DEP'T OF ENERGY, DOC. NO. DOE/NTP 96-1204 REV. 1, THE NATIONAL TRU WASTE MANAGEMENT PLAN (1997) [hereinafter NATIONAL TRU PLAN]; U.S. DEP'T OF ENERGY, DOC. NO. DOE/EIS-0200-F, FINAL WASTE MANAGEMENT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR MANAGING TREATMENT, STORAGE AND DISPOSAL OF RADIOACTIVE AND HAZARDOUS WASTE (1997) [hereinafter PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE]; U.S. DEP'T OF ENERGY, DOC. NO. DOE/EIS-0026-S-2, WASTE ISOLATION PILOT PLANT DISPOSAL PHASE FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT (1997) [hereinafter DISPOSAL PHASE FINAL SEIS].

6. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. 3624, 3624-26 (1998); Record of Decision for the Department of Energy's Waste Management Program: Treatment and Storage of Transuranic Waste, 63 Fed. Reg. 3629, 3632 (1998).

7. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. at 3625.

8. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, D-9 tbl.D-11.

9. *See id.*

10. *See* telephone Interview with Philip Gregory, TRUPACT-II Cognizant Engineer, *Westinghouse Inc., Carlsbad, N.M.* (Mar. 3, 1999) ($900,000 equals three TRUPACTS and a trailer; $900,000=3 ($285,000)+$45,000).

percent of the $1.26 billion cost for CH-TRU waste truck transportation.[11] Finally, the 60-day shipping constraint required by the Nuclear Regulatory Commission (NRC) to prevent buildup in the drums of flammable hydrogen by radiolysis, produced by the interaction of alpha particles with organic material, may be addressed by scheduling, by using the DOE space-tracking system, and by ensuring that a courier accompanies each train.

Other factors to consider in the selection of truck include the over $300 million spent on upgrades of the WIPP highway routes, the establishment of an emergency-response capability, and a major campaign to educate the public about the trucking system to transport CH-TRU waste. However, none of these factors rule out the use of rail transport. Additionally, DOE estimates fewer deaths with regular rail than with truck.[12]

Given the large potential savings and slight reduction in risks by the use of regular rail, it would appear that the public interest may well be served by a reconsideration of the use of rail for two of the major generators of TRU waste, the Hanford, Washington, site and Idaho National Engineering and Environmental Laboratory (INEEL),[13] for the following reasons. First, both facilities have played major roles in the production of nuclear weapons for the nation's defense. Combined, these generators will have 65 percent of the total CH-TRU waste[14] and 79 percent of the total Remote-Handled (RH)-TRU waste.[15] Second, both sites have rail capability. Third, there are large potential savings using regular rail. Fourth, there is a slight reduction in risk by use of regular rail. Fifth, over the next 35 years, cleanup operations at these two sites may substantially increase the quantities of waste requiring disposal. Given the long routes to WIPP and lower cost, rail can handle such additional quantities of waste. Finally, shipments for RH-TRU waste from these sites will not begin until 2006,[16] so there is still time to plan for rail.

The objectives of this article are to identify the benefits of transporting TRU waste to WIPP by rail from two major waste generating sites and to cite examples where the DOE analyses could be improved. To these ends, the article is organized as follows: Section II provides background information; Section III presents cost analyses of truck versus rail transportation; Section IV presents information about rail shipments from Hanford and INEEL; and Section V provides concluding remarks.

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11. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 5-10 tbl.5-2.

12. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. 3624, 3628 (1998).

13. INEEL is 43 miles west of Idaho Falls, Idaho.

14. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-15 tbl.E-1 (estimated by number of shipments where (13,666+5782)/29,766=65.3%).

15. *See id.* at E-17 tbl.E-2 (estimated by number of shipments where (3178+3136)/7957=79%).

16. *See* NATIONAL TRU PLAN, *supra* note 5, at 26.

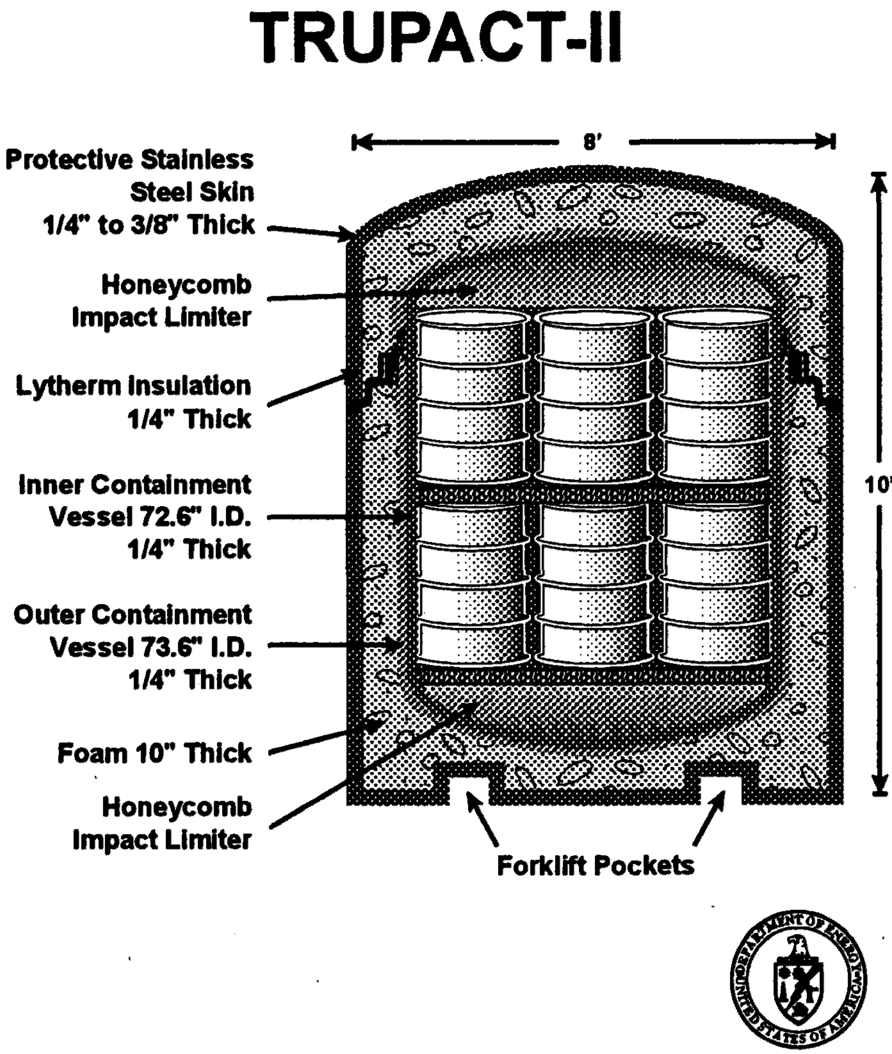

FIGURE 1—DIAGRAM OF A TRUPACT II SHIPPING CONTAINER (SOURCE: DOE WIPP PROJECT)

II. BACKGROUND

This section provides background information about TRU waste shipping containers and the advantages and disadvantages of both truck and rail shipments.

A. TRU Waste

The two categories of TRU waste, Contact Handled (CH) and Remote Handled (RH), require different shipping containers. The external dose rate of radiation on drums and boxes of CH–TRU waste is less than 0.2 rem per hour.[17] CH-TRU waste will be shipped in a reusable container called a TRUPACT II (TRUPACT), as seen in figure 1. Certified by the Nuclear Regulatory Commission (NRC),[18] the cylindrically shaped TRUPACT is designed to hold 14 drums[19] or two steel waste boxes.[20] The equivalent of approximately 850,000 drums of CH-TRU waste will be disposed of at WIPP, amounting to 6.4 million curies of radioactivity, of which plutonium accounts for 92 percent of the total radioactivity.[21] Due to limitations on the weight a truck can transport, a shorter, lighter version, called Halfpack, designed to hold seven drums of CH-TRU waste, is being developed[22] for certification by the NRC.

