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Additional Information on Monitored Retrievable Storage

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EXECUTIVE SUMMARY

On March 31, 1987, the Department of Energy (DOE) submitted to the Congress, in response to Section 141 of the Nuclear Waste Policy Act of 1982 (the Act), a proposal for the construction of a facility for monitored retrievable storage (MRS). The proposed MRS facility would be fully integrated into the overall waste-management system to serve as a centralized facility for receiving spent fuel from commercial reactors, for preparing spent fuel for permanent disposal in a geologic repository, and for temporarily storing a limited amount of the prepared waste pending shipment to the repository.

The integrated MRS facility offers important advantages that would benefit both development and operation of the overall waste management system. The MRS facility would improve system development by providing a stepwise approach to moving from the current state of experience to full-scale operation of a disposal system including a repository. It would allow DOE to proceed immediately to plan for, and implement a major part of, the waste-management system independent of the remaining issues to be resolved about the repository. The siting and construction of an MRS facility would also yield major institutional benefits by making a significant step forward that would give added momentum for implementing the entire system and provide experience at interactions with a host State and local community that would benefit later relations with the repository host.

The MRS facility would enhance the operation of the waste-management system in several important ways. It would accelerate waste acceptance, thus reducing the need for new temporary storage facilities at reactors and the attendant spent-fuel-handling operations, licensing efforts, and costs. The buffer-storage capacity of the MRS facility would provide improved system reliability and flexibility by allowing the functions of spent-fuel acceptance from reactors and spent-fuel emplacement in the repository to proceed independently, so that interruptions in one would not affect the other. It would simplify facilities and operations at the repository by shifting a major part of waste-package preparation to another site. Finally, it would improve transportation by allowing the longest leg of the journey from the reactor to the repository to take place in very large casks on dedicated trains, thereby reducing the costs and impacts of waste transportation.

These benefits can be obtained at a reasonable cost. Recent estimates show that the overall cost for the development and operation of a waste-management system that includes an MRS facility would be approximately \$1.5 to \$1.6 billion higher than that for a system without an MRS facility. This difference is less than 5 percent of the total-system life-cycle costs for the current reference system without an MRS facility.

Since the DOE developed the MRS proposal for the Congress, a number of questions have been raised by the General Accounting Office (GAO), the State of Tennessee, and others concerning the need for the MRS facility and the feasibility of achieving comparable performance for the overall waste-management system without an MRS facility. This report was prepared to provide additional information to address these questions.

This report reviews potential modifications to the currently authorized system (the "reference no-MRS system"); describes and compares alternative no-MRS systems that incorporate these potential modifications to varying degrees; and provides a summary comparison of a modified no-MRS system with a similar system that includes an MRS facility. Also included are additional information on the views of some U.S. utilities on the need for the MRS facility and preliminary estimates of institutional costs identified but not quantified in the DOE's proposal to the Congress.

Nothing in this analysis indicates the need for any substantive changes in the conclusions reached in the DOE's proposal about the system benefits and costs of an integrated MRS facility. The research and development programs described in the DOE's proposal to the Congress may yield technological advances that can improve the waste-management system with or without an integrated MRS facility. However, none of these advances appears likely to significantly alter the net relative advantages offered by the MRS facility or the relative costs of adding that facility to the system.

In particular, the system-development and institutional benefits of the MRS facility can best be obtained by the construction and operation of a large-scale centralized waste-management facility--the MRS facility--several years before the first geologic repository. Without an MRS facility, many of the first-of-a-kind technical and institutional challenges of waste management and disposal will be faced at the first repository. With the MRS facility in the system, many of the pertinent issues, except for the issue of long-term disposal, will have been addressed before the final development efforts for the first repository.

Of the operational benefits identified for the MRS facility, it would appear that only the transportation improvements can be obtained by modifications to the no-MRS system, and then only to a lesser degree than would be possible if the same modifications are applied to the system that includes an MRS facility.

The views of the utility industry--as represented by testimony before the Congress and determined in a limited DOE study of several utilities--indicate strong support for an MRS facility and similarly strong opposition to performing at reactor sites several waste-preparation operations that would be performed at the MRS facility.

The discussions that follow briefly describe the evaluations performed in this study and summarize the results.

Achieving comparable performance without the MRS facility

The GAO and others have contended that the MRS proposal to the Congress does not compare an improved waste-management system without an MRS facility with a system that includes an MRS facility. According to these commenters, such a comparison is needed to determine the true value of an MRS facility to the system.

Assessment of alternative no-MRS cases. This report presents the benefits and costs associated with five alternative modifications to the reference no-MRS system that incorporate various combinations of technologies. The technological options considered include large-capacity transportation casks; dual-purpose storage-and-transportation casks for the at-reactor storage of spent fuel; at-reactor preparation of spent-fuel canisters that are compatible with the rest of the waste-management system; and at-reactor spent-fuel consolidation. The alternatives evaluated represent increasing degrees of transfer of waste-management activities from the Federal waste-management system to reactor sites. They range from an alternative system that involves only modifications to the Federal waste-management system to one in which the preparation of a repository-ready disposal canister--a key function planned for the MRS facility--is performed at reactor sites instead.

The evaluation of the five no-MRS alternatives identified one option that has significant advantages over the current reference no-MRS system and all of the other options. This option--alternative 1--involves the use of large-capacity transportation casks and DOE guidance and advice to encourage utilities who choose to consolidate spent fuel to use a canister that is compatible with the rest of the waste-management system. These modifications can be implemented in the Federal waste-management system with little intrusion into utility activities. They would reduce overall system costs by $400-$500 million and also reduce the occupational and public risk of radiation exposure, primarily as a result of the transportation improvements resulting from the use of large-capacity casks.

The comparison indicates that involvement by the utilities in waste-preparation activities beyond those they would voluntarily undertake to deal with their own storage problems would lead to cost impacts that range from only minor cost reductions to substantial cost increases compared with performing those activities at the repository. For example, the analysis indicates that DOE action to encourage or require the consolidation of spent fuel at reactors (a function now planned for the MRS facility or for a repository if an MRS facility is not authorized) would have at most a marginal cost benefit. Furthermore, once the large-capacity transportation casks are employed, at-reactor consolidation yields only minimum additional reductions in transportation costs. In sum, the small net cost benefits resulting from the promotion of at-reactor consolidation would not offset the negative impacts associated with the increased Federal intrusion into utility operations and the associated risks of interference with reactor operations.

The evaluation of cases involving differing degrees of preparation of disposal-ready waste packages at the reactors showed the same results for each case: overall system costs would increase; significant institutional and utility opposition to widespread utility involvement in spent-fuel preparation would be expected; and substantial technical feasibility issues would need to be resolved. In fact, the alternatives involving the performance of most or all MRS functions at reactor sites have costs that are comparable to, or higher than, the costs of the system with an MRS facility and provide none of the substantial system-development benefits of the MRS facility.

Comparison of no-MRS and MRS cases. The no-MRS case that was identified as having advantages compared to the current reference no-MRS system was compared with an updated MRS case that incorporates the same improvements made in the no-MRS case. The comparison showed that the only significant change from the analysis presented in the MRS proposal is the large reduction in transportation costs and impacts resulting from the use of large-capacity transportation casks for shipments from the reactors to the MRS facility or the repository. While the large-capacity transportation casks do improve transportation substantially in the MRS case, the benefit is greater in the no-MRS case because in the latter case the benefits accrue over the entire distance from the reactors to the repository.

The larger reduction in transportation costs for the no-MRS case compared with the MRS case increases the calculated cost difference between the two cases to \$1.6-\$1.9 billion (about 13 percent higher than previous estimates), although the absolute cost of both cases is reduced. However, the updated MRS case still shows net improvements in transportation compared with all of the no-MRS cases simply because the 150-ton casks that will be used to ship from the MRS facility to the repository--the longest portion of the journey from the reactor to the repository--have a substantially larger capacity than the largest rail cask that can be used at a reactor. Furthermore, the MRS case will reduce the number of separate jurisdictions affected by transportation by restricting shipments to a single cross-country route rather than the several that would be involved in the no-MRS case.

In summary, a qualitative examination of various modifications to the no-MRS system shows that no realistic combination of technological modifications and varying degrees of shift of waste-preparation functions from the DOE to the utilities will result in equivalent advantages or in any substantive way alter the advantages that would accrue to the waste-management system as a result of the MRS facility. Many of the major advantages of the MRS facility can be obtained only by the construction and operation of a central waste-management facility before the repository--so that no conceivable improvements to a no-MRS option, in which activities are performed instead at separate reactor sites, can provide comparable benefits.

<u>Views of the utility industry on the need for the MRS facility</u>

The benefits of an MRS facility are considered to be sufficient to warrant the small percentage increase in the overall system cost. This conclusion has been endorsed by various utility companies or organizations representing the utility industry. From the testimony of utility representatives before the Congress, the GAO findings, and the results of a limited DOE study, the following observations about the views of the utility industry can be made:

- The nuclear utility industry supports the addition of an MRS facility to the waste-management system.

- The utility industry can and will implement technological solutions to the problem of spent-fuel management until the spent fuel is transferred under the Act to the Federal Government. The solutions are, however, likely to vary among the utilities in the absence of significant Federal intervention.

- The utilities are not inclined to commit to substantially greater waste-preparation operations at reactor sites than those required to sustain the safe operation of the nuclear power plant. This attitude stems mainly from concerns about institutional, liability, and licensing issues rather than simply technical concerns.

- Any waste-management option that requires extensive at-reactor consolidation or other at-reactor operations that are beyond those otherwise needed to safely and efficiently store spent fuel pending acceptance by the DOE would require facility modification and operations that encroach on the primary function of reactors--the generation of electricity.

Costs unquantified in the MRS proposal

The DOE has been asked to provide estimates for certain costs that were identified but not quantified in the MRS proposal. These costs fall into the general categories of impact mitigation, consultation-and-cooperation (C&C) agreements, payments equivalent to taxes, and licensing and permit fees.

These costs were not quantified in the MRS proposal because the DOE felt that including them in the proposal was not appropriate. As explained in the DOE's comments on the GAO report, such costs were not specified in the proposal "to allow the DOE flexibility in the consultation-and-cooperation process that will be initiated if Congress approves the MRS proposal." An estimate of State and local taxes (or payments in lieu thereof) was nonetheless included in the proposal documents. The DOE's comments also pointed out that some of these costs should be determined by the Congress "as a matter of national policy and of the value of the MRS to the waste-management system, as opposed to a DOE estimate." The authority for these expenditures would come from the legislation authorizing the MRS facility. Only funds for impact mitigation have already been approved by the Congress, as they are included in the Act. Other payments to the affected State and local jurisdictions, although proposed by the DOE, are yet to be approved by the Congress. Consequently, the costs for these items may be as low as zero. This report contains an estimate of the range of costs that could be expected if the Congress approves these expenditures.

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1. INTRODUCTION

1.1 PURPOSE

In March 1987, the Department of Energy (DOE) submitted to the Congress a proposal[1] to construct a facility for monitored retrievable storage (MRS). This facility would be fully integrated into the waste-management system being developed by the DOE's Office of Civilian Radioactive Waste Management. The resulting waste-management system--consisting of an MRS facility, a transportation system, and two geologic repositories--was designated the "improved-performance system" in the DOE's 1985 Mission Plan[2] because, in comparison with the system that consists only of the transportation element and geologic repositories (i.e., the "authorized system"), it offers several distinct advantages.

Since the proposal was prepared, several parties have raised various questions about the MRS facility and the DOE proposal. One of these was the General Accounting Office (GAO), which had been requested by the Congress to review the MRS proposal in order to assess whether it provides sufficient information for a decision to authorize the integration of an MRS facility into the waste-management system. The GAO and others criticized the DOE's proposal on the grounds that it did not include a comparison of an optimized no-MRS system with the MRS system, nor did it provide the information necessary for such a comparison.

The report[1] prepared by the GAO makes two principal recommendations:

1. The DOE should identify the best configuration of the authorized system, "combining the most feasible alternatives for maximizing the effectiveness, efficiency, and safety of the system in lieu of an MRS."

2. The DOE should prepare an estimate of the cost of all elements associated with the MRS facility, including costs not reported in the proposal, such as payments equal to taxes and the costs of mitigating the impacts of MRS construction and operation.

This report examines various ways in which the transportation and the storage of spent fuel can be managed without an MRS facility and then compares these alternative waste-management systems with a system containing an MRS facility; the comparison is made in terms of several criteria (e.g., system development, operations, cost, risk, feasibility). It also discusses the costs not quantified in the proposal. In addition, it summarizes the views of several U.S. electric utilities and representative groups on both the MRS facility and various at-reactor options that have been proposed for spent-fuel management.

1.2 THE MRS FACILITY AND ITS ADVANTAGES

As described in the DOE proposal[1] and the 1985 Mission Plan,[2] an MRS facility would be fully integrated into the waste-management system being developed by the Civilian Radioactive Waste Management Program. Its principal functions would be to prepare the spent fuel discharged from commercial nuclear power reactors for disposal in a geologic repository and to serve as the central receiving station for the waste-management system. The preparation for emplacement may include removing the spent-fuel rods from the metal grids that hold them together in a square array and consolidating them into a more closely packed array. Consolidation offers several advantages, such as a reduction in the number of waste shipments to a repository and a reduction in the number or the size of the "waste packages" requiring handling and emplacement in a repository. Whether consolidated or not, the spent fuel would be sealed in canisters that are uniform in size and free of surface contamination with radioactive material. Such canisters would facilitate handling, shipping, and further processing at the repository.

In addition to its waste-preparation function, an MRS facility would provide temporary storage for a limited quantity of spent fuel (up to 15,000 metric tons of uranium). (The quantity of spent fuel to be emplaced in the first repository is 70,000 metric tons of uranium.) The canisters of spent fuel would be stored at the surface, in concrete casks equipped with monitoring instruments and designed for easy retrieval of the spent fuel for shipment to the repository.

The integrated MRS facility proposed by the DOE is not a temporary expedient designed to alleviate problems in spent-fuel storage. Its principal purpose is to facilitate the development and operation of the overall waste-management system, including the repositories and transportation, and it thus could provide significant advantages. Briefly summarized, these advantages are as follows:

- Improvements in system development. An MRS facility would allow the DOE to separate a major part of the waste-management process (acceptance, transportation from the reactor sites, consolidation, and sealing in canisters) from uncertainties about the repository and to proceed immediately with detailed planning for, and implementation of, that part. Early accomplishment of these separable steps would significantly enhance confidence in the schedule for the operation of the total system.

- Accelerated waste acceptance. An MRS facility would allow the system to begin receiving spent fuel 5 years earlier than the system without an MRS facility, thus significantly reducing the need for new temporary storage capacity at reactor sites and the attendant spent-fuel handling operations, licensing efforts, and costs.

- Improvements in system reliability and flexibility. Improvements in system reliability and flexibility would be realized by separating the function of spent-fuel acceptance (from the reactors) from the function of spent-fuel emplacement in the repository and by adding significant operational storage capacity to the system.

- Advantages for the repository. An MRS facility would simplify waste-handling facilities and operations at the repository.

- Transportation improvements. The MRS facility would facilitate the use of dedicated trains, reduce the number of shipment-miles and cask-miles,* reduce the number of individual shipments in transit, and serve as a hub for transportation operations.

- Institutional benefits. The MRS facility would provide institutional benefits through the experience gained from interactions with the host State. Institutional benefits would also result from the opportunity to demonstrate earlier that in developing and operating waste-management facilities the DOE is prepared to be a responsible corporate citizen and neighbor. Progress in waste management, starting with the designation of a specific site and facility construction, would help to provide momentum for implementing the entire system.

Of these advantages, only the above-mentioned transportation improvements can be accomplished in the Federal waste-management system without an MRS facility. Under particular circumstances, some advantages for the operation of the repository might be gained by performing certain operations (e.g., spent-fuel consolidation) at the reactor sites, but such operations would be performed outside the Federal waste-management system as defined at present. None of the advantages listed above could be gained from the various other waste-management functions that could be performed at the reactor sites, such as the reracking of storage pools to accommodate more spent-fuel assemblies, and the provision of dry at-reactor storage. Nonetheless, the alternative waste-management options that have been suggested as potentially beneficial have been identified and evaluated in this report.

1.3 APPROACH

In order to provide comparisons of waste-management systems with and without an MRS facility, the DOE used the following approach:

- Review the status of technology developments in spent-fuel storage and transportation that may result in technological improvements.

- Evaluate a number of no-MRS system configurations that embody potential technological and operational improvements.

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*Cask-miles are defined as the distance traveled times the number of casks transported; shipment-miles are defined as the distance traveled times the number of shipments made. When a shipment consists of only one cask, the shipment-miles are equal to the cask-miles. With multiple-cask shipments, the cask-miles are a multiple of the shipment-miles.

- Identify the no-MRS system and an operational scenario that might maximize the effectiveness, efficiency, and safety of the waste-management system and that can be reasonably considered to be feasible both technically and institutionally.

- Examine how the identified technological improvements in transportation and storage might provide comparable benefits to the proposed waste-management system with an integral MRS facility.

- Compare the resulting system benefits for a system with an MRS facility and one without.

For the purposes of this report, the terms "reference no-MRS system" and "reference MRS system" will be used in lieu of the terms "authorized system" and "improved-performance system," respectively. The systems designated by these terms are those described in the DOE's proposal to the Congress,[1] but with the waste-acceptance schedules given in the Mission Plan Amendment.[4]

The remainder of this report is divided into seven sections. Section 2 describes and evaluates potential modifications to the waste-management system and waste-management options that could be implemented at reactor sites. Section 3 describes and evaluates the various alternative system configurations that are possible without an MRS facility. Section 4 describes and evaluates the reference MRS system and explains how it could be updated, and Section 5 presents a comparison of the identified no-MRS and the MRS systems. Section 6 discusses the views and attitudes of several U.S. nuclear utilities about the MRS facility and about the various waste-management functions that could be performed at reactor sites in the absence of an MRS facility. To address the second GAO recommendation, Section 7 presents estimates of the potential institutional costs of the MRS facility. The conclusions of the report are presented in Section 8.

Also included in the report are two appendixes that provide supporting information for the no-MRS and the MRS systems. Appendix A contains details concerning the assumptions and calculations performed to estimate the system-cost impacts of various alternatives. Appendix B reviews the description and evaluation presented in the DOE proposal of various potential options for modifying the no-MRS system and provides some additional information on these and other potential options.

2. REVIEW OF POTENTIAL MODIFICATIONS TO THE WASTE-MANAGEMENT SYSTEM

As mentioned in the introduction, questions have been raised about spent-fuel handling, packaging, storage, and transportation modifications that could be implemented in the reference no-MRS system to improve its effectiveness, efficiency, and safety.

The suggested options can be grouped into four main categories:

- Expanded storage capacity at reactor sites.
- Transportation.
- Use of Federal interim storage.
- Expanded lag storage at the repository.

This chapter briefly reviews various options for modifications in each category. Those judged to be feasible were considered in defining alternative no-MRS systems (Section 3.1). Much of the information presented here is based on the descriptions and evaluations included in the DOE's MRS proposal to the Congress (Appendixes A and D to Volume II of the MRS proposal[1]). The remainder is based on additional information that has recently become available from research, development, and demonstration activities conducted in the DOE's waste-management program. More-detailed descriptions and evaluations of these options are given in Appendix B of this report.

2.1 EXPANDED STORAGE AT REACTOR SITES

The quantity of spent fuel that could be stored at reactor sites could be increased by the following methods: by "reracking"--that is, installing new racks in the spent-fuel storage pools to accommodate more spent fuel; by consolidating spent-fuel rods into more-compact arrays; and by providing facilities for dry storage. The first two involve expanding in-pool capacity, while the third requires storage outside the pool. For this analysis--and in all DOE analyses examining the need for additional storage--it was assumed that the storage pools at all reactors have already been "reracked" to the maximum extent possible, and therefore this option will not be discussed further.

2.1.1 At-Reactor Consolidation and Canistering

In consolidation, the fuel-bearing components (spent-fuel rods) are separated from the hardware (non-fuel-bearing components) that holds them together in an assembly and loaded into a canister in a more tightly packaged array, reducing by about one-third the space required in a storage pool for the spent-fuel rods and the assembly hardware. At reactor sites, the consolidation operation would be performed under water. Consolidation can also be used to provide a more compact waste form for dry storage. Although generally at-reactor consolidation is considered a means to alleviate the problem of insufficient spent-fuel-storage capacity at reactor sites, it has also been suggested as an alternative to consolidation in the Federal waste-management system.

If the DOE chose to promote large-scale at-reactor consolidation, there is no assurance that all utilities would be willing or able to perform this function. The feasibility of consolidating spent fuel and storing it in a particular spent-fuel storage pool depends on the capacity, structural, thermal, and seismic constraints for that pool. In addition, since at a reactor site the process would be performed in the storage pool, at-reactor consolidation would create the potential for increasing contamination in the water in the storage pool and increasing the background radiation level of the pool area. As indicated below, it is unlikely that consolidation would be a feasible or attractive option for all utilities.

Recent small-scale demonstrations indicate that at-reactor consolidation may be both feasible and economically attractive as a means of providing additional storage space; however, the experience at present is insufficient to confidently estimate either the cost or the feasibility of a large-scale application of consolidation. Confident estimates will require data from larger-scale projects.

To date, all of the development work has been directed at spent fuel from pressurized-water reactors. No efforts to consolidate spent fuel from boiling-water reactors have been undertaken. Five companies have designed equipment for in-pool consolidation, and each has teamed up with one or more utilities to test and refine the equipment. In all cases the equipment was designed for an optimum consolidation ratio of 2:1 (i.e., to load the spent fuel from two assemblies into a canister the size of a single assembly), but its use so far has had mixed success. Where a 2:1 consolidation ratio has been achieved, the tradeoffs have been low production rates, substantial labor requirements, and/or high costs. However, a more recent demonstration by the Combustion Engineering Company at the Millstone 2 plant of Northeast Utilities is encouraging: a consolidation ratio of 2:1 was achieved with reasonable production rates.

At present, planning for at-reactor consolidation entails uncertainty about the licensing requirements of the Nuclear Regulatory Commission (NRC). The position taken by utilities--and to date not disputed by the NRC--is that consolidation itself does not need to be licensed because the operations involved would be within the envelope of technical operations approved for the nuclear power plant in most cases. However, a license amendment is required if a utility plans to increase, through consolidation, its in-pool storage beyond the approved capacity. Since this is the principal reason for undertaking at-reactor consolidation, a utility's decision to consolidate will have to include an assessment of the factors associated with an operating license amendment. In this regard, the experience of the Maine Yankee Atomic Power Company in attempting to attain a license amendment for this purpose is not encouraging (see Appendix B, Section B.2.1). As a result, Maine Yankee has abandoned its plans to pursue consolidation, although it believes that consolidation and in-pool storage of consolidated spent fuel are technically and economically feasible. Similarly, Northeast Utilities applied to the NRC for a license to consolidate (and store in the spent-fuel pool) the entire spent-fuel inventory at its Millstone 2 plant. The NRC, however, granted this utility the very limited authority to consolidate (and store) only up to 10 assemblies. The licensing problems encountered by Maine Yankee and Northeast Utilities are probably not unique.

In regard to the views of the utilities, the results of a recent limited study[5] performed for the DOE by the Nuclear Assurance Corporation (NAC) showed that some utilities are willing to consider consolidation to meet their storage requirements prior to the inception of spent-fuel acceptance by the Federal waste-management system (see Section 6 for more details). However, the NAC study also indicated that the interviewed utilities had strong objections to voluntary consolidation for the purpose of achieving benefits elsewhere in the waste-management system, even if substantial incentives are provided. Large-scale at-reactor consolidation would require the utilities to obtain a license for, construct facilities, and install equipment for predisposal spent-fuel-preparation operations. It would shift these operations from a Federal facility specifically designed for that purpose (either the MRS facility or the repository) to many different reactor sites that are not equipped for the operation and may have difficulties in accommodating it.

For purposes of this evaluation, three different options for large-scale at-reactor consolidation have been postulated, depending on the type of storage canister that is used. The choice of canister would at least partly depend on the purpose of consolidation (to alleviate at-reactor storage problems or as an alternative to consolidation at a Federal facility) and the status of the DOE's repository-development program. The types of canister that might be used are as follows:

- A utility-selected canister.
- A repository-specific canister.
- A repository-compatible canister that is also compatible with existing spent-fuel-pool racks.

The utility-selected canister could, and probably would, differ in size from reactor to reactor. If such canisters are used, the repository will eventually receive a variety of canisters, and additional operations may be required to accommodate these canisters at the repository. (At the repository, the spent-fuel canisters will be encapsulated in a site-specific disposal container before emplacement in the underground disposal area.)

The repository-specific canister would be a large cylindrical canister that is specifically designed to fit inside the repository disposal container. Such a canister is not compatible with existing spent-fuel-pool storage racks, which accept square spent-fuel assemblies; it would thus complicate at-reactor spent-fuel management and may be counterproductive with regard to extending at-reactor storage capacity. Furthermore, specifications for this canister will not be available for several years--until a repository site is selected and more-advanced site-specific repository and waste-package designs have been completed. Any spent fuel that is consolidated before the specifications for the repository-specific canister are available may need to be reloaded into a different canister.

The third alternative is to use canisters that are compatible with the spent-fuel-pool storage racks and also compatible with the repository disposal containers (compatible in that their use would entail minimal reduction in the efficiency of the disposal containers). For example, one alternative that is being investigated is a combination of standard-size square and half-square canisters, where a single square canister or two half-square canisters are the nominal size of an assembly. These canisters are compatible with the existing racks in the spent-fuel pools and can be loaded into repository disposal containers with a fairly high packing efficiency. Two square and two half-square canisters can be arranged in a cylindrical disposal container in such a way that very little void space is left. This alternative would permit at-reactor consolidation while limiting the risk that the canisters will be incompatible with either the repository disposal container or the spent-fuel-pool storage racks.

2.1.2 Dry Storage

The dry storage of spent fuel in out-of-pool modular containers is used in several nuclear installations in Europe and by some nuclear utilities in the United States. Two dry-storage methods, using metal casks and horizontal concrete vaults, have been licensed to date for use at specific U.S. reactor sites. Dry storage in concrete casks, a third storage option, has been selected by one U.S. utility and is the preferred storage mode for the proposed MRS facility. A fourth option, that of dual-purpose metal casks used for both storage and transportation, is used in Europe and has been under study for several years in this country.

The costs of dry storage are higher at individual reactor sites than in a central storage facility like the MRS facility because economies of scale favor a central facility and because storage at many different sites entails duplication of equipment. However, with no central facility available, several utilities are taking steps to solve their storage problems by implementing dry storage. Brief descriptions of dry-storage options are given below.

Dry storage in metal casks

The storage of spent fuel in metal casks is the most mature and best accepted of any dry-storage technology, with more than 40 years of development and experience in shipments of nuclear fuels and other radioactive materials. This technology is being enhanced through extensive testing and demonstration programs being conducted by the DOE, both through its contractors and in cooperative programs with utilities. The Virginia Power Company has a license for storing intact spent-fuel assemblies in metal storage casks at its Surry plant and has initiated the transfer of spent fuel to dry storage.

Dry storage in concrete casks (silos)

At-reactor storage in concrete casks is similar to storage in metal casks. It entails lower capital costs, but the concrete casks require more-extensive support facilities. Concrete casks have been used in experimental storage programs; they have also been used in other countries (e.g., Canada). They have been proposed as the primary storage modules for the MRS facility.

Storage in concrete casks has not yet been licensed at any site, although no impediments to licensing are evident.

Dry storage in horizontal vaults (NUHOMS system)

The NUHOMS system is licensed for use at the Robinson site of the Carolina Power & Light Company. The Duke Power Company also recently announced its intention to investigate the use of a form of the NUHOMS system for spent-fuel storage at its Oconee site. In the NUHOMS system, intact spent-fuel assemblies are encapsulated, in the the spent-fuel pool, in large canisters. A canister is then loaded into a transfer cask that moves the spent fuel out to an out-of-pool storage vault. The transfer cask is coupled to the vault, and the canister is transferred to and sealed inside the concrete vault.

The canister used in this system is not compatible with transportation-cask designs. Unless specialized casks are developed, the spent fuel in the canisters may have to be removed and either shipped as integral assemblies or reloaded into transport-compatible canisters before shipment from the reactor.

Dry storage in dual-purpose casks

The concept of the dual-purpose storage cask, which has been under study by the DOE for several years, is a variant of the metal-storage-cask concept, in which the cask used for storing spent fuel is later used to transport the fuel to a Federal facility. In essence, this option amounts to using the metal cask for storage and then, if necessary, using it as part of the transportation fleet or for lag storage at the repository or the MRS facility.

The major feasibility issue related to the dual-purpose cask is certification for transportation after extended periods of use for spent-fuel storage. Current NRC interpretations of its regulations could preclude certification under those circumstances. There is no evidence as to whether such certification could be expected in the future. The integration of the dual-purpose casks into the transportation-cask fleet also depends on their availability when needed for shipment from reactors to the repository. The casks must be made available early in the acceptance schedule, in order to reduce the need for transportation-only casks. The use of such casks for lag storage at the repository may reduce the need for some in-process lag storage that is currently envisioned and may provide increased flexibility in the surge capabilities of the system.

The most advantageous use of the dual-purpose casks would be their integration into the transportation-cask fleet. The potential benefits resulting from their later use for lag storage at a Federal facility do not appear to be significant. An analysis presented in Appendix A indicates that fewer than 20 dual-purpose casks would be needed to meet the requirements of the transportation system for 125-ton casks. The potential benefits are therefore limited to a relatively small number of casks, and the overall effect of dual-purpose casks on the costs of waste management would not be significant.

2.2 TRANSPORTATION

A number of options for modifying the transportation system have been evaluated. The primary effect of these options is a reduction in the number of shipments required to move the spent fuel from the reactors to the Federal waste-management facilities. Many of these modifications could be applied to the reactor-to-MRS portion of the MRS system, with similar effects as those associated with the reactor-to-repository shipments in the no-MRS system. It should be noted that, because of the reduction in the number of shipments, the implementation of many of these options would reduce the potential transportation benefits associated with at-reactor consolidation.

The potential options for modifying the transportation system are briefly described in the sections that follow.

2.2.1 Larger-Capacity Standard Casks

Responses from commercial vendors to the DOE's recent request for proposals for transportation-cask designs have indicated that it is possible to develop a new generation of truck and train casks that would have a much higher capacity than previous designs of the same weight and size. These larger-capacity standard casks would decrease the size of the cask fleet that would be needed, and the receiving facilities would need to handle fewer cask arrivals.

2.2.2 Extra-Large Rail Casks

The use of extra-large rail casks (125 to 150 tons loaded) in the no-MRS system would increase the capacity of rail casks and thus reduce the total cask-miles* traveled as well as the total number of cask-shipments* required. The actual percentage reduction that may be obtained in cask-miles and in the number of shipments is directly proportional to the relative cask capacities. Only the reactors that are currently listed as having rail-cask-handling capabilities (i.e., capabilities to load a rail cask under water in the storage pool) can handle rail casks with a loaded weight of 100 to 125 tons. As a result, the use of these casks would be limited unless modifications are made in the rail-cask-handling capabilities of the rest of the reactors currently operating in the United States. Alternatively, the facilities needed for out-of-pool cask loading would have to be provided at the reactor sites.

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*Cask-miles are defined as the distance traveled times the number of casks transported. Cask-shipments are simply the numbers of shipments of casks.

2.2.3 Overweight Truck Casks

The capacities of truck casks are generally limited by the gross vehicle weight limits. Thus, the size and capacity of truck shipments could be increased, with corresponding reductions in the number of such shipments, by using overweight, rather than legal-weight, shipments.

One complication with this option is that the regulations and statutes governing overweight truck shipments are not consistent throughout the United States, but vary from State to State. This requires complex scheduling and interactions with many State officials to ensure that the overweight shipments are consistent with the regulations of the various States along the transportation routes. Overweight shipments might also be constrained to operate only during certain times of the day or at reduced speeds, resulting in a net reduction in shipment speed. Some States also do not allow overweight truck shipments during the winter months because of possible damage to highways. A sensitivity analysis in Appendix A shows that, if all truck shipments use legal-weight truck casks, the costs of transportation would be about $200 million higher than the costs of using a near-optimum mixture of legal-weight and overweight casks.

2.2.4 Multicask Shipments

The total number of shipments and shipment-miles* can be reduced by combining single-cask shipments into multicask shipments. Several options for combining shipments have been considered, including truck convoys, marshalling rail shipments, multicask shipments from individual reactors, and pick-up trains.

Inherent in each of these options is the added amount of nontransport time or idle time that is required for individual casks. This increased nontransport time is incurred either at the reactor, where loaded casks are idle while awaiting the loading of subsequent casks, or at the marshalling yards, where early-arriving casks remain while awaiting the arrival of other casks to be added to the shipment. The increased nontransport time lengthens the average total time required for a trip for casks and requires a larger cask fleet to ship the same amount of spent fuel in the same time. These extra casks will add to the overall cost (capital and maintenance) of shipping the spent fuel.

All of these multicask options entail various degrees of additional planning, scheduling, and control of operational parameters. No new technology is required for the implementation of any of these options. In the case of marshalling shipments, public opposition to the siting of a marshalling yard is possible.

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*Shipment-miles are the distance traveled times the number of shipments made. When a shipment consists of only one cask, the shipment-miles are equal to the cask-miles. With multiple-cask shipments, the cask-miles are a multiple of the shipment-miles.

2.2.5 Increased Use of Rail Transport

Recent studies of the cask-handling capability at existing reactors have shown that about half of the reactor sites are limited in their ability to handle large rail casks. These limitations stem from such factors as inadequate crane-lifting capacity, the lack of a railspur onto the site or into the fuel-handling building, limitations associated with the pathway to the storage pool, and the structural limits of the pool (the casks are loaded in the pool). Three options for increasing the use of rail transport for shipments originating from reactors are discussed in this section:

- Upgrading reactor facilities to provide direct rail access (e.g., by adding railspurs and modifying crane capacities).

- Using trucks in the "heavy-haul" mode (special flatbeds capable of accommodating heavy weights, very slow speeds, etc.) to transport rail casks from the site to a rail access, provided crane and storage-pool capabilities are adequate.

- Using smaller casks loaded in the storage pool to transfer spent fuel to large rail casks outside the pool.

The first of these options can be accomplished without new technology development or application. Upgrading reactor-handling capabilities would require retrofitting or recertifying present equipment to handle heavier rail casks. Also, reactors that do not have rail service into the reactor site would need that service. Moreover, changes to a reactor facility might require an amendment to the NRC license, a process that utilities may be reluctant to undertake because it is costly and time consuming. Heavy haul has been used many times to move heavy components like reactor vessels onto sites without rail access, but it has not been used for spent-fuel shipments and may require special permits. The third option would require the development and NRC certification of dry-cask transfer methods. This technology is currently being investigated, especially for its use as a method for loading storage units that could be used at reactor sites. The cost, risk, and feasibility of this option are uncertain at this time. A sensitivity analysis presented in Appendix A shows that the costs of upgrading at-reactor facilities to accommodate rail shipments would about equal the savings that would be realized in transportation costs if the reference casks are used; if the improved-capacity casks under development are used, these upgrading costs would be about 10 times larger than the transportation-cost savings. Regarding the transfer of spent fuel from a smaller cask to a larger cask outside the pool, this operation at a reactor site would probably require a license amendment and may meet public opposition. For the various reasons given above, these options were not deemed practicable and were not included in further analyses.

2.2.6 Use of Dedicated Trains for Shipments from Reactors

Rail shipments could be made in dedicated trains that carry no other commodity. These trains would go directly from a reactor to the repository. Dedicated trains would simplify system operations by allowing the scheduling and routing of trains to meet the needs of the waste-management system rather than the convenience of the railroads.

System costs might be slightly increased by dedicated trains, although the higher over-the-rail cost could be partially offset by higher average speeds and reduced stopped times. The increased control over the arrival and departure of trains would allow the receiving facilities to be designed for a lower surge capacity.

2.3 USE OF FEDERAL INTERIM STORAGE (FIS)

The Nuclear Waste Policy Act of 1982 includes provisions for Federal interim storage to assist those utilities that are unable to provide adequate at-reactor storage capacity when needed to ensure the continued orderly operation of their reactors. This Federal interim storage is limited to no more than 1900 MTU.

The Act makes it clear, however, that the primary responsibility for providing interim storage for spent fuel rests with the individual utility owning reactors by maximizing, to the extent practicable, the effective use of existing onsite storage facilities and by adding new onsite storage capacity in a timely manner where practicable. Those utilities that have pursued all the above licensable alternatives for additional spent-fuel storage without solving their storage difficulties may seek the required determination from the NRC that all such alternatives have been exhausted and, after receiving this determination from the NRC, apply to transfer their spent fuel to Federal storage facilities. Such arrangements in the form of contracts with the DOE are required to be enacted not later than January 1, 1990. There is no evidence at present that any utility plans to apply for Federal interim storage.

The costs of Federal interim storage must be fully paid by assessments against utilities using the services. Costs will depend heavily on such factors as the site, the storage technology, and the capacity required.

2.4 EXPANDED LAG STORAGE AT THE REPOSITORY

Expanded lag storage capability at the first repository might provide to the waste-management system some of the same benefits that would be provided by the MRS facility. For example, waste acceptance and the orderly transfer of spent fuel from the utilities could be insulated from disruptions in repository emplacement. If such storage could be licensed separately from the underground portion of the repository, spent fuel could also be received earlier and contingency storage could be provided in case of some types of delays in repository startup or diminished emplacement capability. Present designs for repository surface facilities provide a 3-month operational buffer (750 MTU), which is sufficient to ensure smooth functioning during normal emplacement operations, to unload the transportation system during slowdowns or brief stoppages in emplacement activities, and to maintain emplacement operations at a steady rate during brief disruptions in transportation.

If expanded lag (buffer) storage at the repository could be provided, it could accelerate the initial spent-fuel-acceptance rates in the no-MRS system. The spent-fuel-acceptance rate at the repository during the first 5 years of operation is limited by the rate at which the underground emplacement excavations and operations progress after NRC licensing. (The completion of repository surface facilities will also affect the acceptance rate but to a lesser degree.) The amount of storage that could be provided to accelerate acceptance of spent fuel while not impeding repository construction cannot be predicted at present. The Act prohibits the construction and operation of an MRS or FIS facility in a State in which a repository is located. Also, to avoid characterization as a separate facility, the lag storage would have to be licensed in the same licensing action as the repository. Thus, spent-fuel acceptance in meaningful quantities could not begin much in advance of repository disposal activities; in other words, lag storage could not effectively separate the DOE's acceptance of spent fuel from the schedule of spent-fuel acceptance at the repository.

3. DESCRIPTION AND EVALUATION OF THE REFERENCE AND ALTERNATIVE NO-MRS SYSTEMS

This section briefly describes and evaluates the reference no-MRS system and five alternative no-MRS systems. The alternative systems represent various combinations of the options identified in Section 2. The discussion begins by explaining the approach used to develop the suite of systems examined.

3.1 APPROACH

In the 1985 Mission Plan,[2] the authorized system was defined as consisting of a geologic repository, the necessary transportation system for moving the wastes to the repository, a provision for Federal interim storage as authorized by the Nuclear Waste Policy Act, and a program to encourage and expedite the most efficient use of existing storage facilities and the addition of new capacity in a timely fashion. This authorized system is the reference no-MRS system discussed in this document.

Five alternatives to the reference no-MRS system were identified and evaluated. Of these alternatives, only two, alternatives 1 and 2, represent modifications that could be made to the Federal waste-management system, and even these alternatives involve some operations at some reactor sites. The others depend on waste-management operations performed by the utilities, and as such they represent increasing DOE involvement in, or intrusion into, utility operations. These at-reactor alternatives were identified and evaluated in response to suggestions that certain waste-preparation functions could be performed more cost effectively at reactor sites than at the MRS facility. In developing the modifications, the approach was to group together potential system improvements that had similar system-wide impacts, so that each alternative represented a significant change from the other alternatives.

Table 3-1 provides an overview of each alternative no-MRS system, with the progression from left to right in the table corresponding to the progression of performing increasing waste-preparation functions at the reactor.

3.2 DESCRIPTION OF THE NO-MRS SYSTEMS

Presented below are brief descriptions of the reference no-MRS system as well as five alternative systems. Evaluations of these no-MRS systems are given in Section 3.3.

3.2.1 Reference No-MRS System

The reference no-MRS system is the authorized system described in the DOE's 1985 Mission Plan[2] but with the waste-acceptance schedule presented in the Mission Plan Amendment.[4] Spent fuel is shipped directly from reactors to the repositories. The first repository begins to receive and emplace spent

TABLE 3-1

DESCRIPTION OF ALTERNATIVE NO-MRS SYSTEMS

No-MRS System Reference	No-MRS System Alternative 1	No-MRS System Alternative 2	No-MRS System Alternative 3	No-MRS System Alternative 4	No-MRS System Alternative 5
Reactors					
-- Extra handling or packaging of fuel is limited to that required to solve on-site storage problems. Activities consist of a mix of consolidation and out-of-pool dry storage, with method chosen strictly up to the utilities. Rest of fuel is transferred to DOE as discharged.	-- Extra handling or packaging of fuel is limited to that required to solve on-site storage problems. Activities consist of a mix of consolidation and out-of-pool dry storage. DOE provides guidance, advice, and encourages utilities to choose those options which provide overall waste-management benefits (e.g., repository-compatible canisters for consolidated fuel). Rest of fuel is transferred to DOE as discharged.	-- DOE provides incentives and takes other action to influence utilities in their technology choices to solve storage problems. DOE influence aimed at system-wide optimization of reactor storage choices (e.g., consolidation into repository-compatible canisters, dry storage in dual-purpose casks, etc.) Rest of fuel is transferred to DOE as discharged.	-- DOE takes action to require utilities to consolidate majority of fuel into unsealed repository-compatible canisters. DOE also compensates utilities for operations performed.	-- DOE takes action to require utilities to consolidate majority of fuel into repository-compatible canisters and seal and decontaminate the canisters. DOE also compensates utilities for the operations performed.	-- DOE takes action to require utilities to consolidate majority of fuel into repository site-specific (round) canisters and seal and decontaminate the canisters the DOE also compensates utilities for operations performed.
Transportation					
-- Legal weight truck and 100 ton rail casks with capacities identified in proposal.	-- Improved transportation system (e.g., higher capacity casks, overweight truck casks, 125 ton rail casks, etc.)	-- Improved transportation system plus utilize dual-purpose cask to supplement fleet.	-- Same as Alternative 2.	-- Same as Alternative 2.	-- Same as Alternative 2, with casks designed for site-specific canisters.
Repositories					
-- Lag storage provide inside facility.	-- Same as Reference.	-- Utilize dual-purpose casks to supplement lag storage.	-- Same as Alternative 2.	-- Same as Alternative 2.	-- Same as Alternative 2.
-- Receive majority of fuel as discharged and consolidate at repository.	-- Same as Reference.	-- Same as Reference.	-- Receive canisters from reactors.	-- Receive from reactors canisters that have been cleaned of surface contamination.	-- Receive from reactors canisters that have been cleaned of surface contamination.
-- Load and seal repository consolidated fuel into site-specific containers.	-- Same as Reference.	-- Same as Reference.	-- N/A	-- N/A	-- N/A
-- Reactor-consolidated fuel handled as a special case (due to non-uniform canisters used by utilities).	-- Load and seal reactor consolidated fuel into modified site-specific containers (modified to accommodate canisters).	-- Same as Alternative 1.	-- Same as Alternative 1.	-- Same as Alternative 1.	-- Load and seal reactor consolidated fuel into site-specific containers (due to site-specific canisters).

7 0 2 5 3 0 5 0 1

fuel from the reactors in the year 2003. Until the first repository begins to receive spent fuel, there are no Federal activities for the management of commercial spent fuel; all Federal activities--acceptance, transport, and disposal--happen at once after repository startup.