Unlike CH-TRU waste, RH-TRU waste must be handled remotely due to the high external dose rate. It requires a shielded shipping cask[23] where 95 percent by volume can have a dose rate up to 100 rem per hour, and five percent can have a dose rate as high as 1000 rem per hour.[24] (Figures 2 and 3 show trucks loaded with CH-TRU and RH-TRU waste shipping containers.) It is important to note, however, that the dose rate on the external surface of all shipping packages must be less than 0.2 rem per hour.[25] Principal radionuclides accounting for 96 percent of the one million curies of RH-TRU waste radioactivity are cesium-137, barium-137, strontium-90, yttrium-90, and plutonium-241.[26] While the toxicity differs

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17. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-3.
18. *See id.*
19. Each drum is a 55-gallon (208-liter) container.
20. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-3.
21. *See* TRU BASELINE INVENTORY REPORT, *supra* note 5, at 3-7 to 3-9 tbl.3-1.
22. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-3.
23. This is called a "72-B shipping cask." *See id.*
24. *See id.* at 2-4.
25. *See* U.S. DEP'T OF ENERGY, DOC. NO. DOE/CAO 98-3103 REV. 0, WASTE ISOLATION PILOT PLANT TRANSPORTATION PLAN 2 (1998).
26. *See* TRU BASELINE INVENTORY REPORT, *supra* note 5, at 3-3 to 3-9 tbl.3-1.

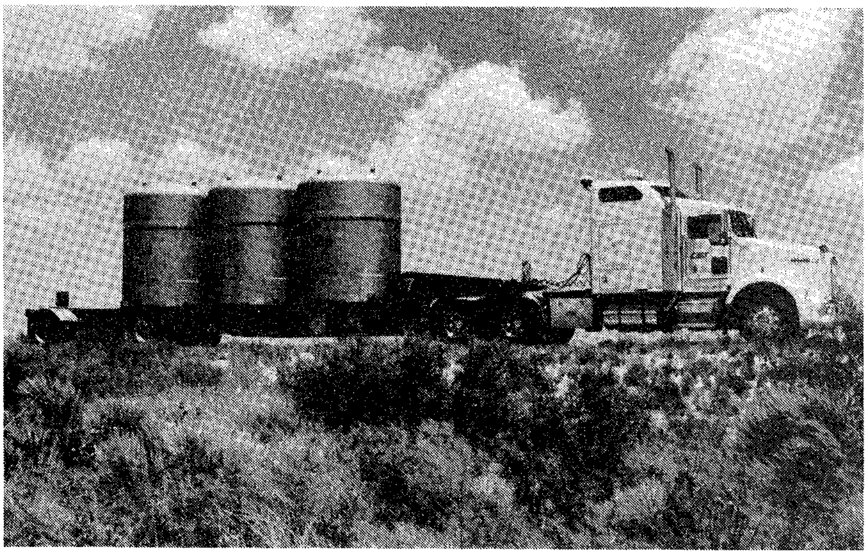

FIGURE 2—TRUCK CARRYING THREE TRUPACT II SHIPPING CONTAINERS (SOURCE: DOE WIPP PROJECT)

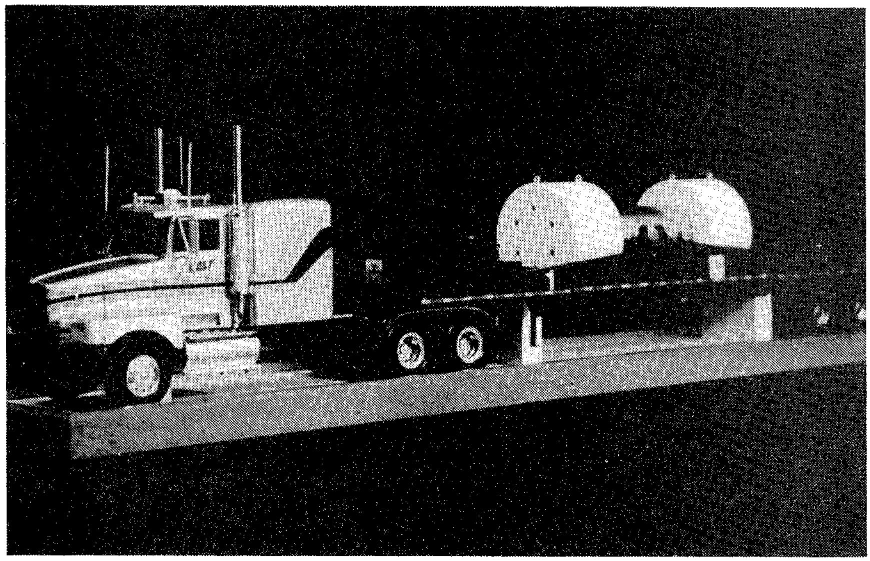

FIGURE 3—MODEL OF TRUCK CARRYING RH-72-B SHIPPING CASK (SOURCE: DOE WIPP PROJECT)

for each of these radionuclides, they all require isolation.[27] The required certification by the NRC has not yet been received for the RH-TRU reusable shipping cask.[28]

The amount of waste to be disposed of at WIPP may be considerably greater than the 175,000 cubic meters currently authorized because cleanup efforts at the various DOE sites will create additional TRU waste.[29] The following examples illustrate how the eventual transportation costs may be increased considerably. First, INEEL notes that their facility is expected to treat and process 65,000 cubic meters of CH-TRU waste, but could process an additional 120,000 cubic meters.[30] Second, DOE estimates there may be an additional 43,000 cubic meters of RH waste in addition to the 7,080 cubic meters authorized. [31] Third, a decision has not been made on exhuming 138,000 cubic meters of CH-TRU waste and 3,100 cubic meters of RH-TRU waste buried prior to 1970 in shallow land burial.[32] Finally, the repository will contain 3.5 million curies of alpha-emitting radioactivity; the EPA disposal standard allows 100 million curies.[33] Hence, future shipments and costs may increase substantially, whether to WIPP or some other repository or facility for processing and disposal.

DOE considered many alternatives to process and ship the waste. In one DOE report, the "preferred alternative" is to treat and store the waste at sites where it is generated, then ship it to WIPP. [34] In another DOE report, the "proposed action" for the disposal of TRU waste is to ensure that it meets the DOE Waste Acceptance Criteria (WAC),[35] consolidate the material at 10 major generating sites, and ship by truck to WIPP.[36] DOE chose the latter course of action.

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27. Contrary to public perception, TRU waste is not low-level waste.

28. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-3.

29. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. 3624, 3624 (1998).

30. *See* Record of Decision for the Advanced Mixed Waste Treatment Project at the Idaho National Engineering and Environmental Laboratory, 64 Fed. Reg. 16,948; 16, 949; 16,952 (1999) [hereinafter INEEL ROD Advanced Mixed Waste Treatment Project].

31. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 3-3 tbl.3-1.

32. *See id.* at 1-3.

33. *See* Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, 40 C.F.R. § 191 app.A (1999).

34. *See* PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE, *supra* note 5, at 118 (Summary).

35. The waste acceptance criteria for waste (WAC) to be received at WIPP were developed to have knowledge of the characteristics of the waste, (radioactivity, absence of free liquids, etc.) to be able to predict the long-term disposal performance of the repository, and evaluate operational and transportation risks. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-5.

36. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 3-4.