Until the first repository starts to accept spent fuel, the utilities must store their spent fuel at their reactor sites. A number of reactors are projected to discharge more spent fuel than can be stored in the spent-fuel storage pools even if the storage pools are reracked to the maximum extent possible. Additional storage at reactors is required for about 9500 metric tons of uranium (MTU), distributed over approximately 50 sites.* The DOE does not take explicit action to influence the methods used by the utilities to solve their spent-fuel-storage problems. It is expected that each utility with a storage problem will choose from available options of dry storage and possibly in-pool consolidation the option it deems best for its particular needs. Although it is recognized that some at-reactor consolidation may occur, in the cost analysis for this case it is assumed that no spent fuel will be consolidated at the reactors.

Once the first repository begins operations, spent fuel is shipped from the reactors in legal-weight truck casks or 100-ton rail casks. All reactors capable of shipping by rail are assumed to do so. The spent fuel is assumed to be transported and received by the repositories as intact assemblies.

The repositories in the reference no-MRS system receive the spent fuel shipped from reactors, prepare it for disposal by consolidating and packaging it in disposal containers, and emplace the loaded disposal containers in the underground repository. Depending on the host rock of the repository, the consolidated rods may be loaded into a thin-walled canister that is then filled with an inert gas like argon and welded closed before being placed in a thicker-walled disposal container, which is also closed by welding. The loaded disposal container is transferred underground and emplaced. A portion of the spent fuel that is assumed to present difficulties in consolidation, such as failed or damaged spent fuel, is not consolidated at the repository. Instead, it is packaged and emplaced intact.

3.2.2 No-MRS System: Alternative 1

Alternative 1 is basically the reference no-MRS system described above with two general modifications that are currently envisioned as occurring independently of a decision to develop the MRS facility. One is a modification of the transportation system, and the other is increased coordination between the DOE and the nuclear utilities with respect to the management of at-reactor spent-fuel storage.

*All projections of spent-fuel inventories in this report are based on the spent-fuel data base for 1986.[6]

The transportation modifications included in alternative 1 are increases in the capacities of the legal-weight truck and 100-ton rail casks and the use of overweight truck and 125-ton rail casks where feasible. Many of the other transportation options discussed in Section 2.2 are still under study by the DOE, and the results to date do not clearly indicate that these options will improve the performance of the transportation system. While the specific list of transportation options may not be complete, the modifications incorporated into alternative 1 are reasonably available and their effects can be predicted with reasonable assurance.

As the waste-management system is further developed and uncertainties are resolved, the effects on the waste-management system of various options for at-reactor storage will become better understood. The DOE should then be able to foster the adoption of the preferred options by the utilities and to assist in their implementation. For example, the DOE could develop specifications for dry storage and in-pool consolidation that will standardize the spent-fuel shipments received by the DOE. In alternative 1, it is therefore assumed that the DOE provides the utilities with specifications for a repository-compatible canister, as described in Section 2.1.1 (i.e., a canister that minimizes negative impacts on repository operations). This canister is assumed to be compatible with at-reactor consolidation and the existing spent-fuel-pool racks as well as the repository disposal containers. The spent fuel shipped in these canisters will require minimal handling at the repository.

It is difficult to specify how the DOE would express a preference for, or foster the use of, at-reactor options that might be beneficial to the waste-management system. However, as in the case of the transportation modifications in this alternative, the general implications of such efforts can be reasonably assessed. For the purposes of this assessment it is assumed that a few reactors choose consolidation as a means of accommodating spent fuel that exceeds their current pool storage capacity. For costing purposes only, it is further assumed that about 25 percent of the 9500 MTU requiring storage beyond the current pool capacity in the reference no-MRS system is accommodated by in-pool consolidation. As a result, about 7000 MTU still requires out-of-pool storage and about 2500 MTU is accommodated in the spent-fuel pools. With the limited space in the pools, the spent fuel in existing inventories must first be consolidated to make space for additional spent-fuel storage (regardless of whether the additional spent fuel is consolidated). Assuming a fuel-rod consolidation ratio of 2:1, that the volume of the non-fuel-bearing components is reduced by a factor of 6, and also assuming that all additional spent fuel stored in the pool is consolidated, it is necessary to consolidate approximately three times the amount of spent fuel that is added to the pool. For example, to provide in-pool storage for the additional 2500 MTU, the actual amount of spent fuel that must be consolidated is about 7500 MTU (see Appendix A for further details).

Alternative 1 was chosen because it represents the modifications that the DOE can implement in the Federal waste-management system without significantly affecting its interfaces with the utilities. This alternative still permits utilities to elect supplemental storage options that best meet their individual needs.

3.2.3 No-MRS System: Alternative 2

Alternative 2 involves the same transportation modifications as alternative 1. However, it assumes a higher level of DOE and utility integration in the management of at-reactor storage, with the DOE providing incentives and taking other actions to convince the utilities to choose options that are most beneficial to the waste-management system. For example, this alternative assumes for purposes of analysis that the DOE encourages at-reactor consolidation as a means for utilities to reduce requirements for out-of-pool storage. The canisters used by the utilities for the consolidated rods are specified by the DOE and are compatible with existing reactor-pool racks; at the repository, several canisters are loaded into specially designed disposal containers. The canisters used in alternative 2 are assumed to be basically identical with those specified by the DOE in alternative 1 (described in Section 2.1.1 as repository-compatible canisters).

In spite of the DOE's encouragement of at-reactor consolidation, most utilities are still assumed to use out-of-pool storage. In alternative 2, therefore, it is assumed that the DOE also takes action to influence out-of-pool storage, specifically by promoting dual-purpose casks (see Section 2.1.2), which are assumed to be used to provide maximum benefit. That is, at the reactors the casks are used to store spent fuel in a storage yard until the repository begins operations; the casks are then shipped directly to the repository, where they are unloaded; and finally they are integrated into the transportation cask fleet and are used to make many shipments each year, or the casks are used for lag storage at the repository.

In order to assess the cost impacts of alternative 2, it is assumed for costing purposes that the the amount of out-of-pool storage that is accommodated through in-pool consolidation increases from 25 percent to 50 percent. As a result, about 4800 MTU is accommodated in out-of-pool storage and about the same amount is accommodated by consolidating both some of the newly discharged spent fuel and some of the spent fuel already stored in the pools. As discussed for alternative 1 (Section 3.2.2), approximately three times the amount of spent fuel that is added to the pools must be consolidated to provide the needed space. Therefore, in this alternative about 15,000 MTU of the spent fuel already stored in the pools is consolidated to provide the needed space (see Appendix A for further details).

The at-reactor operations discussed above would be applied only to the spent fuel that presents a storage problem to the utility. The remainder of the fuel discharged from the reactors, which represents most of the spent fuel, is shipped to the repositories as intact assemblies. Thus, the repositories receive spent fuel in two forms: fuel consolidated in repository-compatible non-sealed canisters and intact assemblies. Because their design has been integrated with the Federal waste-management system, these canisters are encapsulated in special disposal containers as a normal repository operation. As in the reference no-MRS system, the intact assemblies are consolidated at the repositories and encapsulated into disposal containers.

Alternative 2 was selected for evaluation for two reasons. First, in comparison with alternative 1, it represents a significant increase in the involvement of the DOE in at-reactor operations. Second, this involvement is limited to storage problems that the utilities must address and is based on voluntary responses to incentives provided by the DOE. In short, in alternative 2 the DOE takes steps toward influencing the utilities, but limits its influence to problems that the utilities must in any case deal with.

Another alternative system that was considered and rejected was a system in which the DOE continues to provide incentives to utilities to persuade them to consolidate spent fuel beyond the amount required to overcome their spent-fuel storage problems. The potential benefits to the DOE would be reduced transportation requirements (since more consolidated spent fuel can be shipped in each cask) and reduced repository operations. However, in order for the benefits to be realized, a large number of reactors must consolidate a significant portion of their total spent fuel; otherwise, this alternative would not allow the elimination of consolidation at the repository. Since only about 12 percent of the projected total spent fuel from reactors has been discharged to date and less than 50 percent will be discharged by the startup of the first repository, this alternative would require at-reactor consolidation well beyond the starting date for the first repository, and the only reason for consolidating would be the incentives provided by the DOE. The results of a limited study sponsored by the DOE[3] indicate that in some cases utilities may not continue consolidation beyond their storage management needs and that utilities without storage problems are very unlikely to volunteer for consolidation in response to DOE incentives. This alternative system was therefore deemed improbable.

3.2.4 No-MRS System: Alternative 3

For this no-MRS system, it is assumed that the utilities are required to perform waste-preparation activities beyond those needed to alleviate their storage problems. This system differs from alternative 2 in that the utilities are required to perform waste-preparation activities, whereas in alternative 2 they are provided incentives to perform these activities. The institutional problems associated with this alternative as well as alternatives 4 and 5 are not addressed in this report. It is simply assumed that, because of Congressional action or some other reason, utilities are required to perform additional functions for the waste-management system.

Alternative 3 incorporates the same modifications as alternative 2 and also assumes that the DOE is authorized to require at-reactor consolidation for all spent fuel, using nonsealed repository-compatible canisters. Some spent fuel that is deemed too difficult to consolidate is excluded, as are some reactors with constraints that would preclude consolidation for licensing or economic reasons. However, most of the spent fuel is consolidated at the reactor site. Even with in-pool consolidation, some reactors will be unable to accommodate all of their spent-fuel discharges in the spent-fuel pool. It has been estimated (see Appendix A) that about 2000 MTU of spent fuel will still require out-of-pool storage. For this alternative, it is assumed that all this spent fuel is first consolidated and then placed in out-of-pool storage. As in alternative 2, the DOE also influences utility decisions about out-of-pool storage by promoting the use of dual-purpose casks; the transportation-system modifications are the same as in alternatives 1 and 2.

In alternative 3, the repository receives most of the spent fuel consolidated in unsealed repository-compatible canisters. Consolidation is no longer needed at the repositories, as the canisters received from the reactors need only encapsulation in disposal containers. Thus the surface-facility operations of the repository are reduced from those assumed in the preceding no-MRS alternatives.

3.2.5 No-MRS System: Alternative 4

Alternative 4 is very similar to alternative 3, except that the repository-compatible canisters are filled with an inert gas, welded closed, and decontaminated at the reactor sites. The functions of the repository are also similar to those in alternative 3, but sealed and decontaminated canisters are shipped to the repository, simplifying the unloading of the shipping casks and handling at the repository. Out-of-pool storage requirements are similar to alternative 3 as well.

Alternative 4 was developed because it represents the next major step beyond alternative 3 with respect to the relationship between the Federal waste-management system and utility operations. In this alternative, the reactors are producing and shipping to the repositories disposal-ready canisters, as the MRS facility would (except for the size and shape).

3.2.6 No-MRS System: Alternative 5

Alternative 5 represents the extreme case, where all the functions performed by the MRS facility are performed at reactor sites. It differs from alternative 4 in that the spent fuel is consolidated at the reactor sites into repository-specific (round) canisters, as described in Section 2.1.1. Since these canisters are not compatible with existing spent-fuel-pool racks, reracking is required to accommodate them. As in alternative 4, the canisters are filled with inert gas, welded closed, and decontaminated at the reactor sites. The functions performed at the repository are similar to those performed at the repository with an MRS facility in the system. The sealed, decontaminated canisters are unloaded, and a single canister is loaded into each disposal container and sealed.

Alternative 5 represents the maximum involvement of at-reactor operations with the Federal waste-management system--it requires the production of repository-specific disposal-ready canisters by the utilities.

3.3 EVALUATION OF REFERENCE AND ALTERNATIVE NO-MRS SYSTEMS

Section 3.2 has described a suite of alternative no-MRS systems that are based on the various spent-fuel-management options discussed in Section 2. This section evaluates each of these alternative systems individually and then compares them with the reference no-MRS system. It begins by defining the criteria used in the evaluations and comparisons.

3.3.1 Evaluation Criteria

The evaluation of the alternative no-MRS systems and the comparison with the reference no-MRS system were based on the following criteria:

- Technical feasibility: Availability and status of the technology needed for implementing the alternative.
- Effects on system development and licensing: Effects on the design and development of the total waste-management system or its elements (the repository or transportation), licensing and regulatory requirements, and public acceptability.
- Effects on system operation: Effects on the waste-acceptance schedule, the operation of the transportation system, the operation of the repository, and the overall operation and efficiency of the total waste-management system once it is implemented.
- Effects on system cost: Effects on the total-system life-cycle cost of implementing a safe and environmentally acceptable waste-management system, including at-reactor costs for alternatives involving at-reactor spent-fuel management.
- Effects on system risk: Effects on the estimated radiation exposure that may result from waste-management operations, including the exposure of both the public and the workers in waste-management facilities.

These criteria were used as qualitative measures of the overall technical, economic, and institutional feasibility of each alternative, including impacts on the utilities.

3.3.2 Alternative 1

Alternative 1 to the no-MRS system consists of various modifications to the transportation system that would reduce the number of spent-fuel shipments. Its implementation is technically feasible without the development of new technologies. There would be an improvement in the operation of the transportation system, but the effect on the operation of the total system would not be significant. System costs, including affected reactor costs, would be decreased by about $400 to $600 million (see Appendix A). Most of this decrease is attributable to transportation-system modifications and would also occur with an updated MRS system, as discussed later. The reduction in the number of shipments would reduce public risks for both transportation and the system as a whole, and the reduction in the exposure of the public to radiation should result in institutional advantages. Even though the use of overweight trucks might raise institutional issues and increase regulatory complexity, the overall institutional effects of this alternative are expected to be positive. No significant effect on the development of the waste-management system is expected.

In summary, alternative 1 shows some overall advantage in comparison with the reference no-MRS system and represents the current direction of the waste-management program regardless of the MRS decision (i.e., implementing modifications to from-reactor transportation as their advantages are demonstrated and continuing to support the development of various at-reactor storage options with the expectation of encouraging their implementation when, and to the extent that, such actions can be shown to be advantageous to the overall system). For a comparison of this alternative with the MRS system, see Section 5.

3.3.3 Alternative 2

This system incorporates the same transportation-system modifications as alternative 1 along with a higher level of DOE involvement in the management of out-of-pool storage, with the DOE providing incentives to utilities to choose options that are most beneficial to the waste-management system (e.g., consolidation into repository-compatible canisters and the use of dual-purpose casks for out-of-pool storage). A number of technical and institutional issues are associated with this alternative. For example, the capability of at-reactor consolidation has not been fully demonstrated. Furthermore, as discussed in Section 7, many utilities may be unwilling to assume the risks and liabilities of in-pool consolidation. Moreover, the incentives that the DOE might offer have not been established and might elicit some public opposition. The use of dual-purpose casks for dry at-reactor storage also raises some regulatory issues. While the casks appear to be technically feasible, there is a major licensing uncertainty--the uncertainty that the NRC will certify a cask for transportation after it has been used for storage for an extended period. The overall system benefits of dual-purpose casks also depend on whether these casks can be made available to the waste-management system on a timely basis (see Section 2.1.2 for details).

It is not expected that voluntary incentives provided by the DOE will significantly increase the number of utilities that choose to consolidate in comparison with the reference no-MRS system or alternative 1, and therefore the overall effects of alternative 2 on system development and operation are not expected to be significant. In terms of total-system operation, the waste-preparation functions performed at reactors should decrease the waste-handling workload at the repository, but the waste-management operations of the utilities choosing consolidation would become considerably more complicated and could interfere with normal reactor operations.

In terms of system cost, alternative 2 is expected to reduce overall costs by approximately \$600-\$700 million, primarily through the modifications in transportation, the same as in alternative 1. The incentive program increases at-reactor consolidation and otherwise reduces the costs of at-reactor storage. Any savings are likely to be somewhat offset by the DOE's additional administration costs for the incentive program.

In terms of system risk, alternative 2, like alternative 1, would reduce public exposure to radiation because of the decreased number of shipments. (It should be noted, however, that the exposure of the public to radiation from waste-management operations anywhere--at reactor sites, at the MRS facility, in transportation, or at the repository--would be extremely low in all cases. It would be dominated by the exposure resulting from transportation, although the exposure would be very low in an absolute sense.) However, the additional waste-management operations that would be performed at the reactor sites would increase the occupational exposure.

In summary, the potential development and operation issues that would result from an active DOE role in influencing utility storage choices do not appear to be justified by the marginal benefits. In comparison with the reference no-MRS system, the transportation modifications would produce some benefits, but the same benefits are obtained from alternative 1. Overall, the institutional problems outweigh the potential benefits, and alternative 2 is, as a result, less attractive than alternative 1.

3.3.4 Alternative 3

In alternative 3, the technical-feasibility issues are much more complex than those of the preceding alternatives--namely, the feasibility of consolidating all spent fuel at all reactor sites has not been established. In addition, substantial licensing activity for these reactor sites would be required for such extensive consolidation. Institutional issues would become considerably more significant than they are in alternatives 1 and 2 because of the requirement that utilities consolidate all of their spent fuel. In addition to problems concerning authority for compensation for at-reactor operations, alternative 3 could require legislation to make this requirement mandatory. Opposition to local waste-preparation operations can be expected at many of the reactor sites, especially as it would generate low-level waste that would not be acceptable for disposal at the repository because of its form (e.g., liquid) or composition (e.g., organic-matter content). In short, the institutional barriers associated with the DOE requiring full-inventory consolidation at reactor sites are very formidable.

In terms of effects on system development, alternative 3 entails significant issues, especially as it requires an integration of at-reactor activities with the Federal waste-management system and the development and implementation of this system at many reactor sites owned by many different utilities. The surface facilities of the repository could be simplified because of the elimination of facilities for consolidation; however, the overall system development would be complicated by more complex requirements for reactor interfaces with both the transportation system and the repository. Moreover, opposition at many locations might adversely affect the public acceptability of other portions of the total system (i.e., transportation and the repository).

In regard to system operations, alternative 3 would shift a significant waste-preparation function to reactor sites. One effect of this shift would be the complexity of coordinating operations at nearly 100 different sites. There would be commensurate reductions in the number of cask receipts at the repository and the elimination of rod consolidation operations, thus simplifying the repository surface facilities.

Many indeterminate costs would be incurred by the utilities if they undertake large-scale consolidation and canistering. Examples of such indeterminate costs are the costs of replacement power in the event at-reactor consolidation causes a forced plant shutdown, the costs of facility modification, and the costs of liability insurance. These costs, which are discussed in more detail in Appendix A, could be very significant. A rough estimate (see Appendix A) shows that they could range from $1.2 to $1.6 billion. In comparison with the reference case, this would increase total-system costs, including at-reactor costs, by $200-$700 million, although the overall effect on system costs is unclear because of the uncertainty associated with these estimates. Because in alternative 3 a significant portion of the cost of waste management would be shifted to the utilities, the costs of the Federal waste-management program would decrease by about $1.6-$1.7 billion, but the utility costs would increase by $1.9-$2.3 billion.

In alternative 3, the radiation-exposure risk to the public would be nominally decreased because at-reactor consolidation would decrease spent-fuel shipments. (As mentioned in Section 3.3.3, the exposure of the public in all cases would be very low in an absolute sense.) On the other hand, extensive at-reactor consolidation would increase the occupational risk because more workers would be involved and because at-reactor consolidation would result in more exposure to radiation than would consolidation at a centralized facility in a shielded "hot" cell equipped with remote-control equipment.

In summary, the overall feasibility of alternative 3 is significantly less certain than that of the reference no-MRS system. This alternative would represent a significant intrusion by the DOE into utility operations. The institutional problems are formidable, and opposition from both the State and the public can be expected. The licensing that would be required for each reactor site also constitutes a considerable complication. In addition, utility opposition could be widespread and strong. As a result, this alternative was judged to be highly undesirable in comparison with the preceding alternatives.

3.3.5 Alternative 4

The overall feasibility of alternative 4 is even more questionable than that of alternative 3, because of the additional at-reactor operations that would be required to consolidate spent fuel in sealed and decontaminated canisters (i.e., filling the canisters with inert gas, closing the canisters by welding, and decontaminating the canisters). All of the technical, licensing, and institutional problems of alternative 3 apply to alternative 4 as well, and there are additional difficulties. Performing these operations at reactor sites presents different technical problems from those of consolidation only, including the necessity of developing specialized equipment for welding the canisters closed, and technical feasibility on a production basis has not been demonstrated. Thus, considerable difficulty might be found in the development of the at-reactor portion of the waste-management system. Like the technical difficulties, licensing can also be expected to be more complicated and potentially affected by State and public opposition. Both State and public opposition to performing these additional operations at reactors can be expected to be greater than in alternative 3. The attitude of the utilities can also be expected to be more negative.

Like no-MRS alternative 3, alternative 4 entails significant indeterminate costs, including the considerable additional costs of seal-welding the canisters at reactor sites. The overall system costs, including the costs incurred by the utilities, are estimated to increase by \$2.0-\$2.6 billion over those of the reference no-MRS system. The costs of the Federal waste-management program are reduced by about \$1.6-\$1.7 billion, but the costs incurred by the utilities increase by \$3.7-\$4.2 billion.

In comparison with the reference no-MRS system, the additional at-reactor operations will entail the higher at-reactor occupational risk predicted for alternative 3 with further increases expected from the additional spent-fuel handling. As in alternative 3, the risk to the public is negligible.

In summary, increasing the waste-preparation functions performed at the reactor sites to include seal-welding canisters increases the negative effects of large-scale at-reactor consolidation on system development, system operations, and system cost. Thus alternative 4 is considered to be even less technically and institutionally feasible than alternative 3.

3.3.6 Alternative 5

In alternative 5, the requirement of producing sealed and decontaminated repository-specific canisters at the reactor sites presents another major technical-feasibility issue beyond those associated with alternative 4. The difficulty stems from the requirement to consolidate the spent fuel in sealed repository-specific cylindrical canisters, which are incompatible with the existing spent-fuel-pool storage racks and handling equipment. Thus, the technical feasibility of implementing alternative 5 is even more uncertain than that of alternatives 3 and 4. This alternative also presents the potential scheduling problem of specifications for repository-specific canisters not being available when the utilities start consolidation operations. Canisters of some other design would have to be used until the design of the repository-specific canisters is firmly established. In addition to technical problems, alternative 5 presents extra management difficulties imposed by the requirement for repository-specific canisters and therefore even greater opposition by the utilities can be expected. Public and State opposition would probably be the same as for alternative 4. Other licensing concerns are expected to be similar as in alternative 4.

The added burden of handling and storing repository-specific canisters increases the costs incurred by utilities beyond those predicted for alternative 4. Some reduction in repository costs is achieved through the use of the repository-specific canisters. The overall system costs, including all costs incurred by the utilities, increase by \$2.6-\$3.3 billion over those of the reference no-MRS system.

In terms of occupational exposure, alternative 5 is also less attractive than alternative 4 because the additional at-reactor operations associated with repository-specific canisters will increase at-reactor occupational exposure. Public risk would be essentially the same as in alternatives 3 and 4; as already mentioned in Section 3.3.3, it would be extremely low in an absolute sense in all cases.

Overall, alternative 5 presents the greatest number of technical, licensing, and institutional issues of all the alternative no-MRS systems analyzed and thus is judged to be the least feasible of all.

3.4 OVERALL COMPARISON

Presented below is an overall comparison of the five alternatives to the no-MRS system. Its purpose was to identify the alternative that would best meet the objectives of the waste-management system and would therefore be the more likely alternative that the DOE would pursue if the MRS facility is not approved by the Congress. This no-MRS system will be compared with the MRS system in Section 5. The comparisons presented in this section are summarized in Table 3-2.

The summary evaluations in Section 3.3 indicate that alternative 1 to the reference no-MRS system has the greatest technical and institutional feasibility. This alternative incorporates transportation modifications that reduce system costs and risks. In addition, the voluntary integration that is achieved between the DOE and the utilities improves the overall efficiency of out-of-pool storage management. Alternative 1 maintains the waste-management structure identified in the Nuclear Waste Policy Act, with the DOE providing to utilities research and development support for increasing storage capacities.

Alternative 2 increases the DOE's influence in utility out-of-pool storage to an active role of providing incentives and taking other actions to affect utility choices in the management of spent fuel. Because the choices are voluntary, the DOE's incentives are not likely to exert a significant effect on the choices of utilities; however, the system development and operations difficulties make the alternative less feasible than alternative 1 from both a technical and an institutional perspective.

Alternatives 3, 4, and 5, by requiring utilities to perform widespread spent-fuel consolidation, would produce significant negative impacts on the development, operation, cost, and overall feasibility of the total waste-management system. While the negative impacts increase with the number of operations performed at reactor sites (i.e., alternatives 4 and 5), all of these no-MRS alternatives are judged to be significantly less desirable and likely than the reference no-MRS system to meet the objectives of the waste-management system.

Overall, alternative 1, which incorporates transportation modifications and the DOE/utility integration needed to efficiently manage the utility spent-fuel storage problem, was found to be the best estimate as to how the Federal waste-management system could be improved so as to function most efficiently, effectively, and safely if an MRS facility is not included in the system.

TABLE 3-2

COMPARISON OF ALTERNATIVE NO-MRS SYSTEMS TO THE REFERENCE NO-MRS SYSTEM

System Development	System Operations	System Cost	System Risk	Technical Feasibility
No-MRS System: Alternative 1				
Minor development activities required for transportation system improvements and DOE-utility integration.	Some improvements in transportation system associated with fewer shipments.	System costs reduced by $400-$600 million due to transportation modifications.	Reduction in both public and occupational risk associated with fewer cask shipments.	No new technologies require development.
No-MRS System: Alternative 2				
Additional development required for DOE incentive program. Potential development work necessary for NRC licensing of dual-purpose casks. Public opposition to incentive program may occur.	Increased level of coordination of systems operations necessary between DOE and utilities. Minor simplication of DOE operations resulting from consolidation at reactors. Significant increase in operations at reactors that are consolidating.	System costs reduced by $600-$700 million, due to transportation modifications and dual-purpose casks.	No significantly difference from the benefits achieved in Alternative 1. Higher occupational risk associated with additional at reactor consolidation.	No new technologies require development, however, the capability of at-reactor consolidation has not been fully demonstrated.
No-MRS System: Alternative 3				
Additional development required for integration of utilities waste-preparation functions into waste-management system. Significant institutional barriers will exist with utilities and opposition is expected from a large number of affected States and localities. Legislative action would be necessary to require utilities to consolidate fuel.	Shift of waste-preparation functions from DOE to many reactor sites. Significant demands placed on at-reactor operational schedules for fuel handling and preparation. Coordination and control problems associated with consolidation at many reactor sites. Repository consolidation operations eliminated, simplifying repository operations.	Costs shift from the Federal waste-management system to the utilities. Overall system costs increase by $200-$700 million, due largely to indeterminate utility-related costs.	Further reduction in public risk due to fewer shipments associated with consolidated fuel. Occupational risk increases due to reactor consolidation.	Significant technical issues associated with widespread consolidation at reactors.
No MRS System: Alternative 4				
Same issues as Alternative 3 plus major development, licensing, and institutional issues of seal-welding canisters on a production basis at reactors.	Same issues as Alternative 3 plus difficulties associated with widespread sealing and decontaminating canisters at reactors. Higher demands placed on reactor operational schedules for the handling and preparation. Added coordination and control problems.	Similar to Alternative 3, there is a shift in costs from Federal waste-management system to utilities. Overall system costs increase by $2.0-$2.6 billion.	Same as Alternative 3 plus further increase in occupational risk due to additional handling at reactors.	Same issues as in Alternative 3 plus new technology development required for widespread sealing and decontaminating canisters at reactors.
No-MRS System: Alternative 5				
Same issues as Alternative 4 plus significant development issues at-reactors for incorporation of additional in-pool equipment and modifications for repository-specific canisters.	Same issues as Alternative 4 plus difficulties associated with widespread storing and handling of repository-specific canisters at reactors. Potentially unacceptable demands placed on reactor operational schedules for fuel handling and preparation.	Similar to Alternative 4, with overall system costs increasing by $2.6-$3.3 billion.	Same as Alternative 4 plus further increase in occupational risk due to additional complexity in handling operations at reactors.	Same issues in Alternative 4.

4. DESCRIPTION AND EVALUATION OF THE REFERENCE AND UPDATED MRS SYSTEMS

4.1 REFERENCE MRS SYSTEM

For the purposes of this analysis, the reference MRS system is the waste-management system called the "improved-performance system" in the Mission Plan[2] with the waste-acceptance schedule given in the Mission Plan Amendment.[4] It consists of geologic repositories, a transportation system, and a facility for monitored retrievable storage (MRS) that is integrated into the system. A detailed description of the MRS facility is given in the DOE's proposal to the Congress.[1] As discussed in the Mission Plan Amendment,[4] the MRS facility would start receiving spent fuel in the first quarter of 1998.

Before the start of operations at the MRS facility, a number of reactors will have spent-fuel discharges in excess of their pool capacity. With the MRS facility starting in 1998, the amount of out-of-pool storage required is significantly reduced from the 9500 MTU required in the reference no-MRS system to about 3000 MTU, distributed over about 30 reactor sites. Although it is recognized that some at-reactor consolidation may occur, in the cost analysis for this case it is assumed that no spent fuel will be consolidated at the reactors.

The MRS facility will receive and prepare spent fuel for future emplacement at the geologic repository. The spent fuel will arrive by truck or rail. The principal waste-preparation function will be spent-fuel consolidation into repository-specific canisters. After being loaded with the consolidated fuel rods, the canisters will be filled with an inert gas and closed by welding. Being uniform in size and free of surface contamination with radioactive material, these canisters will facilitate handling, shipping, and further packaging at the repository (i.e., loading into disposal containers). The canisters containing consolidated spent fuel and the non-fuel-bearing hardware removed from the spent-fuel assemblies during consolidation will be loaded into high-capacity 150-ton rail casks and shipped to the repository in dedicated trains.

The spent-fuel-consolidation operations will be performed in a specially designed waste-handling building that will also have facilities for receiving the spent fuel and for storing a limited number of canisters pending shipment to the repository. For the consolidation operations, the waste-handling building will contain "hot" cells with radiation shielding and remote-control equipment in order to protect workers from exposure to radiation. All operations at the MRS facility will be performed in a dry environment rather than under water. One of the advantages of this approach is that the outer surface of the canister produced at the MRS facility will be kept free from contamination with radioactive material.

To accommodate spent fuel received before the repository starts operating in 2003 and until the repository reaches its design throughput rate, the MRS facility will include a storage yard in which canisters of spent fuel will be stored in sealed concrete casks. The casks will allow radiation monitoring and easy retrieval for eventual shipment to the repository.

The MRS facility will operate at an estimated throughput of 2650 MTU per year for most of its operating lifetime. The total throughput is estimated at about 65,000 MTU during an operating lifetime of 31 years. The onsite spent-fuel inventory will be limited to 15,000 MTU.

4.2 UPDATED MRS SYSTEM

In order to provide an equitable basis for comparison with alternative 1 to the no-MRS system, the options reviewed in Section 2 have been assessed for potential benefits in a system with an MRS facility. This evaluation indicated that, where applicable, the modifications involved in alternative 1 to the no-MRS system would be of value in the MRS system as well. These modifications pertain mainly to the transportation system. In addition, increased coordination between the DOE and the utilities in the management of spent-fuel storage would also be beneficial.

The transportation modifications that would be beneficial to the reference MRS system are applicable to the transportation of spent fuel from reactors to the MRS facility. They include the use of overweight trucks, heavy rail casks, and increased-capacity standard-weight casks.

As in the case of alternative 1 to the no-MRS system, it is assumed that increased coordination between the DOE and utilities results in the use of limited in-pool consolidation as a means to reduce requirements for out-of-pool storage. It is assumed that about 25 percent of the 3000 MTU requiring out-of-pool storage is accommodated through in-pool consolidation. Therefore, about 2300 MTU is accommodated in out-of-pool storage and about 700 MTU is accommodated by consolidating some of the newly discharged fuel and some of the spent fuel already stored in the pools. As discussed in Section 3.2.2, approximately three times the amount of fuel that is added to the pools must be consolidated in order to provide the required space. Therefore, for the updated MRS system it is assumed that about 2000 MTU of the fuel already stored in the pools is consolidated to provide the required space (see Appendix A for further details).

The system cost and operating advantages of these modifications to the reference MRS system would be similar to those identified in Section 3 for alternative 1 to the no-MRS system. Overall system costs, including the costs incurred by the utilities, are reduced by about $300 million. Most of this saving is attributed to the transportation-system modifications. Appendix A presents the assumptions and calculations performed to estimate these cost impacts.

Both occupational and public risk would be reduced by the postulated modifications to the transportation system. As in alternative 1 to the no-MRS system, the reduction in risk is attributable mainly to the reduction in the number of cask shipments. As already mentioned, the exposure of the public to radiation from the waste-management system would be extremely low in all cases.

5. COMPARISON OF THE NO-MRS SYSTEM WITH THE MRS SYSTEM

This section compares the alternative no-MRS system with modifications for the best overall performance (i.e., no-MRS alternative 1) and the MRS system, which has been updated to include similar applicable changes. This comparison is based on the evaluation criteria described and used in Sections 3.2 and 3.3.

5.1 TECHNICAL FEASIBILITY

In the proposal to the Congress,[1] the DOE concluded that the MRS facility is feasible because it is based on established technologies and its design, licensing, and construction are typical of, but less demanding than, activities that have been well demonstrated with many other nuclear facilities. Similarly, the waste-preparation facilities in both the modified no-MRS system and the updated MRS system would use current technology that has been demonstrated. The potential modifications in transportation and utility management of at-reactor storage are equally feasible in both the modified no-MRS system and the updated MRS system.

The technical feasibility of modified no-MRS system and the updated MRS system is therefore considered to be equivalent.

5.2 SYSTEM DEVELOPMENT AND LICENSING

In comparing the system development and licensing aspects of the modified no-MRS system with the modified MRS system, a number of significant differences are found. From an overall system position, the MRS facility becomes a clear focal point for integrating all predisposal functions, including the transfer of responsibility for spent fuel from nuclear utilities to the DOE. It provides earlier experience with key institutional interactions between the DOE and State and local governments; those interactions can benefit the repository program.

Because the MRS facility can be licensed and constructed much earlier than the repository, it provides a more definitive basis for spent-fuel acceptance schedules from utilities. Also, the MRS facility lessens the likelihood that the licensing and the startup of the repository would be affected by delays in developing the predisposal functions because the MRS facility would be developed much earlier and at a site independent of the repository.

The modified no-MRS system does not provide the development and licensing benefits that would be obtained with an MRS facility in the waste-management system. The benefits provided by the updated MRS system make it clearly preferable with respect to system development and licensing.

5.3 SYSTEM OPERATIONS

As in the case of system development and licensing, the updated MRS system has distinct advantages over the modified no-MRS system with respect to system operations. From an overall system perspective, the MRS facility would provide improvements in system reliability and flexibility. These improvements would be realized by separating spent-fuel acceptance from reactors from the function of spent-fuel emplacement in the repository and also by adding significant operational storage capacity to the system. Thus it would provide flexibility to accommodate changes in the repository schedule or changes in repository operations without affecting waste acceptance. Another important improvement would be the increased control over the rate of spent-fuel transfer to the repository, which would enhance the efficiency of repository operations. In addition, the MRS facility eliminates the requirement for continued expansion of at-reactor storage capacity.

The MRS facility does require a canister in which the spent fuel is consolidated for storage and shipment to the repository; this canister provides an extra barrier for permanent waste isolation. Without the MRS facility this canister may not be required. Conversely, the MRS facility reduces surface-facility operations at the repository by providing fuel for emplacement in large rail casks containing sealed and decontaminated canisters of consolidated fuel rather than in smaller truck and rail casks containing intact fuel assemblies. In comparison with the modified no-MRS system, the updated MRS system improves the efficiency of emplacement operations by providing the capability to select fuel from the MRS facility inventory on the basis of its heat emission.

The application of the transportation improvements made in the modified no-MRS and updated MRS systems would affect operations by reducing shipment receipts at any of the DOE facilities. This would reduce facility operations for cask handling and unloading in both systems.

The above comparison of the modified no-MRS and updated MRS systems indicates that the system with an MRS facility provides major system-operation benefits.

5.4 SYSTEM COSTS

The 1987 total-system life-cycle cost (TSLCC) analysis[7] published by the DOE indicates that for the same reference-case repository-site combination (i.e., sites for the first and the second repository), the incremental cost of the reference MRS system over the reference no-MRS system ranges from $1.5 billion to $1.6 billion, depending on the repository site. The TSLCC analysis also points out that in the reference MRS system the utilities realize cost savings in at-reactor out-of-pool storage because of the earlier acceptance of spent fuel at the MRS facility, and these savings were estimated to range up to $1 billion.

As discussed in Section 3 and Appendix A, modification 1 to the no-MRS system reduces the overall system cost by about $400-$600 million, most of which is attributable to transportation modifications. Similarly, Section 4 discusses the cost benefits associated with the updated MRS system, identifying an overall system-cost reduction of about $300 million, most of which is also attributable to transportation modifications. A comparison of these estimates shows that the overall savings accruing to the modified no-MRS system are about $100-$300 million greater than the overall savings to the updated MRS system.

As a result of the modifications described in Sections 3 and 4 for the no-MRS and MRS systems, the difference in overall system costs between these systems is $1.6-$1.9 billion (versus the $1.5-$1.6 billion estimated in the 1987 TSLCC report[7]). To put this difference in perspective, the estimated life-cycle costs for the total waste-management system (TSLCC 1987) range from approximately $30 billion to approximately $38 billion, depending on the host rock and the location of the repository and depending on whether an MRS facility is included in the system. Thus, the estimated incremental cost of including an MRS facility in the overall waste-management system is on the order of 5 percent of the total-system cost. This incremental cost difference is smaller than the cost differences among repository host rocks and locations.

5.5 SYSTEM RISK

The system risk evaluated in this section refers to the public and the occupational radiation doses that would result from the spent-fuel-handling operations at the reactors, the MRS facility, surface facilities at the repository, and transportation between those facilities. The transportation improvements made to both the no-MRS and the MRS systems will contribute to the objective of keeping both public and occupational exposures to radiation as low as is reasonably achievable. The reduction in the number of shipments that results from the transportation improvements reduces the public exposure, and the corresponding reduction in handling requirements at the system facilities reduces the occupational exposure. A comparison of the modified no-MRS system with the updated MRS system indicates that the occupational exposure will be slightly higher in the updated MRS system, and the public exposure will be higher in the modified no-MRS system.

Although the updated MRS system requires a slightly larger number of shipments, the average length of each shipment is significantly shorter, and the resulting number of cask-miles and shipment-miles is significantly lower than in the modified no-MRS system. The number of cask-miles is estimated to be more than 60 percent greater in the no-MRS system. Because the MRS-to-repository shipments are made in multiple-cask dedicated trains, the number of shipment-miles in the modified no-MRS system is over 140 percent greater than that in the updated MRS system. These differences cause the increase in the public exposure that is predicted for the modified no-MRS system.

As already mentioned, the exposure of the public to radiation from waste-management activities at reactor sites, in transportation, at the MRS facility, and at the repository would be extremely low in all cases. Public exposure would be dominated by the exposure resulting from transportation, although this exposure would be very low in an absolute sense.

The radiation exposures received by the public from the MRS facility--including from normal operations, postulated accidents, and spent-fuel transportation to and from the MRS facility--are below the regulatory limits set by the Nuclear Regulatory Commission in 10 CFR Part 72 (0.025 rem annually for the maximally exposed individual for normal operations and 5 rem for any design-basis accident). The population doses are consistently estimated to be less than 1 percent of the radiation dose received by the same population group from naturally occurring background radiation. In summary, the improvements to the no-MRS and MRS systems have not significantly changed the risk comparison from that presented in the MRS proposal.[1] The occupational risk is slightly higher and the public risk is significantly lower with an MRS facility in the waste-management system.

6. VIEWS OF THE UTILITIES

Certain parties have questioned whether the construction of an MRS facility is supported by the U.S. electrical utilities. This section provides information on the views expressed by various utilities or representative groups at Congressional hearings and in other forums. It also discusses the concerns expressed by certain utilities about performing certain spent-fuel-management activities at reactor sites rather than the MRS facility.

6.1 SUPPORT FOR THE MRS PROPOSAL

In November 1985, before the MRS proposal to the Congress[1] was completed, the GAO asked the 74 utilities that either own or operate nuclear power plants for their views of the DOE's plans for an MRS facility and their plans to accommodate growing inventories of spent fuel.[8] After receiving 54 completed responses covering 71 utility companies, the GAO published the results in a fact sheet.[9] Of the completed responses, 44 percent supported an MRS facility and 31 percent opposed it, with 20 percent taking a neutral position. Almost all of the responding utilities said that they could provide storage for their spent fuel until 1998, but the provision of storage would be more difficult after 1998. If a repository is not available by 1998, 52 percent of the responses said that spent-fuel storage at an MRS facility would be preferable to at-reactor storage, and 70 percent indicated that the utility was willing to pay a share of the MRS costs.

The GAO viewed the results of this survey as indicating that the utilities' opinions vary on the need for an MRS facility. However, it acknowledged that the survey was conducted before the DOE had made its proposal and since that time nuclear-industry positions indicate "strong support for DOE's MRS proposal." In particular, the GAO mentions MRS support by the Edison Electric Institute (EEI) and notes that the EEI cites several advantages of integrating the MRS facility into the waste-management system. According to the EEI, the principal advantage is the requirement to mobilize the DOE's waste-management development efforts several years before they would be required for a system with only a repository. The GAO report says that the EEI believes this early focus is essential because of the duration and cost of the program.[10]

To better understand the views and attitudes of the utilities about spent-fuel management, the DOE in 1987 sponsored a limited study involving eight utilities that operate about 20 percent of the nuclear power plants in the United States. The results, published in a draft report,[5] outline the benefits of using a central facility, such as the MRS facility that is specifically designed for waste-management operations and economy of scale, as opposed to performing these operations at multiple reactor sites not designed for such activities.

More recently, various representatives of the utilities and/or their trade associations have explicitly supported the construction of an MRS facility in testimony at Congressional hearings. The testimony was given on behalf of the American Nuclear Energy Council, the Edison Electric Institute, the utility Nuclear Waste Management Group, and the Electric Utility Companies' Nuclear Transportation Group.[11,12]

These organizations regard the MRS facility as a vital addition to the waste-management system--and an addition that would provide a variety of benefits, such as providing needed flexibility in the planning, design, construction, and operation of the disposal system and allowing the DOE to focus its efforts more efficiently and effectively by separating the functions of waste preparation on the surface from those of emplacement underground for permanent disposal.

These organizations have also requested that the Congress act on the DOE's proposal by not only authorizing and funding the MRS facility but also by providing incentives to the host State, affected Indian Tribes, and local communities.

6.2 UTILITY VIEWS ON AT-REACTOR OPTIONS

As already mentioned, in 1987 the DOE sponsored a limited study of utility views on spent-fuel management. The eight utilities selected for this study* operate about 20 percent of the nuclear power plants in the United States and represent a wide range of experience in reactor operations and spent-fuel management. The principal purpose of the study was to ascertain attitudes and concerns about performing certain spent-fuel-management activities at reactor sites as part of the Federal waste-management system; these activities include spent-fuel consolidation and dry at-reactor storage. The results of the study are summarized below.

The interviewed utilities expressed the following general concerns about performing new spent-fuel operations at their reactor sites:

- The supervision of additional waste-management functions would distract management personnel from their responsibilities in reactor operation.

- New operations create concerns about engineering, safety, the exposure of workers to radiation, and the frequency of maintenance operations or equipment breakdowns.

- Additional spent-fuel-handling and storage-pool operations are likely to increase the efforts needed to keep the storage pools and equipment free of contamination with radioactive material.

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*The utilities interviewed in this study were the Duke Power Company, the New York Power Authority, Northeast Utilities, the Portland General Electric Company, the Public Service Electric and Gas Company, the Southern California Edison Company, Southern Company Services, Inc., and the Wisconsin Electric Power Company.

- In the event of a release of radioactive material or other incidents that must be reported to the Nuclear Regulatory Commission (NRC), it may be necessary to shut down the reactor, and downtime is of great concern: because of the need to buy replacement power, it may cost as much as $500,000 per day. In addition, the utility might be faced with adverse public reaction and an NRC fine.

In view of these concerns, the interviewed utilities felt that indemnification by the DOE would be necessary for any liability arising from DOE-mandated activities, including the reimbursement of costs of replacement power, NRC fines for operational irregularities, and the cleanup for contamination.