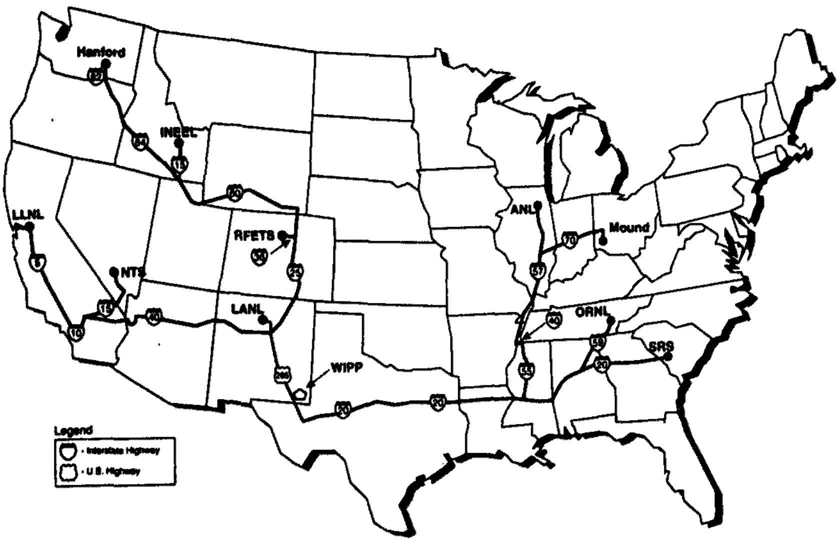

FIGURE 4—WIPP SHIPMENT ROUTES (SOURCE: DOE, 1997b)

B. Truck Shipments

Each truck shipment would carry three TRUPACTS or one RH-72-B cask. Truck shipments can be scheduled to ensure the arrival of 51 TRUPACTS each week.[37] The waste packages can be controlled continuously during shipment since one of the two drivers must remain with the truck at all times.[38] It should be relatively easy to meet the NRC requirement to complete the shipment within 60 days.

Figure 4[39] shows the proposed highway routes to ship TRU waste to WIPP from the major generator sites. RH-TRU waste shipments, scheduled by DOE to begin in 2003, will require NRC certification of the cask design and a permit issued by the New Mexico Environment Department for disposal of the non-radiological Resource Conservation and Recovery Act (RCRA) waste materials.[40]

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37. *See* NATIONAL TRU PLAN, *supra* note 5, at 12 (approximately 36.7 drums per shipment times 17 shipments per week equal 620 drums per week).

38. *See* Western Governors' Ass'n Technical Advisory Group for WIPP Transp., Report to the Western Governors' and Secretary of Energy: Safe Transport of Transuranic Wastes to the Waste Isolation Pilot Plant 10 (1991).

39. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-7 fig.E-1.

40. *See generally* Hazardous Waste Act, N.M. Stat. Ann. § 74-4-1 to 74-4-14 (Michie Repl. Pamp. 1993).

One disadvantage of shipping by truck is the perceived risk by the public from the high profile of 39,000 easily recognizable truck shipments. During the 35-year operational period, the expected number of accidents is 56,[41] with 39 injuries and five fatalities for approximately 106 million truck miles.[42] Stopping every two hours to check the shipment, as required by DOE, may cause onlookers to perceive a risk. The two drivers are trained in radiation safety, but they will not be radiation-protection specialists as proposed for train shipments.

C. Rail Shipments

Shipments of waste by rail have seven advantages. First, about half the number of shipments would be required: only 21,594 shipments[43] by train versus 38,290 by truck. If eighteen TRUPACTS of CH-TRU waste or six RH 72-B casks were carried on a train, either by increasing the number of railcars or the number of containers per rail car, shipments could be reduced another 50 percent.[44] RH-TRU train shipments could drop from 3,795 to 2,530, which would reduce costs. Second, two truck drivers would not be required. A trained radiation protection specialist could accompany the train to provide enhanced radiation safety as well as continuous control of the shipment. Third, due to weight limitations on the highway, DOE estimates the average truckload will contain 36.7 drums. In contrast, 42 drums can be carried in three TRUPACTS per railcar. Hence, only 87 percent as many shipments would be required for CH-TRU rail shipments. The absence of a weight limit for rail also eliminates the need for a fleet of Halfpack shipping containers. Fourth, there are fewer weather delays caused by snow and ice with rail. Fifth, the concept of piggyback truck shipments on rail from consolidating sites at which loaded truck trailers are placed on railcars to simplify loading and unloading operations could be further explored by DOE. Sixth, the DOE TRANSCOM tracking system can track all shipments and advise officials of the precise location of each TRU waste shipment to better schedule arrivals. Finally, DOE Disposal SEIS[45] provides a number of additional cost analyses indicating that shipment by rail is considerably cheaper and has a slightly lower risk. In addition to the advantages of using rail to transport TRU waste from two sites, rail is an

41. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-28 tbl.E-9.

42. *See id.* at D-9 tbl.D-11.

43. This includes 5462 truck shipments from Los Alamos National Laboratory (LANL) and the Nevada Test Site (NTS). *See infra* Tables B-1 & B-2.

44. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at ES-1.

45. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-8 to D-9, E-28 tbl.E-9, E-68 tbl.E-29.

alternative method of shipment from other sites with rail capabilities if a strike disrupts truck operations.

Rail shipments do have some problems but most can be resolved. First, rail beds may require upgrades. The extent of such work and associated costs are unknown. Second, an emergency-response capability must be established along rail lines for an accident involving TRU waste. Recent rail shipments of High Level Waste (HLW)[46] have addressed such an emergency-response capability. Part of the emergency-response capability along truck routes could be used, and the presence of a trained radiation protection specialist accompanying the train would also help fulfill this need.

Third, the rate of receipt of waste via rail may be more problematic. On average, deliveries by rail shipments provide three times more waste than truck. Drums and boxes containing TRU waste might require temporary emplacement underground or at an aboveground facility at WIPP to accommodate this variable rate. The RCRA permit by the New Mexico Environment Department allows the temporary storage of 122 cubic meters of CH-TRU waste at WIPP.[47] This would be equivalent to 43 TRUPACT-II containers.[48] The permit would need to be modified to store additional waste at WIPP. The temporary-storage period would not exceed 60 days.[49] Hence, the planned weekly emplacement of waste from 51 TRUPACTS with CH waste and 10 RH-72-B casks with RH waste would require careful scheduling.[50] With the space-tracking system, TRANSCOM,[51] the time of arrival could be precisely identified, and those shipments required to be made by truck from other facilities could be coordinated to ensure the desired throughput in an orderly manner.

Fourth, the 60-day NRC shipping constraint to limit hydrogen generation must be met. A factor helping to solve this problem is that the U.S. Department of Transportation (DOT) regulations do not permit hazardous materials to be left on a railroad siding where railcars can be parked. Shipments must be expedited to their destination within 48 hours (Saturdays, Sundays and holidays are excluded).[52] Also, a trained radiation

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46. High Level Waste is considerably more radioactive and has a greater thermal loading than TRU waste.

47. NEW MEXICO ENVIRONMENT DEP'T, EPA NO. NM4890139088, I HAZARDOUS WASTE FACILITY FINAL PERMIT: ISSUED TO WASTE ISOLATION PILOT PLANT III-1 tbl.III.A.1, III-3 tbl.III.A.2 (Oct. 27, 1999).

48. Calculation by authors ((122m3)/(14 drums X 0.2m3/drum) = 43 containers).

49. *See id.* at III-2.

50. *See* NATIONAL TRU PLAN, *supra* note 5, at 12.

51. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 3-7 (Transportation Tracking and Communications System).

52. *See* Movements to be Expedited, 49 C.F.R. § 174.14 (1998).

protection specialist serving as a courier on the train would keep track of the shipment to ensure timely completion.

Fifth, dedicated trains are very expensive, but are not required. TRU waste shipped by regular rail would be flanked with two buffer cars, thus isolating the shipment from the regular train. A trained radiation protection specialist would travel with each shipment and monitor all activities involving the TRU waste. Sixth, railroads have fewer alternative routes than trucks, and it might be difficult to reroute rail shipments promptly if a portion of the rail route was blocked by a derailment. Truck shipments from other sites could ensure the planned rate of receipt at WIPP.

III. COST ANALYSES

A mixture of economic, logistical, political, public confidence, and social issues was the basis for DOE's decision to transport TRU waste by truck in lieu of rail. This section examines some of the costs that may have affected the decision and, where possible, compares the total costs of each mode of transport. DOE cost calculations were inconsistent in some respects, as documented in the previous section.