The interviewed utilities were also concerned about regulatory requirements and the responses of their public utility commissions (PUCs). For example, they stated that license amendments for large numbers of reactors for perhaps more than one activity or facility modification might be difficult to obtain in a timely manner; they also said that full compensation from the DOE for costs incurred would be required to satisfy PUC requirements. In addition, utilities expect varying degrees of public concern about waste-management activities not previously licensed and pointed out that a license amendment makes the local communities more conscious of the presence of a nuclear power plant.

The utilities explained that, because of the differences in physical facilities among the reactor plants, it would be difficult, and in some cases prohibitively expensive, to mandate that certain operational activities be performed by the utilities on behalf of the waste-management system. Specific concerns about rod consolidation included the following:

- Conflicts in the use of in-pool or pool-side space would arise.
- The floor-loading limits of the spent-fuel storage pools will limit the quantity of consolidated spent fuel that can be stored.
- Pool equipment is not designed for some of the operations that may be necessary, with the potential for creating operating problems.

The general attitude of U.S. utilities on performing additional spent-fuel-management activities at reactor sites was summarized at recent Congressional hearings:[11,12]

> We question whether electric utilities that operate nuclear energy plants should be required to perform functions as part of the high-level radioactive waste-disposal system. There are tremendous technical, operational, regulatory and institutional barriers to having electric utilities perform these unctions. Also, it only makes sense to concentrate these activities at a single location rather than at 72 locations across the country.

7. COST UNQUANTIFIED IN THE MRS PROPOSAL

The GAO[3] and others have stated that the cost estimates in the MRS proposal to the Congress[1] are not complete because they do not include the cost of certain elements that have been identified, but not quantified, by the DOE. These cost elements include the following:

1. Aid to affected localities for mitigating the impacts of the MRS facility.

2. Consultation-and-cooperation agreements.

3. Payments equal to State and local taxes.

4. Fees for local, State, and Federal permits and licenses.

5. Costs for transporting spent fuel from reactors to the MRS facility.

6. Costs of site acquisition.

In regard to item 4, most licensing and permit fees, which are spread over about 35 years during the licensing and operational phases, are easily covered by the 25-percent contingency established for design and operation. In regard to item 5, the costs of transporting spent fuel are more properly evaluated from a total-system perspective. Transportation costs are included in the total-system cost analyses. Costs for upgrading roads, railroads, and bridges are not appropriate since the transportation of spent fuel to and from the MRS facility will be accomplished through commercial transport; however, included in the estimate for the consultation-and-cooperation agreements is the cost of improvements in the transportation infrastructure. In regard to item 6, the DOE did provide an estimate in the MRS proposal of $2 million.

The other costs listed above (items 1, 2, and 3) were not quantified in the MRS proposal because the DOE felt that including them in the proposal was not appropriate. As explained in the DOE's comments on the GAO report,[1] such costs were not specified in the proposal "to allow the DOE flexibility in the consultation-and-cooperation process that will be initiated if Congress approves the MRS proposal." An estimate for State and local taxes (or payments in lieu thereof) was nonetheless included in the proposal documents. The DOE's comments also pointed out that some of these costs should be determined by the Congress "as a matter of national policy and of the value of the MRS to the waste management system, as opposed to a DOE estimate." However, additional information on of these costs is presented in this report.

For an MRS facility, the Act does not authorize the DOE to fund C&C agreements, make payments equal to taxes, or to mitigate impacts (except for limited impacts on public services). The authority for these expenditures would come from the legislation authorizing the MRS facility. The legislation that has been drafted for this purpose directs the DOE to "implement the monitored retrievable storage proposal and program plan submitted to the Congress in March 1987, including but not limited to provisions relating to financial assistance and measures designed to be responsive to the concerns and recommendations of the State of Tennessee and affected local governments."

In response to the above-mentioned comments, the DOE has prepared preliminary estimates of the costs unquantified in the MRS proposal. These estimates are given in Table 7-1. The assumptions on which these preliminary estimates are based are briefly discussed in the text that follows. The authority for these expenditures would come from the legislation authorizing the MRS facility. Only funds for impact mitigation have already been approved by the Congress, as they are included in the Act. Other payments to the affected State and local jurisdictions, although proposed by the DOE, are yet to be approved by the Congress. Consequently, the costs for these items may be as low as zero. The table below presents the low estimates and the estimated range of costs for the items unquantified in the MRS proposal.

Table 7-1. Estimated MRS Life-Cycle Costs

Item	Estimated cost (millions of dollars)
Impact mitigation/preoperational financial assistance	10-150
Payments equal to taxes	0-400
Consultation-and-cooperation agreements*	0-150
Total	10-700

*This item covers the special provisions discussed in Section 7.3. It should be noted that all of the items listed in this table will be included in the negotiation of consultation-and-cooperation agreements.

7.1 IMPACT MITIGATION/PREOPERATIONAL FINANCIAL ASSISTANCE

The impact aid authority in Section 141(f) of the Act is restricted to public services. More general authority is requested in Section 4.3 of the MRS proposal. During the operational phase, impact mitigation would be authorized "as under Section 116(c)(2)." For the preoperational phase, the DOE has proposed to provide financial-assistance payments to address State and local concerns regarding socioeconomic impacts.

Impact mitigation covers both direct and indirect impacts, such as postulated negative effects on tourism and industrial recruitment. The items listed below are examples of the types of programs the State, regions, or local community might implement in order to offset any indirect negative impacts. These programs are not meant to be all inclusive. They represent ideas and should be considered only as possible projects subject to applicable laws and regulations and any policy guidance that may be provided by the Congress if it decides to approve the MRS facility.

- Provide funding for the upgrading of services like sewer and water lines.
- Allocate impact-mitigation monies to area chambers of commerce.
- Fund a distinguished fellowship program.
- Fund a job-training program at local technical institutes.
- Conduct public education programs for area officials.

The MRS proposal[1] also proposes that, during the preoperational phase, financial-assistance payments be made to State and local governments to "approximate the taxes that would eventually be paid to those governments by a fully operational MRS facility valued at $1 billion." The level of preoperational assistance would be established by agreement but could range up to $15 million per year for each of the 10 preoperational years. If authorized, the life-cycle cost would be up to $150 million.

The total costs for this category would depend on the type of financial assistance approved by the Congress during the authorization of the MRS facility. Should preoperational assistance payments be approved, then impact-mitigation payments would be incorporated within those payments. Should preoperational payments not be approved, then impact-mitigation payments would be limited under Section 141(f) of the Act to mitigating public-services impacts related to the siting, construction, and operation of the MRS facility. The socioeconomic analysis contained in the MRS proposal (Volume 2, "The Environmental Assessment") indicates that expenditures for impacts defined within the limits prescribed in Section 141(f) would probably not exceed $10 million for the life of the facility.

7.2 PAYMENTS EQUAL TO TAXES

Section 4.3.2 of the MRS proposal[1] requests that the Congress authorize the DOE, during the operation of the MRS facility, to make payments equal to the taxes that State and local governments would receive if the MRS facility were treated like other real property and industrial activity. Such payments are authorized for repositories in Section 116(c)(3) of the Act.

Under existing law, MRS contractors would pay use taxes equal to the sales taxes that would be paid by a private owner. Thus, these taxes fall outside payments equal to taxes. The considerations used to arrive at preliminary estimates for the important tax-related payments are described below.

<u>Property taxes paid to local governments - $250 million</u>

If such payments are authorized, future property taxes are assumed to be bounded on the high side by a case for which current tax rates are constant and on the low side by a case for which current local government revenues are constant. Using an initial value of $1 billion for capital cost, a statutory assessment ratio of 40 percent, and an assumed straight-line depreciation to a salvage value of $250 million at the end of operation and staying constant during decommissioning, the life-cycle property taxes are about $300 million in the constant-rate case and about $150 million in the constant-revenue case. The midpoint is about $250 million.

Other taxes - up to $100 million

If authorized, this category would include State and local taxes paid on taxable activities conducted at the MRS site by the Federal Government--that is, taxes that, in the absence of sovereign immunity, would be paid by a private corporation.

When combined, the payments equal to taxes are estimated at up to $350 million. With an uncertainty of plus or minus 15 percent, the costs may be up to about $400 million over the life of the facility.

7.3 CONSULTATION AND COOPERATION (C&C) AGREEMENTS

The authority to enter into a consultation-and-cooperation (C&C) agreements with the State is derived from Section 117, which is referenced by Section 141(h) of the Act. The purpose of the C&C agreements is to resolve the concerns of the State or affected Indian Tribes regarding the "public health and safety, environmental, social, and economic impacts." In addition, the MRS proposal states that "DOE would fully reimburse the State for reasonable and direct expenses incurred in association with the MRS facility."

Steering Committee costs - up to $70 million

If the Steering Committee is authorized, it could have an independent staff. For a staff of eight to ten persons, basic office equipment and space, and the reimbursement of expenses incurred by the members of the MRS Steering Committee, the cost is estimated to range from about $500,000 to $1.5 million per year. The committee is assumed to meet over a period of 40 to 45 years, and hence the total cost would range between $20 and $70 million.

State inspection - up to $15 million

The proposal indicated receptiveness to State inspection. Depending on a number of items that would need to be discussed with the State, provision for State inspection is estimated to cost $1.5 million, from information provided by transportation specialists. The operating cost would be about $350,000 per year for 31 years, assuming three inspectors (to cover two shifts per day, 6 days per week), clerical support, and maintenance. An uncertainty of plus or minus 20 percent is assumed.

Emergency-preparedness training - up to $7 million

This estimate assumes that a five-person team travels throughout the State to conduct training programs in counties through which the spent fuel will move. The estimated cost is about $750,000 per year for the 5 years of facility construction. A higher cost estimate is also given; this estimate assumes additional training through the 31-year operating period at an annual cost of $100,000.

Improvements to the transportation infrastructure - up to $60 million

This estimate is based on ugrading the roadways affected by the MRS facility. As an example, if the Clinch River site proposed by the DOE is selected, the estimated cost ranges from $45 to $60 million. This estimate is based on estimates by the Tennessee Department of Transportation for providing four lanes and straightening State Route (SR) 58 and improving bridges. Because SR 95 is curvier and hillier than SR 58, the cost per mile for SR 95 has been estimated to cost 30 percent more than for SR 58. The cost of upgrading Bear Creek Road from its intersection with SR 95 to the Clinch River site is based on the same cost per mile as SR 58. The total cost for these projects is estimated to be about $50 million, and an uncertainty of plus or minus 15 percent is assumed.

These estimates total up to $150 million. The separate high and low estimates for each item above are added to obtain these totals.

8. CONCLUSIONS

This report was prepared to provide information to address questions raised by the General Accounting Office (GAO)[3], the State of Tennessee, and others after the submittal of the DOE's MRS proposal to the Congress.[1] The principal topics covered in this report are (1) the feasibility of achieving comparable overall waste-management performance without the MRS facility, (2) the views of the utility industry on the need for an MRS facility, and (3) estimates of costs unquantified in the MRS proposal. The principal conclusions are summarized below.

8.1 FEASIBILITY OF ACHIEVING COMPARABLE PERFORMANCE WITHOUT THE MRS FACILITY

The GAO and others have objected that the MRS proposal does not explain how the authorized waste-management system (the reference no-MRS system) could be modified to function most efficiently, effectively, and safely. Information on potential modifications to the authorized system was said to be necessary for a balanced comparison with the improved-performance system.

This report assesses the overall benefits that could accrue to the waste-management system through various modifications to the no-MRS system. Five alternative no-MRS systems were postulated by grouping together potential modifications with similar system-wide impacts. The alternative systems range from those limited to the Federal waste-management system (no-MRS alternatives 1 and 2) to those involving an increasing progression of waste-preparation functions performed at reactor sites. The extreme case (alternative 5) examines the impacts of performing at reactor sites all of the waste-preparation functions that would be performed by the MRS facility.

Each of the alternative no-MRS systems was then compared with the reference no-MRS system in terms of the following criteria: technical feasibility, effects on system development and licensing, effects on system operations, cost, and risk. The results of this comparison indicate that some potential modifications to the transportation system and the DOE's guidance to the utilities with respect to the efficient management of at-reactor spent-fuel storage would result in a no-MRS system (no-MRS alternative 1) that has some advantages over the reference no-MRS system. The transportation modifications include the use of higher-capacity standard-weight casks, the limited use of overweight truck casks, and the limited use of extra-large rail casks. The second modification entails increased participation by the DOE in providing guidance and advice to utilities in regard to at-reactor spent-fuel storage so that their technology choices are beneficial to the waste-management system. These modifications can be implemented in the Federal waste-management system without significantly affecting the DOE's interface with the utilities. These modifications would reduce the overall system costs by about $400 to $500 million and also reduce the occupational and public risk of radiation exposure.

Another alternative no-MRS system is one in which the DOE would provide incentives and take other actions to influence the utilities to choose storage options that are most beneficial to the waste-management system (no-MRS alternative 2). Two options that were considered are spent-fuel consolidation into repository-compatible canisters and the use of dual-purpose (transportation and storage) casks. Alternative 2 represents a significant increase in the integration of at-reactor operations with the Federal waste-management system. However, the evaluation of the benefits associated with this increased level of integration indicates that only marginal cost benefits beyond those predicted for alternative 1 can be expected, and these benefits are outweighed by the negative impacts associated with the intrusion of the DOE into the utilities operations.

Also examined were major increases in the levels of utility participation in the preparation of spent fuel for disposal (no-MRS alternatives 3, 4, and 5). The evaluations of each of these alternatives gave basically identical results: overall system costs would increase; significant institutional and utility opposition to widespread utility involvement in spent-fuel preparation can be expected; and substantial technical feasibility issues would need to be resolved. These alternatives were found to be less desirable than the reference no-MRS system.

No-MRS alternative 1--the system with transportation modifications and increased DOE participation in utility management of at-reactor storage--was then compared against an MRS system updated to include modifications in reactor-to-MRS transportation and increased DOE participation in utility storage choices. This comparison (Section 5) indicates that incorporating these modifications to the no-MRS system (and equally to the MRS system) would not significantly affect the conclusions reached in the MRS proposal about the need for, and the advantages of, an MRS facility. The advantages of the MRS facility, as outlined in Section 1 of this report, include improvements in system development, accelerated waste acceptance, improvements in system reliability and flexibility, simplification of repository operations, transportation improvements, and institutional benefits.

In summary, a qualitative examination of the question as to whether the advantages listed above might accrue from alternative no-MRS system configurations leads to the conclusion that no realistic combination of projected technological modifications and varying degrees of shift of waste-preparation functions from the DOE to the utilities will result in equivalent advantages or in any substantive way alter the advantages that would accrue to the waste-management system as a result of the MRS facility.

8.2 VIEWS OF THE UTILITY INDUSTRY ON THE NEED FOR THE MRS FACILITY

The case for an MRS as presented to the Congress was based on weighing benefits against costs. The benefits were judged to be sufficient to warrant the added costs relative to a no-MRS system configuration. This conclusion has been endorsed by the utility industry. Through Congressional testimony of utility representatives,[11,12] GAO findings, and the results of a limited DOE study, the following conclusions about the views of the utility industry can be made:

- The nuclear utility industry supports the need for an MRS facility in the waste-management system.
- The utility industry can and will implement technological solutions to the problem of spent-fuel management until the spent fuel is

transferred under the Act to the Federal Government. The solutions are, however, likely to vary among the utilities.

- The utilities are not inclined to commit to substantially greater waste-preparation operations at reactor sites than those required to sustain the safe operation of the nuclear power plant. This attitude stems mainly from concerns about institutional, liability, and licensing issues rather than technological concerns.

- Any waste-management option that requires extensive at-reactor consolidation or other at-reactor operations would require facility modification and/or operations that encroach on the primary function of reactors--the generation of electricity.

- Placing additional burdens on nuclear power facilities solely to decrease the costs of the government's spent-fuel disposal program would be inconsistent with the intent of the Nuclear Waste Policy Act.

8.3 COSTS UNQUANTIFIED IN THE MRS PROPOSAL

The DOE has been asked to provide estimates for certain costs that were identified but not quantified in the MRS proposal.[1] Most of these costs fall into the general categories of impact mitigation, consultation-and-cooperation (C&C) agreements, and payments equivalent to taxes.

These costs were not quantified in the MRS proposal to allow the DOE flexibility in the consultation-and-cooperation process that will be initiated if the Congress approves the MRS proposal. Furthermore, some of these costs should be determined by the Congress as a matter of national policy and of the value of the MRS facility to the waste-management system, as opposed to a DOE estimate. The authority for these expenditures would come from the legislation authorizing the MRS facility. Only funds for impact mitigation have already been approved by the Congress, as they are included in the Act. Other payments to the affected State and local jurisdictions, although proposed by the DOE, may not be approved by the Congress. Consequently, the range of possible costs for these items may be as low as zero. The table below presents the full range of estimated costs for the items unquantified in the MRS proposal.

Item*	Estimated cost (millions of dollars)
Impact mitigation/preoperational financial assistance	10-150
Payments equal to taxes	0-400
Consultation-and-cooperation agreements	0-150
Total	10-700

*It should be noted that all of the items listed in this table will be included in the negotiation of consultation-and-cooperation agreements.

8.4 SUMMARY CONCLUSIONS

This report has examined three issues related to the need for an MRS facility in the waste-management system: modifications to the no-MRS system, views of the utility industry, and unquantified costs in the DOE's proposal to the Congress.[1]

The DOE concludes that nothing in this analysis indicates the need for any substantive change in the DOE's proposal to the Congress. Technological advances being made through DOE and industry research and development programs may improve some waste-management operations, such as spent-fuel consolidation, spent-fuel storage, or transportation. These ongoing development programs were described in the DOE's proposal to the Congress and are expected to contribute to the optimization of the waste-management system. The incorporation of the expected advances into the system does not change the conclusions reached in the DOE's proposal about technical feasibility or system benefits and costs.

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11. E. M. Davis, statement on the monitored retrievable storage facility, hearing before the U.S. House of Representatives, June 11, 1987.

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APPENDIX A

DEVELOPMENT OF DETAILED COST ESTIMATES FOR NO-MRS AND MRS SYSTEMS

A.1 INTRODUCTION

This appendix contains the assumptions made and the calculations performed to estimate the cost impacts of the various alternative No-MRS and MRS systems analyzed in this report. It should be noted that the costs presented in this Appendix are preliminary estimates. Some of the equipment and operations examined in this report have not yet been designed or developed, and therefore the uncertainty in certain portions of the cost estimates is significant.

The proposed system modifications include consolidation of spent fuel at the reactor sites (at selected sites to assist utilities in meeting their individual storage needs, or at all sites to eliminate the need for a consolidation facility within the DOE waste management system), and the use of transport casks having capacities much larger than current reference casks. Other aspects examined include the cost differences associated with using dual purpose (storage/transport) casks versus using storage-only concrete casks for at-reactor dry storage. Those elements of the system life-cycle costs that are sensitive to how much consolidation is performed and to where within the system it is performed are estimated for the reference No-MRS and MRS systems and for the various alternative No-MRS and MRS systems, to permit evaluation of each system relative to each of the other systems. The cost estimates contained in this appendix are focussed on those elements of the waste system life-cycle costs that are sensitive to where within the system consolidation is performed and to how many assemblies are consolidated at any given location. Those elements of the system life-cycle costs that are not affected by these considerations (such as underground facilities and emplacement activities) are omitted from these analyses. In this regard, system development and engineering (D&E) costs were assumed to be insensitive to the various system alternatives analyzed. Also, only that fuel emplaced at the first repository is included in these analyses. As a result, the costs presented herein contain fewer elements than do the total system life-cycle costs (TSLCC) developed and reported annually by the Department. By omitting those large cost elements that are unaffected by the variations considered in this study, and by adding elements such as at-reactor storage, the sensitivities of system life-cycle costs to the proposed variations in system configuration and performance are more readily discerned and the large uncertainties associated with examining small differences between large numbers are reduced.

The system areas evaluated in this analysis of suggested system modifications, which include facilities and operations necessary for storage of spent fuel at the reactor sites, transport of the spent fuel through the federal waste management system, and preparation of the spent fuel for emplacement but including neither the actual emplacement packages nor the underground facilities and operations necessary to accomplish emplacement are illustrated in Figure A-1. The system areas encompassed by the TSLCC are also shown in the figure, to identify those areas that the TSLCC and this analysis have in common, and to illustrate those portions of the TSLCC that are excluded from this analysis, such as the emplacement activities at the first repository and the transport, preparation and emplacement activities associated with the second repository.

The reference No-MRS system cost elements are base-lined to Scenario 1 of the MRS Submission to Congress and the reference MRS system cost elements are base-lined to Scenario 4 of the MRS Submission to Congress.

The results of these analyses are summarized in Section A.2. The detailed bases and assumptions used in the analyses are discussed in Section A.3. The detailed analyses and results are presented in Section A.4. A discussion of a number of potential system costs that cannot readily be quantified is presented in Section A.5.

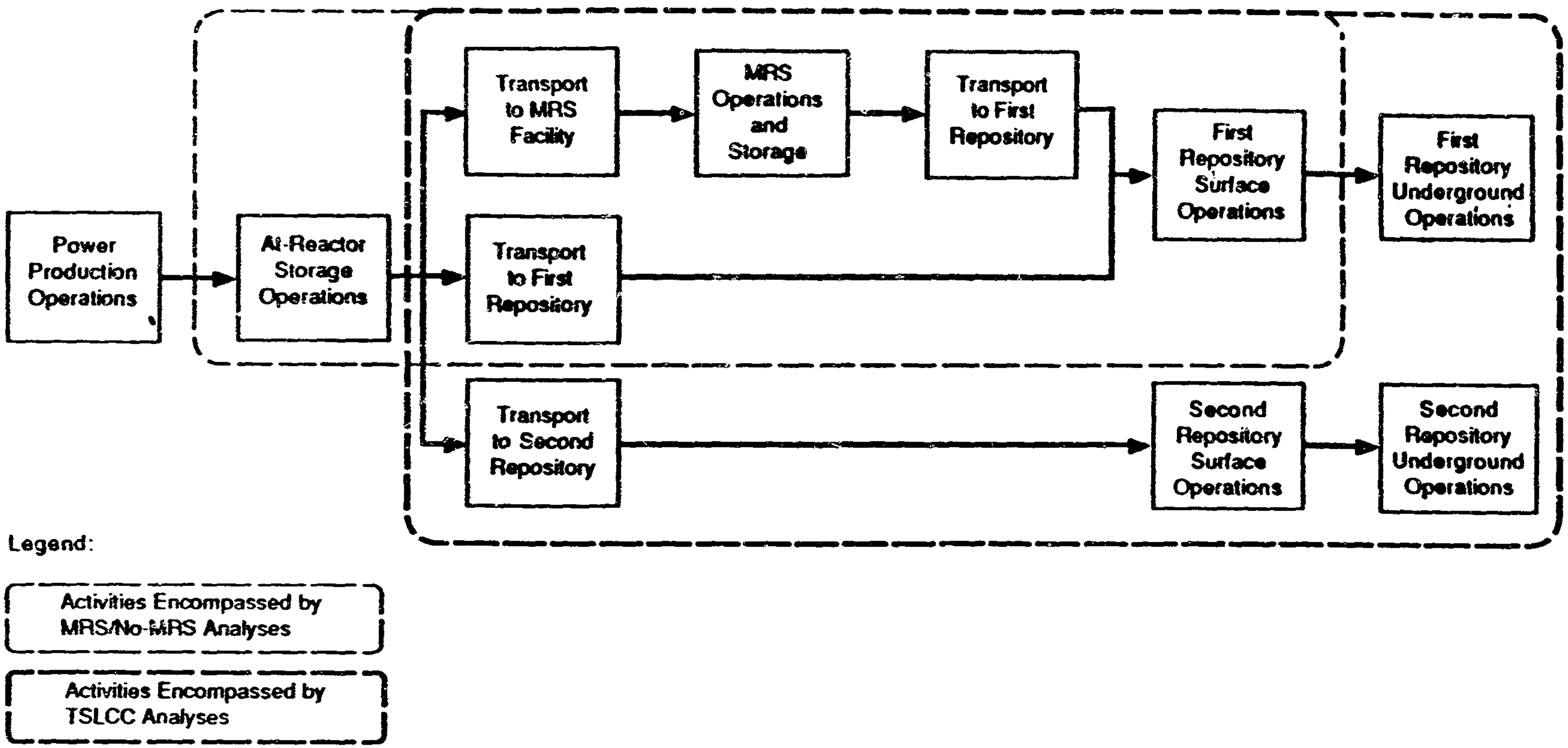

FIGURE A.1 Waste Management System Activities Encompassed By TSLCC and MRS/No-MRS Analyses

A.2 SUMMARY

The estimated life-cycle costs for packaging and transporting 65,360 MTU of spent fuel to the first repository are evaluated in this study for the reference No-MRS system, the reference MRS system, and for alternatives to those reference systems. The estimated system life-cycle costs, including both the determinate costs developed in Section A.4 and the indeterminate cost developed in Section A.5, and shipment-miles and cask-miles for these systems, are summarized for comparison in Table A-2.1. Thus, it can be seen that the alternative MRS system has fewer shipment-miles than any of the No-MRS cases, reflecting lower risk to the public from transport of the spent fuel. The total cost for the system (excluding underground activities at the repository) exhibits a very shallow minimum across Alternatives 1 and 2 where the improved cask capacities are applied. The differences in life-cycle cost between the lowest cost MRS and No-MRS systems (for the same repository) range from about $1.0 billion to $1.3 billion.

Providing at-reactor canister closure and decontamination (as in No-MRS System Alternatives 4 and 5) is clearly not cost-effective, compared to the MRS systems.

Alternatives 3, 4, and 5 also would require all reactors to consolidate, a situation that is beyond the control of DOE at the present time.

TABLE A-2.1 Comparison of the Reference and Alternative No-MRS and MRS Systems

Item	Basalt	Salt	Tuff
Reference No-MRS System			
Cost (billions 1985 $)	5.8	6.2	5.4
Shipment-Miles (millions)	86.0	58.4	80.2
Cask-Miles (millions)	86.0	58.4	80.2
No-MRS System Alt. 1			
Cost (billions 1985 $)	5.2	5.8	4.8
Shipment-Miles (millions)	39.9	27.1	37.1
Cask-Miles (millions)	39.9	27.1	37.1
No-MRS System Alt. 2			
Cost (billions 1985 $)	5.1	5.6	4.6
Shipment-Miles (millions)	38.3	26.1	35.7
Cask-Miles (millions)	38.3	26.1	36
No-MRS System Alt. 3			
Cost (billions 1985 $)	6.0-6.5*	6.5-6.9*	5.6-6.0*
Shipment-Miles (millions)	30.3	20.9	28.5
Cask-Miles (millions)	30.3	20.9	28.5
No-MRS System Alt. 4			
Cost (billions 1985 $)	7.8-8.3*	8.3-8.8*	7.4-7.9*
Shipment-Miles (millions)	30.3	20.9	28.5
Cask-Miles (millions)	30.3	20.9	28.5
No-MRS System Alt. 5			
Cost (billions 1985 $)	8.6-9.1*	8.8-9.3*	8.2-8.7*
Shipment-Miles (millions)	56.4	14.5	29.0
Cask-Miles (millions)	56.4	14.5	29.0
Reference MRS System			
Cost (billions 1985 $)	6.4	7.0	6.2
Shipment-Miles (millions)	32.2	31.7	32.1
Cask-Miles (millions)	39.6	36.5	39.2
Alternative MRS System			
Cost (billions 1985 $)	6.1	6.7	5.9
Shipment-Miles (millions)	16.0	15.7	16.0
Cask-Miles (millions)	22.0	19.6	21.4

*These costs include "indeterminate costs" which are discussed in Section A-5. These indeterminate costs may be higher than estimated herein.

A.3 BASES AND ASSUMPTIONS

The bases and assumptions utilized in the reference and alternative No-MRS systems and the reference and alternative MRS systems are presented in this section. Those bases and assumptions that are common to all systems are presented in Section A.3.1, those specific to the No-MRS systems are given in Section A.3.2, and those specific to the MRS systems are given in Section A.3.3.

A.3.1 Common Bases and Assumptions

The following bases and assumptions are common to all systems:

- All costs are developed in 1985 dollars, to facilitate comparison with the information developed in the MRS Submission to Congress (DOE 1987a).

- System life-cycle costs include: completion of maximum reracking where needed; fuel consolidation; canisters; canister closure and decontamination operations, when appropriate; dry storage of excess fuel; transport costs; and incremental repository cost differences.

- The system life-cycle throughput is 65,360 MTU of spent fuel which is 64 wt% PWR and 36 wt% BWR fuel. The average uranium content of fuel assemblies is 0.434 MTU/assembly (PWR) and 0.180 MTU/assembly (BWR). Only spent fuel and its associated hardware is included in this analysis. Shipment of process wastes other than hardware are not included.

- All cask-miles and shipment-miles calculations are made on a point to point basis using the methodology developed for the WASTES program (Shay 1986). Thus, the distances between each reactor site and the repository or the MRS are computed for each shipment. Similarly, the distances between the MRS and the repository (Basalt, Salt, and Tuff sites) are calculated using the same methodology. The WASTES methodology is also used to calculate the sizes of the cask fleets required to accommodate the postulated shipments, using cask turnaround times based on results from the transportation ALARA study (Schneider 1987).

- All pools are assumed to be re-racked to the maximum feasible capacity and are assumed to be able to accommodate canisters containing consolidated spent fuel and compacted hardware.

- Service lifetimes of the casks are 25 years (DOE 1986).

- Dual Purpose casks have capacities of 24 PWR/60 BWR intact assemblies or 40 PWR/96 BWR consolidated assemblies with compacted hardware, and cost $1.75 million without a carrier, impact limiters, etc. For transport, an additional $0.75 million will be required for these ancillary items.

- Metal storage-only casks are assumed to cost $0.08 million/MTU stored as intact assemblies and $0.053 million/MTU stored as consolidated fuel and hardware.

- Concrete storage casks are assumed to cost $0.06 million/MTU stored as intact assemblies and $0.037 million/MTU stored as consolidated fuel and hardware.

- All fuel inventory data are taken from the Spent Fuel Data Base for 1986 (Heeb 1987).

- All fuel acceptance rates and schedules are taken from the Mission Plan Amendment (DOE 1987).

A.3.2 Bases and Assumptions Specific to the No-MRS Systems

The following bases and assumptions are specific to the No-MRS systems:

Reference No-MRS System

- Dry storage at-reactor is required for 9200 MTU, none of which is consolidated. As a result of loading each cask at each site fully, the amount of fuel stored dry is 9410 MTU, distributed over 50 sites and stored in a 50/50 mixture of metal storage-only casks and concrete casks. The small amounts of fuel that might be consolidated at-reactor are neglected in the analysis of this system.

- Shipment to the repository is made in 100-ton rail casks, one cask/vehicle unit per train, via general freight, where rail shipment is possible. For those sites not rail-capable, shipment is in 25-ton truck casks, one cask/vehicle unit per shipment. The truck cask can carry two PWR or five BWR intact assemblies, and the rail cask can carry 14 PWR or 36 BWR intact assemblies.

- Fuel consolidation at the repository is into media-specific canisters or waste packages.

No-MRS System Alternative 1

- The transport cask fleet reflects designs currently being developed under the From-Reactors Cask RFP (DOE 1986). Legal weight truck cask capacities are 3 PWR/7 BWR intact or consolidated. Overweight truck cask capacities are 4 PWR/14 BWR intact or 6 PWR/14 BWR consolidated. 100-ton rail cask capacities are 21 PWR/48 BWR intact or 28 PWR/72 BWR consolidated. 125-ton rail cask capacities are 24 PWR/60 BWR intact or 40 PWR/96 BWR consolidated.

- Sites that would require dry storage for > 350 MTU in 2006 consolidate their excess fuel into square, rack-compatible canisters and store in their pools. This results in consolidation of 7400 MTU, distributed over 5 sites. The remaining sites store their excess fuel intact in dry casks. As a result of loading each cask fully at each site, the amount of fuel stored dry is 7050 MTU, which is stored in a 50/50 mixture of metal storage-only casks and concrete casks.

- All fuel consolidated at the reactor pools is placed into square canisters that are compatible with the storage racks for intact assemblies at both PWR and BWR sites. Thus, two sizes of basic canister are prepared, a PWR and a BWR size. All hardware is compacted into square canisters, with hardware from six PWR assemblies placed into one square canister and hardware from ten BWR assemblies placed into two square canisters. The resulting volume-reduction ratios are 1.5:1 and 1.4:1 for PWR and BWR assemblies, respectively.

- All canisters of consolidated fuel and compacted hardware are shipped unsealed and without decontamination.

<u>No-MRS Alternative 2</u>

- Cask Capacities are as given for No-MRS Alternative 1.

- Sites that would require dry storage for > 250 MTU in 2006 consolidate their excess fuel and store in their pools. This results in consolidation of 15,100 MTU, distributed over 13 sites. The remaining sites store their excess fuel (4500 MTU) intact in dry casks. To provide for the needs of the transportation system for 125-T casks, about 20 dual purpose casks, containing a total of about 200 MTU, are utilized. The balance of the fuel (4300 MTU) stored is in a 50/50 mixture of metal storage-only casks and concrete casks.

- All canisters of consolidated fuel and compacted hardware are shipped to the repository unsealed and without decontamination.

<u>No-MRS Alternative 3</u>

- All 65,360 MTU of spent fuel at all sites is consolidated at the reactor sites prior to shipment, into square/half-square canisters. Rods from two assemblies are placed into each full-square canister, and rods from one assembly are placed into each half-square canister, for each fuel type (PWR or BWR). The mix of full-square and half-square canisters is two half-squares to one full-square canister of fuel.

- All canisters of consolidated fuel and compacted hardware are shipped to the repository unsealed and without decontamination.

- As a result of fully loading each dry cask at each site, the total amount of consolidated fuel and hardware stored dry is 3100 MTU, distributed over 20 sites. To provide for the needs of the transportation system for 125-T casks, 10 dual purpose casks, containing about 150 MTU, are utilized. The balance of the fuel (2950 MTU) stored is in a 50/50 mixture of metal storage-only casks and concrete casks.

<u>No-MRS Alternative 4</u>

- All spent fuel is consolidated as per No-MRS Alternative 3.

- Dry storage requirements as per No-MRS Alternative 3.

- A pool-side device is installed to provide the capability to dry, inert, and seal-weld the closures on the canisters prior to shipment to the repository. In addition, provisions are made to decontaminate the exterior surfaces of the canisters after loading into shipping casks at the reactor sites by flowing a liquid decontamination agent of the LOMI type through the sealed casks, followed by a clean water rinse.

No-MRS Alternative 5

- All fuel is consolidated into media-specific canisters at the reactor sites prior to shipment, and are sealed and decontaminated as per No-MRS Alternative 4.

- The capacities of media-specific canisters for consolidated fuel are:

  Basalt 4 PWR/9 BWR
  Salt 12 PWR/30 BWR
  Tuff 2 PWR/5 BWR (square/half-square, one size).

- Cask capacities of the improved casks for the media-specific canisters are:

	LWT	OWT	100-T	125-T	150-T
Basalt	1/1	1/1	12/11	16/15	21/19
Salt	0/0	1/1	3/3	5/4	6/5
Tuff	1/1	2/2	14/14	20/20	37/37

A.3.3 Bases and Assumptions Specific to the MRS Systems

Reference MRS System

- Dry storage at-reactor is required for 2750 MTU of spent fuel, none of which is consolidated. By fully loading each cask at each site, the amount of fuel stored dry is about 2800 MTU, stored in a 50/50 mixture of metal storage-only casks and concrete casks, distributed over 30 sites.

- All (65,360 MTU) spent fuel is shipped to the MRS facility, using the casks specified under the reference No-MRS system.

- Consolidation of 65,360 MTU of spent fuel is performed at MRS into media-specific canisters which are sealed, inerted, and decontaminated prior to shipment. The media-specific canister capacities are:

  Basalt (4 PWR/9 BWR), Salt (12 PWR/30 BWR), Tuff (2 PWR/5 BWR).

- Shipment from the MRS to the repository is made in 150-ton steel rail casks, in dedicated trains consisting of five cask/vehicle units containing fuel and an average of about 2 additional cask/vehicle units containing canisters of compacted assembly hardware per train. The payload of each cask is the equivalent of 64 PWR or 135 BWR intact assemblies in Basalt canisters, (60/120) in Salt canisters, and (58/145) in 1 size square/half-square canisters.

Alternative MRS System

- From-reactor shipments are made in the increased capacity casks specified under No-MRS System Alternative 1.

- Sites that would require dry storage for > 300 MTU in 1997 consolidate their excess fuel into square/half-square canisters and store in their pools, resulting in consolidation of 1750 MTU, distributed over 2 sites. The remaining sites with excess fuel store their fuel intact in dry casks. By loading each cask fully at each site, the amount stored dry is 2200 MTU with about 100 MTU stored in 10 dual purpose casks and the remainder (1600 MTU) stored in a 50/50 mixture of metal storage-only and concrete casks.

- The at-reactor consolidated fuel canisters are sealed and decontaminated at MRS prior to shipment to the repository. Consolidation of the balance of the spent fuel (63,610 MTU) is performed at MRS into media-specific canisters which are sealed, inerted, and decontaminated prior to shipment.

- Shipment from the MRS to the Repository is made in 150-T uranium rail casks, in dedicated trains consisting of five cask/vehicle units containing fuel and an average of about 2 additional cask/vehicle units containing canisters of compacted assembly hardware per train. The payload of each cask is the equivalent of 80 PWR or 171 BWR intact assemblies in basalt canisters (72/150) in salt canisters, and (74/185) in single-size square/half-square canisters for tuff.

A.4 ESTIMATED COSTS FOR POSTULATED WASTE MANAGEMENT SYSTEMS

The analyses leading to the system life-cycle costs developed for the reference and modified No-MRS and MRS systems are described in this section. The costs estimated for installing improved storage racks in those pools still needing such modifications are developed in Section A.4.1. The costs for consolidation and canistering of spent fuel at the reactors are estimated in Section A.4.2. The costs estimated to provide and operate devices for sealing and inerting the consolidated fuel canisters at-reactor are presented in Section A.4.3. The estimated costs for providing exterior decontamination of the sealed canisters at-reactor are given in Section A.4.4. The estimated costs for dry storage of fuel in excess of pool rack capacities are given in Section A.4.5, for both Dual Purpose casks, for concrete casks, and for metal storage-only casks. The estimated costs for transporting the spent fuel from the reactors to the MRS facility (if appropriate) and to the repository, and the shipment-miles and cask-miles associated with each of the proposed systems are given in Section A.4.6. The estimated cost penalties associated with emplacing square/half-square canisters in the various repository media are given in Section A.4.7, and a summary compilation of all of these estimated costs for each proposed system and its alternatives is given in Section A.4.8.

The number of significant figures carried throughout the calculations in this section are for computational accuracy only, to avoid introducing significant rounding error into the final results, and do not imply a comparable precision or confidence in the values.

A.4.1 Estimated At-Reactor Reracking Costs

The costs associated with replacing current pool storage racks with maximum capacity racks at those sites where this action is needed are developed in this section.

To accommodate the heavier weight of canisters of consolidated fuel, many of the existing storage racks in the spent fuel storage pools at reactor sites will have to be replaced with stronger, neutron-absorbing racks. The estimated costs for re-racking a PWR and a BWR pool are given in Table A-4.1.

Information on pool racks contained in the Spent Fuel Data Base, maintained for DOE by PNL, suggests that of the 105 pools under consideration, 78 have either re-racked with high-density racks or plan to do so. There is no indication whether these racks will be suitable for storage of canisters of consolidated fuel. Thus, there is a range of from 27 to 105 pools that could require re-racking. For this analysis, it is assumed that 27 pools will require re-racking, with an average cost of $6.5 million each, for a total system cost of about $170 million in 1985 dollars.

For No-MRS Alternative 5, additional rack alternatives are needed at all 105 sites to accommodate temporary storage of one cask-load (125-Ton cask) of media-specific canisters. These alternatives are estimated to add about $60 million to the reracking costs, for a total of $230 million for Alternative 5.

TABLE A-4.1 Estimated Storage Pool Re-Racking Costs(a)

Item	PWR	BWR
Assumed Pool Area (sq.ft.)	1225	1000
Assumed initial capacity (assemblies/MTU)	660/360	1300/250
Re-Racked Capacity (assemblies/MTU)	1370/640	3020/580
New Rack Cost ($ million)	4.6	5.2
Licensing and Installation ($ million)	1.6	1.6
Total Estimated Cost ($ millions)	6.2	6.8

(a) Data from Table D.6, Appendix D, MRS Submission to Congress (DOE 1987a).

It may be necessary to perform a rather complex seismic/stress calculation on the re-racked pools and surrounding structures to assure that the additional weight of the canisters of consolidated fuel does not produce failure of the pool structures during a design-basis seismic event. The cost of these analyses and the costs of possible building structural reinforcements to satisfy the seismic criteria are not included in the above estimate.

A.4.2 Estimated At-Reactor Consolidation and Canistering Costs

For this analysis, it is assumed that consolidation/canistering equipment is purchased, installed, and operated in selected pools. Estimated capital and licensing costs have been reported (Beeman 1986) and are given in Table A-4.2, together with estimates of the associated operating costs. It should be recognized that these costs are highly site-specific. Experience at one site (Garrity 1984) suggests that litigation delays due to intervenors may effectively prevent a utility from proceeding with consolidation at a given site or, as a minimum, greatly increase the costs associated with obtaining the appropriate license amendments.

The 65,360 MTU of spent fuel with the characteristics postulated for this analysis (64 wt% PWR, 36 wt% BWR, 0.434 MTU/PWR assembly, 0.180 MTU/BWR assembly) consists of about 96,000 PWR and 131,000 BWR assemblies, respectively. Consolidating into the two-size square/half-square canisters, with 2 half-square canisters to each full-square canister for fuel, and all non-fuel-bearing assembly hardware compacted into square canisters (6 PWR/canister, 5 BWR/canister) results in about 72,000 fuel plus 16,000 hardware PWR canisters and 98,000 fuel plus 26,000 hardware BWR canisters, for a total of 212,000 canisters over the system life cycle. Consolidating into the single size

TABLE A-4.2 Estimated At-Reactor Spent Fuel Consolidation Costs

Item	Cost Basis	Estimated System Cost (millions of 1985 dollars)			
System		Alt 1	Alt 2	Alt 3,4,5	Alt MRS
No. of Sites		5	13	105	2
Capital Equipment	$2.5 million/site(a)	12.5	32.5	262.5	5
Licensing	$0.1 million/site(a)	0.5	1.3	10.5	0.2
Operations					
Direct Labor and Overhead	$6.30/kgU	46.5	95.1	441.8	11.0
Maintenance & Insurance	2.4% of capital cost, annually, for 16, 16, 26 and 12 years, respectively	4.8	12.5	163.8	1.9
Decommissioning	10% of capital cost	1.3	3.3	26.3	0.5
Subtotal[b]		66	145	905	19
Contingency (40%) [b]		26	58	362	7
Total Consolidation Cost (excluding canister costs)[b]		92	203	1267	26
Canister Costs					
(Square-Only)[b]		21	42	NA	
(Square/Half-Square)[b]				234	8
(Basalt)[b]				142	
(Salt)[b]				76	
(Tuff) (Single-Size/Half-Square)[b]				152	

(a) Beeman 1986
(b) Values rounded off to millions of dollars

square/half-square canisters (2 PWR/5 BWR) results in about 72,000 fuel plus 16,000 hardware PWR canisters and 39,000 fuel plus 10,000 hardware PWR canisters, for a total of 137,000 over the system life cycle. The cost of these canisters has been estimated to be $1100 each. While the PWR and BWR canisters and the square and half-square canisters differ in size, the fabrication and QA costs are judged to totally overshadow the small differences in materials costs. Therefore, a single value for all four canister sizes is a reasonable simplification.

Canister Costs

In the original MRS proposal, system costs were estimated for the three geologic-media-specific canister configurations for Basalt, Salt, and Tuff. The numbers of canisters and the associated costs for using each of these canisters and for using the one-size and two-size square/half-square canisters in the overall MRS system costs are evaluated here.