A. Carrier Costs

Carrier costs are major contributors to total cost. In this article, carrier costs are all based on parameters and methods of calculation used by the 1997 DOE Disposal Phase Final Supplemental Environmental Impact Statement (SEIS) for the number of shipments, fixed and variable costs per shipment, and mileage.[53] The 1994 DOE Comparative Transportation Alternatives document[54] was the source of the cost parameters for rail. Appendix A contains the equations used to calculate costs and their evolution from previous DOE reports. Detailed calculations of carrier costs for truck and rail from all sites are presented in tables B-1 through B-4 in appendix B and summarized in table B-5. Although DOE[55] did not calculate the cost of rail shipments for the proposed action that was used for the Record of Decision to proceed with the project,[56] carrier costs were computed elsewhere to be $1,611 million for truck versus $524 million for

53. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 5-13 to 5-14.

54. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 7-8.

55. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9 tbl.D-11.

56. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. 3624, 3624-26 (1998).

rail.[57] Neither the Los Alamos National Laboratory (LANL) nor the Nevada Test Site (NTS) has rail capability, but combined, these sites only account for five percent of the shipment miles.[58] Their truck transportation costs were included in the tabulation for rail to enable inter-comparison.

There are two important caveats to consider regarding estimates of these direct-carrier costs. First, transportation regulations restrict individual shipments in terms of weight, volume, hydrogen gas generation, plutonium concentration, criticality, and heat generation, which all affect the number of shipments and the costs of their shipment. Second, since more than half the waste has yet to be produced and its characteristics are not yet known, those constraints preclude precise estimates of the number of shipments from the various sites and their associated transportation costs.

In summary, truck carrier costs are more than three times as expensive as rail as reported in table 2. Carrier costs are major contributors to total cost for both truck and rail.

B. Shipping Containers

Rail could carry three times more shipping containers than each truck shipment.[59] The truck fleet for CH-TRU waste requires 60 TRUPACTS according to DOE[60] at a cost of $0.3 million each, for a total of $18 million. Rail shipments could require three times the number of TRUPACTS for a cost of $54 million. While the NRC allows the shipment to be evaluated together with the transporting vehicle,[61] the DOE's Safety Analysis Report is silent on any request to certify the TRUPACT with the transportation vehicle.[62] In effect, this means that the certification would not have to be redone for rail. The shipping trailer has been extensively field-tested and meets DOT regulations.[63] For shipments of CH-TRU that exceed weight limits, a smaller container (Halfpack)[64] is being developed for certification by NRC. Although cost estimates for the Halfpack are not available, DOE

57. DOE reports include Estimates in 1993 and 1994 dollars. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at ES-6 (in 1993 dollars); II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-6 (in 1994 dollars).

58. These values are 4.4% of the CH-shipment miles and 1.2% of the RH-shipment miles. *See infra* Tables B-1 & B-2.

59. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 7-3, 7-7.

60. *See* NATIONAL TRU PLAN, *supra* note 5, at 53.

61. *See* Packaging and Transportation of Radioactive Material, Package Approval Standards, 10 C.F.R. § 71.41(b) (1999).

62. *See* WESTINGHOUSE ELECTRIC CORP., SAFETY ANALYSIS REPORT FOR THE TRUPACT-II SHIPPING PACKAGE (Rev. 17 1999).

63. *See* Parts and Accessories Necessary for Safe Operation, 49 C.F.R. § 393 (1998).

64. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-3; II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-13.

has estimated that 15 TRUPACTS could be replaced with Halfpacks. Similarly, the NRC has not yet approved the shipping container for the RH-TRU waste, so cost estimates are not available. Thus, for CH-TRU waste, the container cost would increase by $54 million if transport were shifted to rail. No estimates can be provided for RH-TRU waste containers. To summarize, while table 2 shows the cost of CH-TRU shipping containers for rail is more expensive than truck, the amount saved is less than two percent of the total cost for truck.

C. Emergency-Response Capability

DOE has conducted a major effort over the past decade to ensure an emergency-response capability by training personnel and by making equipment available to police and fire departments as required in the WIPP Land Withdrawal Act (1992).[65] Description of the required training program is codified in federal regulations issued by the Occupational Safety and Health Administration (OSHA).[66] Routes have been designated by DOT regulations [67] following public hearings. DOE did not estimate costs for the emergency-response capability required for either truck or rail in its 1994 or 1997 document. [68]

D. Couriers or Drivers

A courier trained in radiological emergency response and equipped with radiation-detection instrumentation could accompany the rail shipments to provide greater assurance of public safety, as has been done with High Level Waste shipments. Costs for couriers and cabooses for sleeping arrangements are estimated to be $704 million. Truck transport costs include costs of drivers. As table 2 shows, no comparisons can be made between truck and rail with respect to drivers or couriers because these expenses are included in carrier costs for trucks. While the costs of couriers is significant for rail, a comparison of carrier costs between truck and rail, including the cost of couriers, shows that truck is significantly more expensive than rail.

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65. Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, § 16(c), 106 Stat. 4777, 4791 (1992), *amended by* Waste Isolation Pilot Plant Land Withdrawal Amendment Act, Pub. L. No. 104-201, §§ 3181-91, 110 Stat. 2422, 2851-54 (1996).

66. Hazardous Waste Operations and Emergency Response, 29 C.F.R. § 1910.120 (1999).

67. Routing and Training Requirements for Radioactive Materials, 49 C.F.R. §§ 397.101, 397.103 (1998).

68. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 1-6; I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 5-14 to 5-15.

E. Road and Rail Upgrades

Cost estimates exist for upgrading roads but not for upgrading rail beds. New Mexico has received federal funding and is expected to receive additional federal funding for WIPP. The state has elected to invest in upgrading roads and building bypasses for the shipments to WIPP. Federal funding currently exceeds $300 million of the total estimated cost for WIPP highway improvements of $490 million.[69] No estimates are available for upgrading rail beds to comparable levels of safety. DOE has built a rail spur to the WIPP site. Although the rail lines are owned by private corporations and are independent of federal funding, the precedent has been established to use federal funds for Amtrak when it has been in the public interest. Therefore, public funds could be used to upgrade rail lines. If rails move radioactive shipments at a slower speed than regular rail shipments, as has been done for High Level Waste shipments, some form of fair financial compensation could be made by the government to the rail carrier for lost revenues. This would increase the transportation cost by rail. Due to the absence of estimates for upgrades and compensation to rail carriers, one cannot make a meaningful cost comparison between truck and rail with respect to upgrades.

F. Accidents and Fatalities

DOE estimates the risks from rail are lower than from truck.[70] Considerable experience in the successful transportation of radioactive material has demonstrated that the risks of both rail and truck transportation are quite low.[71] Estimates by DOE of truck accidents and fatalities are shown in table 1,[72] since half the waste has yet to be produced and the total

69. *See* Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, § 15, 106 Stat. 4777, 4793 (1992), *amended by* Waste Isolation Pilot Plant Land Withdrawal Amendment Act, Pub. L. No. 104-201, §§ 3181-91, 110 Stat. 2422, 2851-54 (1996); NEW MEXICO STATE HIGHWAY & TRANSP. DEP'T, WASTE ISOLATION PILOT PLANT TRANSPORTATION INFRASTRUCTURE STATUS REPORT 1 (1996).

70. *See* Record of Decision for the Department of Energy's Waste Isolation Pilot Plant Disposal Phase, 63 Fed. Reg. 3624, 3628 (1998).

71. *See* C. SARICKS & T. KVITEK, LONGITUDINAL REVIEW OF STATE LEVEL ACCIDENT STATISTICS FOR CARRIERS OF INTERSTATE FREIGHT 20 (Argonne National Laboratory Doc. No. ANL/ESD/TM-68, 1994). Foster and Jordan acknowledge that radioactive materials have a better transportation record than any other type of hazardous material. *See* BARBARA FOSTER & JULIE JORDAN, A GUIDE TO RADIOACTIVE MATERIALS TRANSPORTATION 50 (Sandia National Laboratories No. SAND84-7143, Sharon Bjorkman ed., 1984).

72. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-26 to E-29 tbl.E-8, E-55, E-66.

number of shipments may vary. Consequences of rail transport shown in the table were interpolated from values based on the number of shipments in the seven alternative rail analyses.[73] The difference of 4.6 deaths between the estimated total of 8.8 deaths by truck and 4.2 deaths by rail over a 35-year period is a soft calculation. Society has established more stringent efforts to prevent deaths from radioactive exposure than from other sources. In quantifying this disparity, Tengs et al.[74] estimated in 1993 dollars that for transportation the median cost per life saved each year was $56,000, accomplished by reducing fatal injuries. By comparison, the environmental sector had a median annual cost per life saved each year of $4.2 million, all by controlling toxins. The concept that society values five traffic fatalities at $280,000 and 3.7 radiation-induced fatalities at $15.5 million is illogical. Similarly for rail, the value of three accident fatalities and 1.2 radiation-induced latent cancer fatalities totals $5.2 million. Based on our willingness to fund efforts to prevent fatalities, the analysis shows that the value of lives lost by truck transport to WIPP is $15.8 million and the value of lives lost through transport by rail is $5.2 million. The calculation is of dubious merit but illustrates inconsistencies in our willingness to fund activities to reduce different perceived risks. A National Research Council report recognized the complex basis of such inconsistencies in risk perceptions, including compensating benefits.[75] Table 2 shows those costs for the rail and truck options.

DOE did not calculate the number of rail accidents for any of the rail alternatives. Saricks and Kvitek calculated accident rates for truck and rail.[76] Considering a total distance of 106 million miles by truck and 55 million miles by rail,[77] this yields 41 truck accidents and only five rail accidents.

73. *See id.* at E-68 to E-71, tbls.E-29 to E-32.

74. *See* Tammy O. Tengs et al., *Five-Hundred Life-Saving Interventions and Their Cost-Effectiveness*, 15 RISK ANALYSIS 369, 371 tbl.1 (1995).

75. *See* NATIONAL RESEARCH COUNCIL, IMPROVING RISK COMMUNICATION 172, 175 fig.7.1 (1989).

76. *See* SARICKS & KVITEK, *supra* note 71, at 32 tbl.A.4, 36 tbl.A.5b (3.9×10^{-7} accidents per mile for truck and 9×10^{-8} accidents per mile for rail).

77. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9 tbl.D-11.

TABLE 1: IMPACTS OF TRU WASTE SHIPMENTS TO WIPP BY TRUCK AND RAIL

	Truck[78]	Rail[79]
Accidents	56[80]	
Injuries	39	
Fatalities	5	3
Vehicle Pollution (LCF)[81]	0.1[82]	
Accident-Free Occupational Radiation Impacts[83] (LCF)	0.3[84]	0.3
Accident-Free Non-Occupational Radiation Impacts[85] (LCF)	3[86]	0.6
Radiological Accidents[87] (LCF)	0.4[88]	0.3
Total Deaths Including LCF	8.8	4.2

G. Summary of Truck and Rail Costs

The estimated costs, which are not totally comparable due to the unavailability of various parameters, indicate truck costs are approximately $1,900 million and rail costs $1,300 million. Conclusions should not be drawn since they would be based on a number of uncertainties discussed below. The cost estimates of rail include the costs of truck shipments from LANL and NTS, as well as consolidation of shipments by truck from the smaller generator sites. Note that estimates are not available of the existing

78. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-28 tbl.E-9.

79. *See id.* at E-68 to E-71 tbls.E-29 to E-32 (predictions of health effects from rail transport were all prorated from the number of shipments of rail alternatives).

80. *See id.* at E-28 tbl.E-9.

81. Latent cancer fatalities.

82. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-28 tbl.E-9.

83. Radiation induced latent cancer fatalities in workers resulting from normal transportation.

84. *See* II DISPOSAL PHASE SEIS, *supra* note 5, at E-38 tbl.E-14.

85. Radiation induced latent cancer fatalities in the general population resulting from normal transportation.

86. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-38 tbl.E-14.

87. Radiation induced latent cancer fatalities resulting from severe accidents.

88. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-53 tbl.E-22.

emergency-response capability for truck or of the costs to establish a similar capability along rail lines. Cask costs for the RH-TRU wastes are not available. Rail courier costs include cabooses for living arrangements. However, while cost is important, it is not the only factor in the decision-making process. Table 2 summarizes the overall costs of transporting the TRU waste by rail and truck.

TABLE 2: ESTIMATED TOTAL TRANSPORTATION COSTS TO WIPP OF TRUCK AND RAIL TRANSPORT

	Truck ($ million)	Rail ($ million)
Carrier Cost	1,600	525
Emergency Response	Not Available	Not Done
Road Upgrades	300	Unknown
Drivers or Courier	Included in Costs	704
Shipping Containers[89]	18	54
Value of Lives Lost	15.8	5.2
Approximate Total Costs	1,935	1,290

H. Inconsistencies in DOE Analyses

The following provides some examples of inconsistencies in DOE reports that affect the ability to estimate transportation costs with accuracy. First, table 3 shows the variations in distances from the generating sites to WIPP used in truck calculations in DOE reports. Second, the difference is substantial between total truck miles to WIPP in different DOE reports. DOE shows the total TRU waste truck miles to WIPP as 74 million miles in the 1995 Engineered Alternatives Report[90] and 106 million miles in the 1997 Disposal Phase Final SEIS.[91] Third, the "preferred alternative" for the 1997 DOE Programmatic EIS is to treat and store waste at sites where generated, and then ship to WIPP,[92] producing results that are not fully comparable with the 1997 Disposal Phase Final SEIS, which states a "proposed action" of meeting the WIPP WAC and then shipping to WIPP.[93] Fourth, the

89. This calculation is only for CH-TRU TRUPACT shipping containers.

90. *See* ENGINEERED ALTERNATIVES, *supra* note 5, at P-89 tbl.P-53, P-110 tbl.P-74.

91. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9 tbl.D-11.

92. *See* PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE, *supra* note 5, at 119 (Summary).

93. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 3-2.

number of shipments to WIPP will be proportional to the quantity of waste requiring disposal, and that exact quantity is unknown. Table 4 illustrates the variation in projected quantities of RH-TRU waste that will be generated at Hanford. The DOE estimated the stored (existing) waste plus the projected (yet-to-be-generated) pre-treatment volume to be 29,000 cubic meters and the post-treatment volume to be 42,000 cubic meters at Hanford.[94] The disposal of RH-TRU at WIPP is limited to 7,080 cubic meters,[95] so it is important to note that DOE may have 50,000 cubic meters of RH-TRU waste to dispose of, 42,000 cubic meters of which would originate at Hanford. Hence, the RH quantities at Hanford may require 44,000 additional shipments. Alternatives for the disposal of this waste include (a) modification of the Consultation and Cooperation Agreement between New Mexico and the DOE to increase the 7,080 cubic meters disposal limit at WIPP,[96] (b) modification of the WIPP Land Withdrawal Act,[97] (c) decontamination of the RH-TRU waste—an expensive and hazardous endeavor, or (d) EPA approval for another deep geological repository. Fifth, although DOE evaluated both regular train and dedicated train options for all the alternatives not selected, it did not evaluate the rail option for the proposed action.[98] Sixth, table 5 shows the variation in the estimated number of truck shipments in different reports. Seventh, DOE did not include the cost of transporting 77,600 metric tons of magnesium oxide to be emplaced as backfill around the waste in the repository to decrease the solubility of the waste and improve the long-term repository performance. Assuming typical truck shipments of 44,000 pounds, this would require 3,900 shipments. Rail shipments of 38,000 pounds per container and three containers per rail car would require 1,500 rail shipments. Eighth, table 6 documents considerable variability in the relative costs of rail and truck for identical shipments to WIPP in different DOE reports.[99]

94. *See id.* at 3-3 tbl.3-1.