Formulae have been developed to calculate the numbers of canisters required for each canister type. These formulae have the following form:

$$\frac{\text{(No. of assemblies to consolidate)}}{\text{(No. of consol. assemblies/canister)}}\ \text{fuel} \quad \text{plus}$$

$$\frac{\text{(No. of assemblies to consolidate)}}{\text{(No. of intact assemblies/canister x hardware compaction ratio)}}\ \text{hdwr.}$$

In the square/half-square concepts, the fuel term is also multiplied by the following ratio:

$$\frac{\text{No. of square + No. of half-square canisters}}{\text{No. of square canisters}}$$

which in this analysis was equal to 3/2. The formulae for the various canisters are listed in Table A-4.3. The results of applying these formulae to the 96,000 PWR and 131,000 BWR assemblies assumed to be consolidated are also presented in Table A-4.3. The costs of providing these numbers of canisters are given in Table A-4.4.

TABLE A-4.3 Formulae and Numbers of Canisters Required for 65,360 MTU

Canister Type Required[b]	Formulae[a]		Numbers of Canisters[d]		
	PWR	BWR	PWR	BWR	Total
Basalt	N/3	7N/45	32,200	20,400	52,500
Salt	N/9	3.5N/75	10,700	6,100	16,800
Tuff (One-Size Square/Half-Square)	11N/12	19N/150	88,400	49,700	138,000
Two-size Square	2N/3	3.5N/5	64,300	91,600	156,000
Two-size Sq/H(c)	11N/12	19N/20	88,400	124,000	213,000

(a) Based on the consolidation and packing efficiencies discussed in Section A.4.2. N is the number of intact assemblies to be consolidated.
(b) Assumes every assembly of the 65,360 MTU system input is consolidated.
(c) Incorporates 2 half-square canisters per 1 full square canister, for fuel, and full-square canisters of hardware only.
(d) Values rounded to 3 significant figures.

TABLE A-4.4 Estimated Costs for Canister Configurations Containing 65,360 MTU

Canister Type	Number of Canisters	Cost/Canister (1985 dollars)	Canister Cost (millions of 1985$) Total Cost
Basalt	52,000	2,700	142
Salt	16,800	4,500	76
Tuff (One-Size Square/Half-Square)	138,000	1,100	152
Two-size Square	156,000	1,100	172
Two-size Sq/H	213,000	1,100	234

A.4.3 Estimated At-Reactor Canister Closure Costs

The costs associated with including canister closure and external decontamination in the MRS functions performed at the reactor site are presented below. It must be recognized that neither of these operations have been developed beyond the conceptual de sign stage. Thus, the estimated costs contain a larger degree of uncertainty than do the consolidation cost estimates.

Closure of a canister filled with spent fuel while in the storage pool includes the steps of removing the pool water from the canister, drying the canister interior and the contained fuel, evacuating and backfilling the canister with an inert gas, seal welding the closure, and leak-testing the weld. These operations require either that one end of the canister be elevated above the pool surface within a shielded enclosure or that the operations be performed in a dry underwater "bell". In either case, remote operation is required. For this analysis, a conceptual, shielded, poolside work station was assumed for these operations. A rough estimate of about $2.9 million per unit was made for the capital and installation costs of such equipment, based on preconceptual sketches. The total estimated costs associated with procuring, installing, operating, and decommissioning this equipment are given in Table A-4.5.

It must be recognized that installation of the conceptual closure equipment may not be feasible at some or many pools, due to the large weight of the shielded enclosure. If the enclosure could not be installed, construction of a small, dry hot cell might be required, with transfer casks to move the canisters from the pool to the cell. This latter concept would result in significantly higher costs and greater effort to accomplish canister closure.

TABLE A-4.5 Estimated At-Reactor Canister Closure Costs

Item	Cost Basis	Estimated Cost (millions of 1985 dollars)
Capital Equipment	105 pools @ $2.9 million	305
Licensing	105 pools @ $0.3 million	32
Operation		
Direct Labor	65,360 MTU @ $1.00/kgU	65
Overhead	40% of direct labor	26
Maintenance & Insurance	2.4% of capital cost, annually for 26 years	191
Decommissioning	10% of capital cost	31
Subtotal		650
Contingency (40%)		260
Total Estimated Canister Closure Costs		910

A.4.4 Estimated At-Reactor Canister Decontamination Costs

To provide a product comparable to that produced by the MRS facility, the sealed canisters must also be decontaminated on their exterior surfaces prior to shipment to the repository. This operation presents some interesting difficulties if attempted wit h the canisters still in the pool, since the pool water, which is normally contaminated, would have to be excluded from contacting the canister surfaces following decontamination. One approach would be to construct some kind of small hot cell at the site for performing the decontamination and subsequent loading into the shipping casks. This approach does not appear viable at most reactor sites. An alternative approach which might prove feasible is the following: The canisters are loaded into the shipping cask in the normal fashion, the cask closed and placed on a decontamination pad adjacent to the pool area. The pool water is removed from the cask interior, which is flushed with clean water. Subsequently, a stream of decontamination solution of the non-aggressive LOMI type (Bradbury 1983) is circulated throughout the cask interior for a time sufficient to remove the contaminants from the canister and cask interior surfaces. The solution is then removed, the cask interior is flushed again with clean water, drained, dried, inerted, and shipped to the repository.

Since many reactors are moving toward periodically decontaminating their primary piping systems and the reactor vessel interior using LOMI-type processes, the capability for providing and processing the decontamination solutions may be in place at many reactors when needed. If so, the incremental cost would be so small as to be negligible. However, if a dedicated system must be installed at each site to provide the solutions and provide the processing of those solutions after use, the incremental costs could be significant. Commercial systems are currently in use throughout the industry for decontaminating small segments of piping systems and portions of steam generators prior to maintenance activities. The costs of providing such a system at each of the reactor sites are estimated to be on the order of $1 to $3 million per installation, plus annual operating costs of about $50,000 over a 20-year period, for a total system cost for at-reactor canister decontamination in the range from $200 to $400 million (assume $300 million).

A.4.5 Estimated At-Reactor Dry Storage Costs

From examination of the data from the Spent Fuel Data Base (Heeb 1987), storage requirements and associated costs for casks, site alternatives, and licensing are estimated for all of the systems considered in this report.

Reference No-MRS System - Assuming the Mission Plan Amendment receipt rates and schedules (DOE 1987), the amount of fuel in excess of maximum reracked capacities peaks in the year 2006, with a total of 9200 MTU requiring dry storage, distributed over about 50 sites. For this analysis, the amount of fuel consolidated at the reactor sites is assumed to be negligible. Loading each storage cask at each site fully results in about 9400 MTU being stored. Using a 50/50 mixture of metal storage-only casks and concrete casks (@ $60,000 per MTU, ave.) the estimated cost is about $640 million. These estimates neglect any additional operating costs associated with storing and maintaining these casks on-site.

No-MRS System Alternative 1 - Sufficient fuel is consolidated at 5 sites to permit storing 25% of the total excess fuel in the pools at those sites. The balance of the excess fuel (7050 MTU) is stored in dry casks, distributed over 42 sites. Using a 50/50 mixture of metal storage-only and concrete casks, the estimated cost is about $490 million.

No-MRS System Alternative 2 - Sufficient fuel is consolidated at 13 sites to permit storing 50% of the total excess fuel in the pools at those sites. The balance of the excess fuel (4500 MTU) is stored in dry casks, distributed over 34 sites. Utilizing about 20 dual-purpose casks and a 50/50 mixture of metal storage-only casks and concrete casks, the estimated cost is $340 million.

No-MRS System Alternative 3 - Dry storage is required at about 20 sites, all of which is consolidated. Fully loading storage casks at each site would result in storing 3100 MTU. Utilizing about 10 dual purpose casks and a 50/50 mixture of metal storage-only casks and concrete casks, the estimated cost is $190 million.

No-MRS System Alternative 4 - Essentially identical with Alternative 3.

No-MRS System Alternative 5 - Since the media-specific canisters are loaded one cask-load at a time, consolidation is performed one cask load at a time. Thus, the fuel is stored intact until then, requiring approximately the same quantities of dry storage as in the reference No-MRS System, at a cost of about $640 million if a 50/50 mixture of metal storage-only casks and concrete casks are used.

Reference MRS System - With the MRS beginning to accept fuel in 1998 at the MPA rates, the quantity of fuel in excess of the maximum reracked capacities peaks in the year 1997. Loading the excess fuel intact into a 50/50 mixture of metal storage-only and concrete casks and filling each cask fully results in storing 2800 MTU distributed over 30 sites. The estimated cost is about $210 million.

Alternative MRS System - Dry storage for intact assemblies is required, at 28 sites. Filling each cask fully results in storing 2200 MTU. Storing 100 MTU in dual purpose casks and the remaining in a 50/50 mixture of metal storage-only casks and concrete casks, the estimated cost is about $180 million.

A.4.6 Estimated Transportation Costs for the Postulated Waste Management Systems

The costs of transporting the canistered spent fuel and compacted non-fuel-bearing hardware from the reactor sites to the repository were calculated using the WASTES program (Shay 1986) methodology. The criteria for acceptance for shipment from a given reactor site were: 1) the maintenance of Full Core Reserve capacity in the pool, and 2) Oldest Fuel First. The costs, cask-miles, shipment-miles, and cask fleet sizes were calculated for shipment to all three geologic media sites (Hanford, Basalt; Deaf Smith, Salt; Yucca Mountain, Tuff). The rail shipments were made in trains carrying 1 cask/vehicle unit, in general freight service.

Reference No-MRS System

Each rail cask contained 14 intact PWR assemblies or 36 intact BWR assemblies. The truck shipments consisted of single cask/vehicle units shipped in sole-use service. Each truck cask contained 2 intact PWR assemblies or 5 intact BWR assemblies. The shipping was initiated in 2003 at the rates defined in the Mission Plan Amendment (DOE 1987), and 65,360 MTU of spent fuel and associated non-fuel-bearing hardware were delivered to the first repository. The results of these calculations are shown in Table A-4.6.

TABLE A-4.6 Transportation Calculation Results for the Reference No-MRS System

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	33,500	33,500	33,500
	100T	5,800	5,800	5,800
Shipment-Miles (millions)	LWT	72	49	67
	100T	14	9	13
	Total	86	58	80
Cask-Miles (millions)	LWT	72	49	67
	100T	14	9	13
	Total	86	58	80
Number of Casks in Fleet	LWT	61	41	59
	100T	32	28	31
Cask Fleet Cost (millions of 1985$)	LWT	61	48	59
	100T	80	70	78
	Total	141	118	137
Shipment Cost (millions of 1985$)	LWT	565	404	531
	100T	469	362	452
	Total	1034	766	983
Total System Transport Cost* (millions of 1985$)		1180	880	1120

No-MRS System Alternative 1

Approximately 7400 MTU (~11.3 wt%) of the 65,360 MTU system throughput is consolidated at-reactor into square canisters prior to shipment.

The casks used in the reference system are replaced with a fleet of casks having increased capacities, as given in the following listing.

Legal Weight Truck (LWT)	3 PWR/7 BWR intact,	3 PWR/7 BWR consolidated
Over Weight Truck (OWT)	4 PWR/14 BWR intact,	6 PWR/14 BWR consolidated
100-ton Rail Cask	21 PWR/48 BWR intact,	28 PWR/72 BWR consolidated
125-ton Rail Cask	24 PWR/60 BWR intact,	40 PWR/96 BWR consolidated

All shipments are made as single cask/vehicle units, in general freight service. The results of these calculations are given in Table A-4.7.

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* Values rounded to tens-of-millions of dollars.

TABLE A-4.7 Transportation Calculation Results for the No-MRS System Alternative 1

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	670	670	670
	OWT	14,150	14,150	14,150
	100T	440	440	440
	125T	2,930	2,930	2,930
Shipment-Miles (millions)	LWT	2	1	2
	OWT	30	20	28
	100T	1	1	1
	125T	7	5	7
	Total	40	27	38
Cask-Miles (millions)	LWT	2	1	2
	OWT	30	20	28
	100T	1	1	1
	125T	7	5	7
	Total	40	27	38
Number of Casks in Fleet	LWT	2	2	2
	OWT	23	19	22
	100T	3	3	3
	125T	17	15	17
Cask Fleet Cost (millions of 1985$)	LWT	2	2	2
	OWT	23	19	22
	100T	8	8	8
	125T	43	38	43
	Total	76	67	75
Shipment Cost (millions of 1985$)	LWT	14	11	14
	OWT	269	192	251
	100T	42	34	41
	125T	289	221	277
	Total	614	458	593
Total System Transport Cost* (millions of 1985$)		690	530	660

No-MRS System Alternative 2

Approximately 15100 MTU (~23.1 wt%) of the 65,360 MTU system throughput is consolidated at-reactor into square canisters prior to shipment in the increased capacity cask fleet. The results of these calculations are given in Table A-4.8.

* Values rounded to tens-of-millions of dollars.

TABLE A-4.8 Transportation Calculation Results for the No-MRS System Alternative 2

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	670	670	670
	OWT	13,600	13,600	13,600
	100T	430	430	430
	125T	2,810	2,810	2,810
Shipment-Miles (millions)	LWT	2	1	2
	OWT	29	20	27
	100T	1	1	1
	125T	7	4	6
	Total	39	26	36
Cask-Miles (millions)	LWT	2	1	2
	OWT	29	20	27
	100T	1	1	1
	125T	7	4	6
	Total	39	26	36
Number of Casks in Fleet	LWT	2	2	2
	OWT	21	16	20
	100T	3	3	3
	125T	17	15	17
Cask Fleet Cost (millions of 1985$)	LWT	2	2	2
	OWT	21	16	20
	100T	8	8	8
	125	13*	11*	13*
	Total	44	37	43
Shipment Cost (millions of 1985$)	LWT	14	11	14
	OWT	254	179	236
	100T	41	33	40
	125T	277	211	265
	Total	586	434	555
Total System Transport Cost** (millions of 1985$)		630	470	600

*Cost of equipment for transport. Casks costed under dry storage.

**Values rounded to tens-of-millions of dollars.

No-MRS System Alternative 3 and 4

All 65,360 MTU of spent fuel is consolidated at-reactor into square/half-square canisters prior to shipment. The results of these calculations are given Table A-4.9.

TABLE A-4.9 Transportation Calculation Results for the No-MRS System Alternatives 3 & 4

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	670	670	670
	OWT	11,000	11,000	11,000
	100T	330	330	330
	125T	1,850	1,850	1,850
Shipment-Miles (millions)	LWT	2	1	2
	OWT	23	16	22
	100T	1	1	1
	125T	4	3	4
	Total	30	21	29
Cask-Miles (millions)	LWT	2	1	2
	OWT	23	16	22
	100T	1	1	1
	125T	4	3	4
	Total	30	21	29
Number of Casks in Fleet	LWT	2	2	2
	OWT	21	16	20
	100T	3	3	3
	125T	11	9	10
Cask Fleet Cost (millions of 1985$)	LWT	2	2	2
	OWT	21	16	20
	100T	8	8	8
	125T	8*	7*	8*
	Total	39	33	38
Shipment Cost (millions of 1985$)	LWT	14	11	14
	OWT	217	153	203
	100T	33	27	33
	125T	185	142	178
	Total	449	333	428
Total System Transport Cost** (millions of 1985$)		490	370	470

*Cost of equipment for transport. Casks costed under dry storage.
**Values rounded to tens-of-millions of dollars.

No-MRS System Alternative 5

All 65,360 MTU of spent fuel is consolidated into media-specific canisters at-reactor prior to shipment. The results of these calculations are given in Table A-4.10.

TABLE A-4.10 Transportation Calculation Results for the No-MRS System Alternative 5

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	750	0	660
	OWT	23,300	7,600	10,800
	100T	310	390	430
	125T	1,600	1,700	2,350
Shipment-Miles (millions)	LWT	2	0	2
	OWT	50	11	21
	100T	1	1	1
	125T	4	3	5
	Total	57	15	29
Cask-Miles (millions)	LWT	2	0	2
	OWT	50	11	21
	100T	1	1	1
	125T	4	3	5
	Total	57	15	29
Number of Casks in Fleet	LWT	3	0	2
	OWT	43	11	17
	100T	3	3	3
	125T	10	8	14
Cask Fleet Cost (millions of 1985$)	LWT	3	0	2
	OWT	43	11	17
	100T	8	8	8
	125T	25	20	62
	Total	79	39	89
Shipment Cost (millions of 1985$)	LWT	16	0	14
	OWT	457	107	191
	100T	30	31	40
	125T	166	130	218
	Total	669	268	463
Total System Transport Cost* (millions of 1985$)		750	300	550

*Values rounded to tens-of-millions of dollars.

Reference MRS System

All 65,360 MTU of spent fuel is shipped intact to the MRS facility where it is consolidated into media-specific canisters prior to shipment to the repository.

In the MRS system, two different transportation links are involved in delivering the spent fuel and associated hardware to the repository. The first transport occurs from the reactor sites to the MRS facility, and is performed using the same 25-ton and 100-ton casks as were utilized in the reference No-MRS analysis, with cask capacities limited to 2 PWR/5 BWR and 14 PWR/36 BWR assemblies in the truck and rail casks, respectively.

The second transport occurs from the MRS facility to the repository, and is performed using 150-ton rail casks, in dedicated trains carrying five cask/vehicle units containing fuel, and an average of about 2 additional casks containing compacted hardware, per train. The payload of each cask is the equivalent of 64 PWR or 135 BWR intact assemblies in Basalt canisters, (60/120) in Salt canisters, and (58/145) in Tuff (single-size square/half-square) canisters.

The costs of transporting the canistered spent fuel and compacted non-fuel-bearing hardware from the reactor sites to the repository were calculated using the WASTES program (Shay 1986) methodology. The criteria for acceptance for shipment from a given reactor site were: 1) the maintenance of Full Core Reserve capacity in the pool, and 2) Oldest Fuel First. The costs, cask-miles, shipment-miles, and cask fleet sizes were calculated for shipment to the MRS facility and then on to each of the three geologic media sites (Hanford, Basalt; Deaf Smith, Salt; Yucca Mountain, Tuff). The shipping was initiated in 1998 to the MRS and in 2003 to the repository, at the rates defined in the Mission Plan Amendment (DOE 1987). The results of these calculations are shown in Table A-4.11.

TABLE A-4.11 Transportation Calculation Results for the Reference MRS System

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	33,500	33,500	33,500
Reactor/MRS	100T	5,800	5,800	5,800
MRS/Repository	150T	490	540	510
Shipment-Miles (millions)	LWT	26	26	26
Rx/MRS	100T	5	5	5
MRS/Repository	150T	1	1	1
	Total	32	32	32
Cask-Miles (millions)	LWT	26	26	26
Rx/MRS	100T	5	5	5
MRS/Repository	150T	9	6	8
	Total	40	37	39
Number of Casks in Fleet	LWT	28	28	28
Rx/MRS	100T	16	16	16
MRS/Repository	150T	20	20	20
Cask Fleet Cost (millions of 1985$)	LWT	28	28	28
	100T	40	40	40
	150T	55	55	55
	Total	123	123	123
Shipment Cost (millions of 1985$)	LWT	240	240	240
	100T	228	228	228
	150T	286	231	302
	Total	754	699	770
Total System Transport Cost (millions of 1985$)		877	822	893

Alternative MRS System

The cask capacities used in the alternative MRS system are: LWT (3/7); OWT (4/14) intact, (6/14) consolidated; 100-T (21/48) intact, (28/72) consolidated; 125-T (24/60) intact, (40/96) consolidated; 150-T (80/171) Basalt, (72/150) Salt, (74/185) Tuff.

The effects of using the increased capacity casks on the transport costs in the MRS system, plus the consolidation of 2.8% of the fuel at-reactor are reflected in the results of the WASTES calculations summarized in Table A-4.12.

TABLE A-4.12 Transportation Calculation Results for the Alternative MRS System

Item		Basalt	Salt	Tuff
Number of Shipments	LWT	670	670	670
	OWT	14,500	14,500	14,500
Reactor/MRS	100T	460	460	460
	125T	3,000	3,000	3,000
MRS/Repository	150T	390	440	400
Shipment-Miles (millions)	LWT	1	1	1
	OWT	12	11	12
Rx/MRS	100	1	1	1
	125T	2	2	2
MRS/Repository	150T	1	1	1
	Total	17	16	17
Cask-Miles (millions)	LWT	1	1	1
	OWT	12	12	12
Rx/MRS	100T	1	1	1
	125T	2	2	2
MRS/Repository	150T	7	5	6
	Total	23	21	22
Number of Casks in Fleet	LWT	3	3	3
	OWT	16	16	16
Rx/MRS	100T	3	3	3
	125T	11	11	11
MRS/Repository	150T	20	20	20
Cask Fleet Cost (millions of 1985$)	LWT	3	3	3
	OWT	16	16	16
	100T	8	8	8
	125T	28	28	28
	150T	15*	15*	15*
	Total	70	70	70
Shipment Cost (millions of 1985$)	LWT	9	9	9
	OWT	129	129	129
	100T	24	24	24
	125T	149	149	149
	150T	243	189	229
	Total	554	500	540
Total System Transport Cost (millions of 1985$)		624	570	610

*Cost of equipment for transport. Casks costed under dry storage.

Transportation Cost Sensitivity Analysis

Transportation cost sensitivity analyses were performed to assess the cost impacts of two transportation modifications discussed in Section 2. The first analysis examines the use of overweight truck shipments, the second examines the use of all rail shipments from the reactors. The results of these analyses are summarized below.

A sensitivity analysis was performed using the transportation calculations for the No-MRS scenario with no at-reactor consolidation, using the improved capacity casks and shipping to the basalt repository, to explore the changes in transport system costs that would result from making all truck shipments in legal weight truck casks. When all truck shipments are made using legal weight casks, the calculated cost for truck transport is about $550 million. Using overweight truck shipments from all of the truck-limited sites that can accommodate an overweight cask and using legal weight casks only at those sites that cannot handle the overweight casks, the transport costs are calculated to be about $350 million. Thus, exclusive use of legal weight truck casks from those sites limited to truck shipment would increase the transport system costs by about $200 million.