95. *See* Agreement for Consultation and Cooperation, July 1, 1981, State of N.M.–U.S. Dep't of Energy, at art. VI, c & c-5.

96. *See id.*

97. Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, 106 Stat. 4777 (1992), *amended by* Waste Isolation Pilot Plant Land Withdrawal Amendment Act, Pub. L. No. 104-201, §§ 3181-91, 110 Stat. 2422, 2851-54 (1996).

98. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9 tbl.D-11.

99. Each report considers different time periods as well as different assumptions.

TABLE 3: DISTANCE TO WIPP

Site	Mileage stated in DOE Programmatic EIS[100]	Mileage stated in DOE Disposal Phase Final SEIS[101]
Hanford	2,175	1,807
INEEL	1,759	1,392
LANL	693	341
Rocky Flats	1,067	704

100. *See* IV PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE, *supra* note 5, at E-24 tbl.E-2.

101. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-22 tbl.E-5.

TABLE 4: ESTIMATED PROJECTED INCREASE IN VOLUME OF RH-TRU WASTE AT HANFORD (m^3)

Source	Projected
DOE Transuranic Waste Baseline Inventory Report[102]	21,500
DOE Hanford's Remote-Handled Waste Volume Assessment[103]	3,470
DOE TRU Baseline Inventory Report[104]	22,000
DOE National Transuranic Waste Management Plan[105]	2,420
DOE Disposal Phase Final SEIS[106]	28,800
DOE Disposal Phase Final SEIS[107]	29,200[108]
DOE Integrated Data Base Report[109]	1,660
DOE National TRU Plan[110]	1,582

102. *See* U.S. DEP'T OF ENERGY, DOC. NO. DOE/CAO-95-1121 REV. 2, TRANSURANIC WASTE BASELINE INVENTORY REPORT, 4-10 tbl.4-9 (1995).

103. *See* K.J. TEMPLETON ET AL., HANFORD'S REMOTE-HANDLED TRANSURANIC AND TRANSURANIC MIXED WASTE VOLUME ASSESSMENT: MARCH 1996 1.4 tbl.1.2 (U.S. Dep't of Energy, Doc. No. PNNL-11206 1996).

104. *See* TRU BASELINE INVENTORY REPORT, *supra* note 5, at ES-7 tbl.ES-4.

105. *See* U.S. DEP'T OF ENERGY, DOC. NO. DOE/NTP 96-1204 REV. 0, THE NATIONAL TRANSURANIC WASTE MANAGEMENT PLAN 2 tbl.1-1 (1996).

106. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 2-6, tbl.2-2.

107. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at J-3 tbl.J-2.

108. Only 2,800 cubic meters will be shipped to WIPP. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 3-3 n.i.

109. *See* U.S. DEP'T OF ENERGY, DOC. NO. DOE/RW-006 REV. 13, INTEGRATED DATA BASE REPORT–1996: U.S. SPENT NUCLEAR FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS AND CHARACTERISTICS 3-7 tbl.3.1 (1997).

110. NATIONAL TRU PLAN, *supra* note 5, at 3 tbl.1-1.

TABLE 5: ESTIMATED NUMBER OF TRUCK SHIPMENTS

Study	CH-TRU	RH-TRU	Total
DOE Comparative Transportation Alternatives[111]	19,145	9,389	28,534
DOE Engineered Alternatives[112]	17,690	7,958	25,648
DOE Programmatic EIS[113]	Not Done	Not Done	23,900
DOE Disposal Phase Final SEIS[114]	29,766	7,957	37,723

111. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 7-3 tbl.7-1, ES-2.

112. *See* ENGINEERED ALTERNATIVES, *supra* note 5, at P-89 tbl. P-53, P-110 tbl.P-74.

113. *See* IV PROGRAMMATIC EIS TREATMENT, STORAGE DISPOSAL WASTE, *supra* note 5, at E-74 tbl.E-21 (only includes 20 years of TRU waste generation).

114. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at E-15 tbl.E-1, E-17 tbl.E-2. Consolidation requires 27 additional CH and 958 RH shipments. *See id.* at E-19 tbl.E-3.

TABLE 6: COST OF TRUCK AND RAIL

Study	Truck (millions $)	Rail (millions $)	$ Rail/$ Truck
DOE (1994)	236.8[115]	184.4[116]	0.8
DOE (1994)	258.1[117]	334[118]	1.3
Feizollahi et al. (1994)	Not Done	Not Done	1.2[119]
DOE (1995)	929[120]	Not Done	—
DOE (1997)	560[121]	1,440[122]	2.6
DOE (1997)	1,590[123]	525[124]	0.33

IV. RAIL SHIPMENTS FROM HANFORD AND INEEL

Radioactive wastes will be shipped to WIPP over 35 years. It made sense to begin the transport of the CH-TRU wastes by truck because DOE has established a truck-based system: two sites do not have a rail capability, routes have been designated via DOT regulations, an emergency-response capability has been established, highway routes have been upgraded, and shipments from sites with small quantities of waste can best be consolidated with trucks. Hanford and INEEL are the major producers. They will have 65 percent of the total CH-TRU waste and 80 percent of the RH-TRU waste slated for WIPP. They will also have the greatest potential for cost and risk reduction. The following factors support our recommendations that DOE reconsider the use of regular rail shipments from Hanford and INEEL.

115. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at ES-6 (contract rate).

116. *See id.*

117. *See id* at ES-6 (commercial rate).

118. *See id.*at ES-6, 7-8 tbl.7-7 (class rate).

119. Calculated based on Feizollahi's equations for 1500 miles. *See* FRED FEIZOLLAHI ET AL., WASTE MANAGEMENT FACILITIES COST INFORMATION FOR TRANSPORTATION OF RADIOACTIVE AND HAZARDOUS MATERIALS, 11-12 (Idaho National Engineering Laboratory Doc. No. EGG-WM-10877, Rev. 1 1994).

120. *See* ENGINEERED ALTERNATIVES, *supra* note 5, at P-89 tbl.P-53, P-110 tbl. P-74 (value is sum of totals on these two tables).

121. *See* I PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE, *supra* note 5, at 8-73 tbl.8.14-2 (Life Cycle Costs billions of 1994 dollars).

122. *See id.*

123. *See* I DISPOSAL PHASE FINAL SEIS, *supra* note 5, at 5-10 tbl.5.2.

124. Calculated. See tables B-3 through B-5.

a. Shipments of the RH-TRU are not scheduled to begin until 2006 from Hanford and 2007 from INEEL, which will give DOE time to plan for shipment by rail.

b. The 65,000 cubic meters of CH-TRU waste to be processed at INEEL, which amounts to 37 percent of the WIPP total inventory of 175,000 cubic meters, will be available at the earliest in 2003.[125] The facility will have the capability to process an additional 120,000 cubic meters.[126] Hence, INEEL may have much more waste to ship, which would make savings by rail even greater.

c. The presence of a radiological protection courier accompanying the shipments could reduce the need of detailed first-responder training in the event of an accident. Such knowledgeable couriers would improve public confidence.

d. There is a slight decrease in accidents and fatalities with rail.

e. Cost may be reduced by $617 million, as shown below.

Using DOE's assumptions, waste cars in a regular train would be flanked by idler or buffer cars.[127] Accommodations for a courier trained in radiation emergency response to accompany the train would be provided by a caboose. All costs were taken from DOE,[128] with the exception of the courier. Courier costs were estimated by determining both the average number of shipments per year, assuming a round trip of 18 days from Hanford and 16 days from INEEL, and the number of couriers required per year. Annual salaries were assumed to be $50,000 with 100 percent overhead.[129]

The use of a caboose for living arrangements and salary for a radiation protection specialist, based on cost estimates, increase the CH-TRU cost for rail by $155 million for Hanford and $56 million for INEEL.[130] Even with these increased costs, the savings by the use of rail are still $339 million for Hanford and $126 million for INEEL. Figure 5 shows the comparative costs for the carriers and couriers. Costs for emergency response, possible rail upgrades, and shipping containers are not included since they were unavailable. Costs for radiological couriers and cabooses in transporting RH-TRU waste are $38 million and $31 million, respectively. Figure 6 illustrates the potential savings of $81 million by rail for

125. *See* INEEL ROD Advanced Mixed Waste Treatment Project, 64 Fed. Reg. 16948, 16949 (1999). DOE was required to begin shipping 3,100 cubic meters of waste from INEEL by April 30, 1999, under terms of a Settlement Agreement/Consent Order. *See id.*

126. *See id.* at 16948.

127. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 1-5.

128. *See id.* at 7-10.

129. The authors assumed this would be a fair salary for technically trained couriers and an equal amount for overhead was reasonable.

130. *See id.*

Hanford and $71 million by rail for INEEL. This comparison does not include the costs of shipping casks or emergency-response training. Note that the use of rail at these two sites has a potential saving of $617 million. The use of several rail cars for a given shipment could reduce costs even more. These findings support the recommendation that DOE should reexamine the use of rail for two of the generator sites.

V. CONCLUSIONS

Various commitments and constraints preclude shipments completely by rail, including the consolidation of shipments from minor sites and the absence of a rail capability at two sites. However, rail shipments from INEEL and Hanford, the major waste generators accounting for 65 percent of the CH-TRU waste and 80 percent of the RH-TRU waste shipments, warrant further investigation, particularly for all the RH-TRU wastes that will not be shipped until 2006. Substantial savings of over $600 million as well as a slight reduction in risk are potential benefits of rail transport for these two sites.

As demonstrated in section III, there are substantive differences in DOE reports regarding total mileage to WIPP, projected quantities of waste, number of shipments, and cost. Conflicting and inconsistent data and analyses tend to undermine confidence in the DOE determination that truck is the preferred option for all shipments.

Additionally, individual shipments have limits on weight, volume, hydrogen gas generation, plutonium concentration, criticality, and heat generation. Because half the TRU waste has yet to be generated and its characteristics are unknown, it is impossible to estimate precisely the number of shipments and their eventual cost.

Furthermore, the amount of waste to be disposed of at WIPP may be considerably greater than the 175,000 cubic meters currently authorized. Hence, future shipments may increase substantially, whether to WIPP or some other repository or facility for processing.

Based on our findings, we make six recommendations to DOE to save public funds and reduce risks: (1) analyze the costs of using regular trains to transport CH-TRU and RH-TRU wastes from Hanford and INEEL; (2) analyze shipments based on three RH-72-B casks per railcar and nine TRUPACTS per railcar, which could cut rail shipments by 50 percent; (3) consider contract rates for regular trains and work with rail companies to inform them of the level of business available and the free use of the space-tracking system, TRANSCOM, that may have applications in tracking other rail shipments; (4) assess the merits of radiation-protection specialists as couriers to accompany shipments, thus ensuring public confidence; (5) obtain bids of actual rates from rail companies along with truck companies to promote competition and reduce costs; and (6) determine the fraction of the existing emergency-response system for trucks that could be adapted for rail shipments. DOE should begin detailed analyses now in order to be able to use rail transport in several years.

The authors hope to have stimulated interest in addressing anew the benefits and reduced risks associated with the use of rail shipments from two sites. Our analysis of the data, however imperfect, suggests that a reconsideration of the DOE decision regarding the use of rail may in some instances best serve the public interest.

FIGURE 5: TRUCK AND RAIL DIRECT COSTS TO TRANSPORT CH-TRU WASTE TO WIPP, INCLUDING COURIER AND CABOOSE

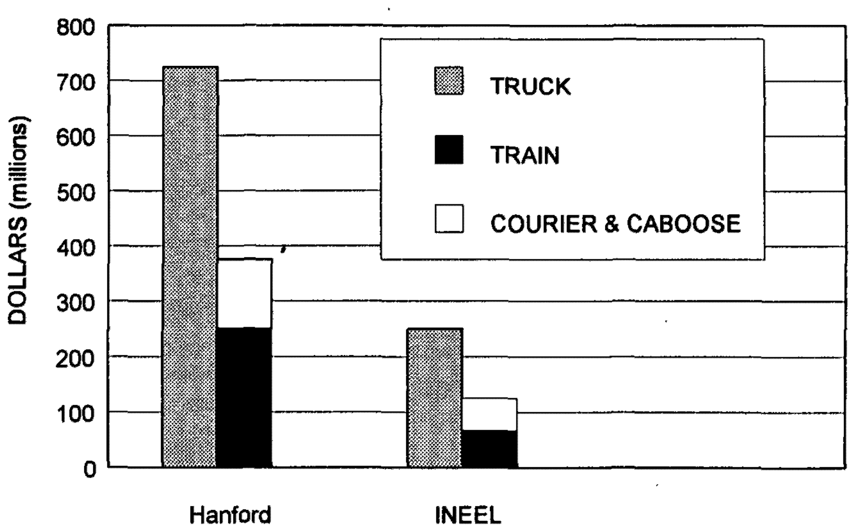
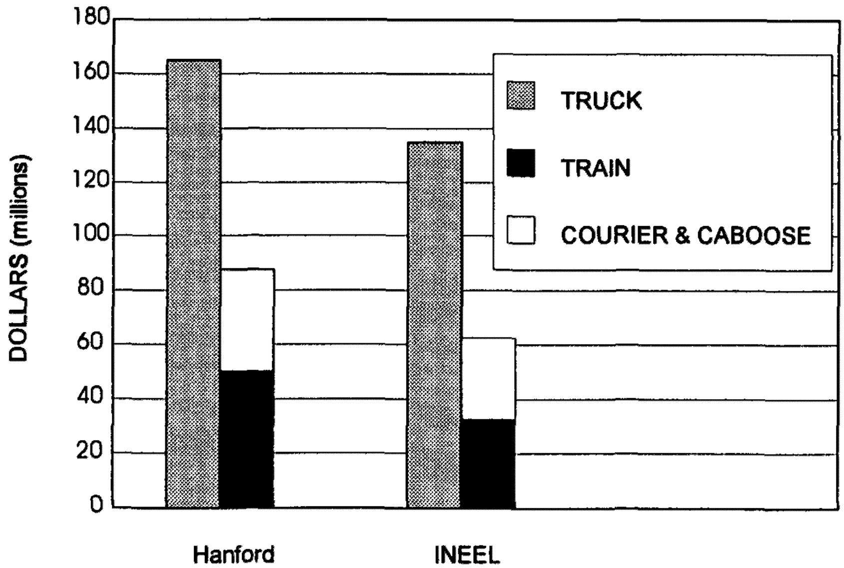


FIGURE 6: TRUCK AND RAIL DIRECT COSTS TO TRANSPORT RH-TRU WASTE TO WIPP, INCLUDING COURIER AND CABOOSE



APPENDIX A

METHOD OF CALCULATING COSTS

Several different studies have calculated transportation costs. Table A-1 cites the equations used in various studies. Q equals the number of truck shipments with three TRUPACT containers or one RH-72B cask; M stands for one-way mileage, and cost per loaded mile (CPLM). DOE[131] estimated truck transportation costs by adding fixed and variable costs as follows:

Total Cost = Q [$ 9,260 + CPLM(M)2)].

It was based on the 1995 DOE equation that used a variable CPLM.[132] That study in turn used the 1994 Feizollahi study with different CPLM values.[133] The DOE Programmatic EIS[134] calculations were based on the 1995 Feizollahi study.[135]

Rail shipment costs in the 1997 DOE Disposal Phase SEIS[136] were based on the 1994 Comparative Transportation Alternatives report,[137] which used a variable cost of $13,880 to $32,841 cost per rail shipment depending on the distance traveled. Rail shipments assumed six TRUPACTS or two RH-72B casks.[138] Hence the number of rail shipments are half the number of truck shipments.

The equations are not directly comparable since shipments may be limited by mass, criticality, or hydrogen concentration. They are provided to show the basic approach used.

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131. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9 tbl.D-11.

132. *See* ENGINEERED ALTERNATIVES, *supra* note 5, at P-28.

133. *See id.* at P-27; FEIZOLLAHI ET AL., *supra* note 119, at 11.

134. *See* III PROGRAMMATIC EIS TREATMENT, STORAGE, DISPOSAL WASTE, *supra* note 5, at C-36.

135. *See id.*; FRED FEIZOLLAHI ET AL., WASTE MANAGEMENT FACILITIES COST INFORMATION FOR TRANSPORTATION OF RADIOACTIVE AND HAZARDOUS MATERIALS (Idaho National Engineering Laboratory Doc. No. INEL-95/0300 Rev. 1, 1995) (formerly FRED FEIZOLLAHI ET AL., WASTE MANAGEMENT FACILITIES COST INFORMATION FOR TRANSPORTATION OF RADIOACTIVE AND HAZARDOUS MATERIALS (Idaho National Engineering Laboratory Doc. No. EGG-WM-10877 Rev. 1, 1994)).

136. See II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-8.

137. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 7-8 tbl.7-7.

138. *See id.* at ES-4.

TABLE A-1: EQUATIONS

Source	Transport	Cost Equation	Values
Feizollahi et al. (1994)[139]	Truck	Q[$4,630 + CPLM (M)]	CPLM varies from $9.31 to $19.65 per mile
DOE (1995)[140]	Truck	Q[$9,260 + CPLM (M)2]	CPLM varies from $9.31 to $10.87 per mile
DOE (1994)[141]	Truck–Contract	Q[$/shipment]	$/shipment varies from $2,469 to $9,755
DOE (1994)[142]	Truck–Commercial	Q[CPLM(M)2]	CPLM is $2.91 per mile
DOE (1997)[143]	Truck	Q[$9,260 + CPLM(M)2]	CPLM is $12 per mile
DOE (1994)[144]	Rail	Q/2[$/shipment]	$/shipment varies from $13,880 to $32,841.
DOE (1997)[145]	Rail	Same as DOE (1994)	Same as DOE (1994)

139. *See* FEIZOLLAHI ET AL., *supra* note 135, at 11-12.

140. *See* ENGINEERED ALTERNATIVES, *supra* note 5, at P-89 tbl.P-53, P-110 tbl.P-74.

141. *See* COMPARATIVE TRANSPORTATION ALTERNATIVES, *supra* note 5, at 7-4 tbl.7-2.

142. *See id.* at 7-5 tbl.7-4.

143. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-9. The $0.12 per mile given in this reference is an error and should be $12.00 per mile. *See* Letter from Harold Johnson, NEPA Compliance Officer, *U.S. Department of Energy*, to Christa Hazlett, Editor, *Natural Resources Journal* (Feb. 4, 2000) (on file with the *Natural Resources Journal*).

144. *See* COMPARATIVE TRANSPORTATION ALTERNATIVE, *supra* note 5, at 7-8 tbl.7-7.

145. *See* II DISPOSAL PHASE FINAL SEIS, *supra* note 5, at D-8.

TABLE B-1: CALCULATING CH-TRU WASTE TRUCK TRANSPORTATION COSTS

SITE	TOTAL SHIPMENTS	FIXED COSTS (MILLION $)	ONE WAY DISTANCES TO WIPP (MILES)	TOTAL SHIPMENT MILES (MILLION MILES)	VARIABLE COSTS (MILLION $)	TOTAL COSTS (MILLION $)
HANFORD	13,666	126.5	1,807	49.4	592.7	719.2
INEEL	5,782	53.5	1,392	16.1	193.2	246.7
ANL-E	28	0.3	1,696	0.1	1.1	1.4
LLNL	162	1.5	1,452	0.5	5.6	7.1
LANL	5,009	46.4	341	3.4	41.0	87.4
MOUND	59	0.5	1,764	0.2	2.5	3.0
NTS	86	0.8	1,214	0.2	2.5	3.3
ORNL	251	2.3	1,439	0.7	8.7	11.0
RFETS	2,485	23.0	704	3.5	42.0	65.0
SRS	2,238	20.7	1,535	6.9	82.4	103.2
TOTAL	29,766	275.6		81.0	971.7	1247.4

TABLE B-2: CALCULATING RH-TRU WASTE TRUCK TRANSPORTATION COSTS

SITE	TOTAL SHIPMENTS	FIXED COSTS (MILLION $)	ONE WAY DISTANCE TO WIPP (MILES)	TOTAL SHIPMENT MILES (MILLION MILES)	VARIABLE COSTS (MILLION $)	TOTAL COSTS (MILLION $)
HANFORD	3,178	29.4	1,807	11.5	137.8	167.3
INEEL	3,136	29.0	1,392	8.7	104.8	133.8
ANL-E	0	0.0	1,696	0.0	0.0	0.0
LLNL	0	0.0	1,452	0.0	0.0	0.0
LANL	367	3.4	341	0.3	3.0	6.4
MOUND	0	0.0	1,764	0.0	0.0	0.0
NTS	0	0.0	1,214	0.0	0.0	0.0
ORNL	1,276	11.8	1,439	3.7	44.1	55.9
RFETS	0	0.0	704	0.0	0.0	0.0
SRS	0	0.0	1,535	0.0	0.0	0.0
TOTAL	7,957	73.7		24.1	289.7	363.3

TABLE B-3: CALCULATING CH-TRU WASTE RAIL TRANSPORTATION COSTS

SITES	TOTAL TRUCK SHIPMENTS	NUMBER RAIL CARS	$ ROUND TRIP PER CARLOAD	TOTAL COSTS (MILLION $)
HANFORD	13,666	6,833	32,841	224.4
INEEL	5,782	2,891	22,321	64.5
ANL-E	28	14	19.165	0.3
LLNL	162	81	24.320	2.0
LANL*	5,009	0	0	87.4
MOUND	59	30	31,363	0.9
NTS*	86	0	0	3.3
ORNL	251	126	23,309	2.9
RFETS	2,485	1,243	13,880	17.3
SRS	2,238	1,119	20,825	23.3
TOTAL	29,766	12,337		426.3

(*) Rail unavailable, transport by truck.

TABLE B-4: CALCULATING RH-TRU WASTE RAIL TRANSPORTATION COSTS

SITES	TOTAL TRUCK SHIPMENTS	NUMBER RAIL CARS	$ ROUND TRIP PER CARLOAD	TOTAL COSTS (MILLION $)
HANFORD	3,178	1,589	30,166	47.9
INEEL	3,136	1,568	20,504	32.2
ANL-E	0	0	17,605	0
LLNL	0	0	0	0
LANL*	367	0	0	6.4
ORNL	1,276	638	18,162	11.6
TOTAL	7,957	3,795		98.1

(*) Rail unavailable, transport by truck.

TABLE B-5: COMPARISON OF TRANSPORTATION COSTS FOR TRUCK AND RAIL

CH-TRU COSTS	**TRUCK**	**TRAIN**
	(Million $)	**(Million $)**
HANFORD	719.2	224.4
INEEL	246.7	64.5
ANL-E	1.4	0.3
LLNL	7.1	2.0
LANL	87.4	87.4
MOUND	3.0	0.9
NTS	3.3	3.3
ORNL	11.0	2.9
RFETS	65.0	17.3
SRS	103.2	23.3
TOTAL	**1247.3**	**426.3**
RH-TRU COSTS	**TRUCK**	**TRAIN**
	(Million $)	**(Million $)**
HANFORD	167.3	47.9
INEEL	133.8	32.2
ANL-E	0.0	0.0
LLNL	0.0	0.0
LANL	6.4	6.4
MOUND	0.0	0.0
NTS	0.0	0.0
ORNL	55.9	11.6
RFETS	0.0	0.0
SRS	0.0	0.0
TOTAL	**363.4**	**98.1**
TOTAL FOR BOTH RH & CH	**1610.7**	**524.4**