A sensitivity analysis was performed using the transportation calculations for the No-MRS scenario, using the reference casks and using the improved capacity casks, to explore the potential transport system cost savings if all fuel were shipped using rail casks. For the basalt repository (maximum shipping costs), making all shipments in rail casks, using the reference capacity casks, would reduce the transport system costs by about $200 million. Using the improved capacity casks presently under development and making all shipments in rail casks, the transport costs would be reduced by about $20 million. A review of an earlier analysis of site shipping capabilities (Konzek 1986) shows that upgrading those sites for which upgrading to rail transport appears feasible would cost at least $200 million. Thus, the upgrade costs, using the reference capacity casks, would be about equal to the transport system savings. Using the improved capacity casks, the upgrade costs would be about ten times larger than the transport system savings.

A.4.7 Estimated Cost Impacts on MRS and Repository Operations

It is anticipated that the packaging of the square and square/half-square canisters will be less efficient in the emplacement packages at the repository, and would result in an increased emplacement cost for those canisters as compared with the media-specific canisters. Estimates of these penalties were made by the repository projects during the Common Canister Study analyses (Weston 1986). Those estimates, adjusted for the slightly larger amount of spent fuel (65,360 MTU versus 62,000 MTU) considered in this analysis were:

Basalt (+ $231 million), Salt (+ $122 million), and Tuff (- $39 million)

Since Tuff has changed its configuration recently, this correction should be zero for Tuff. For those cases where small amounts of fuel are consolidated at the reactors, these estimates are scaled downward proportionately, and become:

Mod 1 (11.3 wt%)	Basalt (+$26 M),	Salt (+$14 M),	Tuff ($0 M)
Mod 2 (23.1 wt%)	Basalt (+$53 M),	Salt (+$28 M),	Tuff ($0 M)
Mod MRS (2.8 wt%)	Basalt (+$6 M),	Salt (+$3 M),	Tuff ($0 M)

These estimated costs are based on the emplacement package designs that were current during the Common Canister study time period and may well change for different package designs.

The effect on the scope and cost of operations at the MRS and the repository are displayed in Tables A-4.13 and A-4.14 for the No-MRS systems and the MRS systems, respectively. For those cases where 100% of the consolidation was performed at the reactors, the costs of the consolidation function were deleted from the repository operating costs entirely. For those cases where lesser amounts (~11%, ~23% or ~3%) of the fuel is consolidated at the reactors, small reductions in consolidation costs were made to account for not having to supply canisters for that fuel as part of the consolidation operation. Since the canisters have to be closed and decontaminated at the facility (MRS or repository), the basic operating costs are unaffected.

TABLE A-4.13 Effects of Various Amounts of At-Reactor Consolidation on the Costs of Repository Surface Activities in the No-MRS System(a)

System	Cost (million $)(g) Waste Handling	Balance of Plant	Emplacement Penalty	Total
Reference				
Basalt	1670	1780	NA	3450
Salt	2630	1510	NA	4140
Tuff	1740	1300	NA	3050
Alternative 1(b)				
Basalt	1650	1780	30	3460
Salt	2620	1510	10	4150
Tuff	1720	1300	0	3030
Alternative 2(c)				
Basalt	1640	1780	50	3470
Salt	2610	1510	30	4150
Tuff	1700	1310	0	3010
Alternative 3(d)				
Basalt	800	1440	230	2470
Salt	1520	1410	120	3060
Tuff	860	1200	0	2060
Alternative 4(e)				
Basalt	800	1440	230	2470
Salt	1520	1410	120	3060
Tuff	860	1200	0	2060
Alternative 5(f)				
Basalt	800	1[illegible]40	NA	2240
Salt	1520	1410	NA	2940
Tuff	860	1200	NA	2060

(a) Data from spreadsheets supporting DOE 1987b.
(b) 11.3 wt% consolidated at-reactor into square canisters.
(c) 23.1 wt% consolidated at-reactor into square canisters.
(d) 100 wt% consolidated at-reactor into square/half-square canisters, unsealed.
(e) 100 wt% consolidated at-reactor into square/half-square canisters, sealed and decontaminated.
(f) 100 wt% consolidated at-reactor into media specific canisters, sealed and decontaminated.
(g) All values rounded off to tens-of-millions of dollars. Some rows may not sum exactly due to rounding.

TABLE A-4.14 Effects of 2.8 Weight-Percent At-Reactor Consolidation on the Costs of MRS and Repository Surface Activities in the MRS System(a)

System	MRS Facility	Repository: Waste Handling	Repository: Balance of Plant	Repository: Emplacement Penalty	Total
	Cost (million $)[d]				
Reference[b]					
Basalt	2730	800	1440	NA	4970
Salt	2730	1520	1410	NA	5670
Tuff	2730	860	1200	NA	4790
Alternative[c]					
Basalt	2730	800	1440	10	4980
Salt	2730	1520	1410	10	5670
Tuff	2730	860	1200	0	4790

(a) Data from spread sheets supporting DOE 1987b.
(b) 100 wt% consolidate at-MRS into media-specific canisters.
(c) 2.8 wt% consolidated at-reactor into square/half-square, 97.2 wt% consolidated at MRS into media-specific canisters.
(d) All values are rounded off to tens-of-millions of dollars. Some rows may not sum exactly due to rounding.

A.4.8 Summary of Estimated System Costs

The detailed cost estimates discussed earlier in this section for the No-MRS and MRS systems considered in these analysis are summarized in Tables A-4.15 and A-4.16.

TABLE A-4.15 Summary of Estimated Costs for The No-MRS Systems

Item / System	Estimated System Cost (millions of 1985 dollars)[a] Ref.	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Pool Re-Racking	170	170	170	170	170	230
Consolidation	0	90	200	1270	1270	1270
Canister Costs At-Reactor						
Square Only	0	20	40	NA	NA	NA
Square/Half-Square	0	0	0	230	230	0
Basalt	0	0	0	0	0	140
Salt	0	0	0	0	0	80
Tuff (One Size Square/ Half-Square)	0	0	0	0	0	150
At-Reactor Dry Storage	640	490	340	190	190	640
Transportation Costs						
Basalt	1180	690	630	490	490	750
Salt	880	530	470	370	370	300
Tuff	1120	660	600	470	470	550
Canister Closure	0	0	0	0	910	910
Exterior Decontamination	0	0	0	0	300	300
Repository Activities						
Basalt	3450	3460	3470	2470	2480	2240
Salt	4140	4150	4150	3060	3060	2940
Tuff	3050	3030	3010	2060	2060	2060
Totals						
Basalt	5440	4920	4860	4820	5740	6490
Salt	5840	5440	5380	5300	6210	6680
Tuff	4980	4460	4370	4400	5320	6120

(a) All values are rounded off to the tens-of-millions of dollars. Some columns may not sum exactly due to rounding.

TABLE A-4.16 Summary of Estimated Costs for The MRS Systems

Item	Estimated System Cost (millions of 1985 dollars)[a] Reference	Alternative MRS
Pool Re-Racking	170	170
Consolidation	0	30
Canister Costs At-Reactor	0	10
At-Reactor Dry Storage	210	180
Transportation Costs		
Basalt	880	620
Salt	820	570
Tuff	890	610
MRS and Repository Activities		
Basalt	4970	4980
Salt	5670	5670
Tuff	4790	4790
Totals		
Basalt	6230	5990
Salt	6870	6630
Tuff	6070	5790

(a) All values are rounded off to the tens-of-millions of dollars. Some columns may not sum exactly due to rounding.

A.5 INDETERMINATE COSTS OF WASTE SYSTEM NO-MRS ALTERNATIVES

The cost estimates in the foregoing subsections represent the definitive costs which can be estimated with reasonable accuracy based on the projected characteristics of the modified waste systems. There is, however, an additional class of system costs associated with system alternatives or new construction that cannot be fully quantified until both the system alternatives themselves and their interfaces with industrial, financial and governmental segments of the economy have been defined and evaluated.

The additional, "indeterminate" costs considered in this section are those which could, and likely would, be introduced by Federal imposition of responsibilities on utilities, impact mitigation payments, etc., which would be chargeable to the Nuclear Waste Fund.

It is normal practice in preparing cost estimates of large projects to allow for these indeterminate costs by including a contingency, usually expressed as a percentage of the total determinate costs. The size of the contingency is dependent on the degree to which the system can be defined. As the project development progresses and its system characteristics and interfaces become better known, some of the "indeterminate" costs can be identified and included in the definitive cost estimate; thus, a smaller contingency may be used at that point.

In the case of alternatives to the No-MRS system, the problem becomes more complicated. System alternatives take the form of alternatives at a large number of reactor sites, each of which may react differently with interfacing sectors of the national economy. Projection of the ancillary costs associated with projects of this nature becomes much more difficult.

The likely categories of indeterminate costs which may be experienced in alternatives to the No-MRS system are discussed in the following subsections, and approximate ranges of the cost impacts which might occur system-wide are estimated for each system modification included in this report, based on available information and engineering judgment. The magnitude of these cost effects can be expected to vary from reactor to reactor, and some may vary in magnitude from one year to the next. Furthermore, cost estimates could not be developed at this time, without added information, for several cost categories that could potentially add significantly to total costs. Thus, the system cost range projections given should be viewed only as first-order, system-wide estimates, and as probably lower than actual costs could be.

Cost ranges for the categories considered are discussed below. They are summarized in Table A-5.3, at the end of this subsection.

A.5.1 Replacement Power Costs

A major characteristic of the alternatives considered for the No-MRS system involves the progressively more intensive in-pool fuel handling and packaging operations at the reactor sites. These operations take up increasing proportions of the time available for use of the storage pools between refuelings of the reactor cores. Under these conditions, even minor scheduling delays in these operations at a reactor could delay the start of refueling operations, and thus extend the scheduled fueling shutdown of the reactor. These delays could arise from minor malfunctions that delay access to the pool to major mishaps including possible radioactive releases or major equipment breakdowns that result in suspension of pool operations.

interferences such as this could even precipitate NRC-ordered shutdowns until the interference with operations is removed. At an individual reactor, such delays could extend from minimal times to several days or even weeks; system-wide, the delays might average from a small fraction of a day to one day per reactor per year.

An electric utility is obligated to meet the demands for electric power which are imposed upon it. Loss of generation from a reactor (as from any generating unit) must therefore be made up by replacing it with power generated elsewhere, either from another unit in the same utility or by purchase from another utility. Typically, this replacement power commands a premium price, considerably above that for power normally produced by the unit that is out of service. Thus, the costs of replacement power can mount quickly. McLeod 1987 has estimated these replacement power costs to range from $200,000 to $800,000 per day, averaging about $400,000 per day. The NRC periodically publishes compilations of replacement power costs for differing areas of the Unit ed States.

Over the lifetime of spent fuel consolidation operations in the system, the costs for replaced power from such reactor shutdowns can become significant. For example, assuming that 100 reactors undertake consolidation operations and that outages resulting from such interference with normal operations average 0.3 days per reactor per year, the total costs for replacement power could range from $150 million to $600 million, with an average value of $300 million. If the forced delays averaged one day per reactor each year, costs could be as high as $2 billion.

Interference with reactor operations would be increasingly likely as the fraction of fuel consolidated increases or when the handling operations become more complex. It is increasing likely, therefore, that additional waste management activities, such a s at-reactor canister closure and decontamination or the use of large, round, repository-specific canisters, would interfere with power production. Thus, the $150-600 million cost range estimated for full consolidation would drift higher when the additional responsibilities are imposed. While these costs cannot presently be quantified, the ranges of increased costs indicated in Table A-5.3 for these situations appear reasonable based on engineering judgment.

A.5.2 Federal Cost Obligations from Use of Dual-Purpose Casks

Alternatives 2 through 5 to the reference No-MRS system involve, among other things, the inducement of utilities to use dual-purpose casks "to their maximum benefit". For purposes of this analysis, the "maximum benefit" is assumed to be achieved when the dual-purpose casks are purchased from the utilities for use in transportation, eliminating the need for DOE to purchase an equal number of the 125-ton dedicated shipping casks, which are assumed to be identical in design to the dual purpose casks. Costs were explored for cases involving more intensive use of dual-purpose casks, up to a mandated 100% usage for all storage and shipment functions. However, the high costs of using casks qualified for shipment, but used only for single trips without re-use, would result in inordinately high system costs. Therefore, the use of these casks in numbers beyond those which could be assimilated into the transportation fleet was not considered.

Direct Assimilation of Casks Into Transportation Fleet

Transportation analyses for the waste system indicate that up to 20 of the 125-ton casks can be effectively used in the transportation fleet, if purchased at the right times. These casks, licensed for transportation, are assumed to cost $1.75 million each. The added equipment needed for transport (including impact limiters, personnel barriers, and rail cars) would cost an additional $750,000 for each cask; it is assumed that DOE would furnish this equipment directly. Thus, up to $50 million would be involved in the purchases and equippage. The DOE could save an equivalent amount by avoiding the purchase of an equal number of dedicated casks of the same capacity for the transportation fleet. However, a program would need to be implemented for assuring the expedited recertification of the dual-purpose casks for transportation use following the storage period. This program, involving demonstrations of adequacy for transportation use in lieu of normal recertification, is estimated to involve development costs of about $10 to $15 million.

It is assumed that the technology involved in cask recertification would be based on state-of-the-art techniques such as ultrasonic imaging. This technique is used, among other applications, in NRC-required inspection of reactor pressure vessels for assessment of integrity, for similar assessments of industrial pressure vessels, for "viewing" in liquid sodium-filled vessels, and for assessment of integrity and bearing capability of support columns in buildings undergoing renovation. It could be a likely candidate for cask recertification inspections. It is assumed that the techniques used, possibly including an ultrasonic imaging technique combined with other automated techniques, could be applied to verify both integrity of the cask and elasticity of the lid seals (therefore confirming ability to maintain a tightly-sealed condition).

The ultimate process chosen would need to compete economically with the manual processes of unloading the casks, performing the required examinations, and reloading; these are estimated at about $4.00 per kgU (intact fuel), or about $40,000 per cask. Additional costs may accrue because of competition for pool operations among the various tasks of reactor operation and of fuel consolidation and packaging. However, for this report, the automated inspection is assumed to be competitive with manual inspection and to cost about $40,000 per cask. An additional $2500 per cask in NRC fees would be required.

For the assumed use of 20 dual-purpose casks, the costs of recertification would thus amount to about $1.5 million, in addition to the $10-$15 million development cost.

A.5.3 Costs Associated with Mandated Facility Alternatives

Alternatives 3 through 5 to the reference No-MRS system involve Federally mandated fuel preparation functions including near-universal fuel consolidation, closure and decontamination of canisters, and use of large, repository-specific canisters at the reactors. The costs associated with these functions were included in earlier paragraphs, including capital costs of the required equipment and the operating costs involved.

The performance of these additional functions at-reactor would also involve alternatives to the reactor pools and associated structures and equipment. Costs for these alternatives, in a mandated situation, would be chargeable to the Waste Fund. Approximate costs for the majority of these activities were included in the costs estimates in Subsection A.4.

However, two cost categories cannot be definitively evaluated within the scope of this analysis. These are the costs of strengthening pool structures to safely carry the weight of a full load of consolidated fuel, and the more localized strengthening required to support the equipment for in-pool canister closure (the equipment for each pool is estimated to weigh about 25 tons). Added to these costs would be the costs, at each site involved, of the complex seismic/stress analyses required. Any pool modifications required, and the costs involved, are highly site-specific and must be determined by the detailed structural/seismic analyses as noted. Therefore, although the costs involved in these categories may be significant, no estimate could be developed.

A.5.4 Added Tax Payments by Utilities

The consolidation, packaging and storage of spent fuel at-reactor would result in significant additions to the capital valuation of the nuclear power plants and to annual expenses incurred at the plants, as indicated in Section A.4. The utilities performing these operations would be subject to added taxation by states and local jurisdictions based on the additional work performed.

The levying of taxes will vary considerably from state to state because of the wide variances in tax bases and differing financial structures among power plant owners. For illustrative purposes, taxes were assumed to be based on a property tax of 40 mills (4%) annually per (undepreciated) dollar of added capital valuation at the reactors for performance of the additional fuel preparation activities. Valuation bases for estimation of the tax levies and insurance premiums (following paragraph) were taken from Subsection A.4 and are summarized in Table A-5.1.

The tax levy would, in this illustrative example, be applied both to the plant capital additions associated with spent fuel handling and packaging, and on capital additions to make provision for out-of-pool dry storage of fuel. The estimates of taxes are based on estimated storage requirements and costs given in Subsection A.4.5.

The dry storage methods assumed for at-reactor storage are 1) storage-only casks, consisting of a 50%-50% mixture of steel and concrete storage casks throughout the system, and 2) dual-purpose casks, steel casks which are initially used for at-reactor storage and later are incorporated into the Federal fleet of spent fuel transport casks. While the illustrative 40-mill levy is assumed to be applied to all such casks while in service at the reactor sites, there is considerable uncertainty as to how long these casks would be in use at a site. Once the repository has commenced acceptance, it is assumed that DOE would want to convert any dual-purpose casks in storage service to transportation service as soon as feasible. It is likely that use of these casks at a utility site would involve a DOE-utility agreement for their early conversion to transport service. On the other hand, a utility would resist delivering fuel that they had stored in a storage-only cask, preferring instead to ship spent fuel from the storage pool, to make room for more freshly discharged fuel. For purposes of this estimate, the storage-only casks were assumed to have an average at-reactor service life of 15 years; the dual-purpose casks were assumed to have an average at-reactor service life of 5 years. The plant capital additions used in fuel handling and packaging have an estimated service life of 26 years. The amounts of estimated tax payments on capital additions to storage, detailed in Table A-5.2, range from a maximum of about $384 million for the No-MRS reference case and Alternative 5, to $112 million for No-MRS Modification 3 and 4, in which all fuel was assumed to be consolidated and dry storage needs markedly reduced. The reference MRS case was estimated to incur storage taxes of $125 million, and for MRS Alternative 1 the estimate was $107 million.

The tax payments indicated in Table A-5.2 are included in the summary of indeterminate costs given in Table A-5.3.

A.5.5 Liability Coverage for Utilities

Utility representatives, in recent Congressional testimony and in other communications, have made it clear that their utilities would expect full indemnification for any liabilities they might be exposed to in performance of work required by the Federal government. This would include not only indemnification against liability from accidents arising from these operations, but defense against and reimbursement for NRC fines, PUC actions, etc., relating to the mandated work. Support for public relations activities and legal defense against intervenors and others could also logically be included.

It has been traditional in proximal cost estimates for nuclear facilities to allow 0.45% of the plant capital cost as an annual insurance premium cost. This amount is assumed to cover industrial property and liability insurance as well as nuclear liability insurance. The addition of responsibility for consolidation of fuel and canister preparation at reactors, while it introduces additional risks, is not likely to affect the balance between capital expenditure and insurance premium costs inferred by the 0.45% relationship. The added operational liability associated with possible NRC fines and other contingencies cannot be estimated at this time, and hence is marked "indeterminate".

A.5.6 Summation of Indeterminate Costs

As was noted in the preceding discussion, several of the categories of indeterminate costs cannot be estimated even as cost ranges at this time. Those which can be estimated, however, could add significantly to the definitive costs discussed in Subsection A.4. As shown in Table A-5.3, the range of added costs for Alternative 2 of the No-MRS system is only from $231 to $236 million. However, with increased responsibility for at-reactor functions (Modification 3 to 5), the additional costs can range from $1 billion to over $2 billion, and could go markedly higher. Cost ranges for the various modifications are given in the Table. Under appropriate conditions the cost categories marked as "indeterminate" in the table could of themselves provide significant additions to those costs estimated.

Table A-5.1 Estimates of Increased Capital Valuation

Costs in millions of dollars (a)

Cost Item		No-MRS Modification Ref	1	2	3	4	5	MRS Mod. Ref	MRS Mod. 1
Pool Reracking (Sect. A.4.1):									
Plant Capital Additions					170	170	170		
At-Reactor Dry Storage (Table 5.2)									
Capital Costs		640	490	340	200	200	640	210	180
Consolidation (Table A-4.2)									
Capital Equip	263								
Licensing	11								
40% Contingency	109								
Total	383			380	380	380	380		
Canister Closure (Table A-4.5)									
Capital Equip	309								
Licensing	32								
40% Contingency	136								
Total	477					480	480		
Decontamination Equip (Sec. A.4.4)						200	200		
Total Capital Valuation		640	490	720	750	1430	1870	210	180

(a) All values are rounded off to the tens-of-millions of dollars. Some columns may not sum exactly due to rounding.

Table A-5.2 Estimates of Tax Payments on At-Reactor Dry Storage Capital Costs

Costs in millions of dollars (a)

No-MRS Mod	Dry Storage (MTU)	Storage Capital Value	Tax Payments on Cask Type: Storage	Dual P.	Total
Ref.	9400	640	380		380
Mod. 1	7050	490	290		290
Mod. 2					
Stg. Casks	4300	320			
D. P. Casks	200	20			
Total	4500	340	190	7	200
Mod. 3 and 4 (Consolidated fuel)					
Stg. Casks	2950	180			
D. P. Casks	150	10			
Total	3100	190	110	4	110
Mod. 5 (Same Reqts as Ref. Case)	9400	640	380		380
MRS Mod:					
Ref.	2800	210	130		130
Mod.1	2200	180	117		110

(a) All values are rounded off to the tens-of-millions of dollars. Some columns may not sum exactly due to rounding.

TABLE A-5.3

Indeterminate Costs in No-MRS System Activities

Costs in millions of dollars (a)

Cost Item	Estimated Costs for System Modification:								
	No-MRS Cases						MRS Cases		
CASE:	Ref.	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Ref	Alt 1	Cost Components
Replacement Power Costs (a)				150-600	250-750	300-800			Replacement costs for power lost in extended outages
Use of Dual-Purpose Casks									
Assimilation into Transportation Fleet			10-20	10-20	10-20	10-20			Expedited licensing program; automated inspection
Facility Modification Costs				(Indeterminate)					Analysis and strengthening of pool structures
Tax Obligations (b)									
Added Plant Capital				790	1280	1280			40 mills (4%) annually on increased capital valuation
Storage Capital Costs	380	290	200	110	380	380	130	110	

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TABLE A-5.3 (Con't)

Indeterminate Costs in No-MRS System Activities

Costs in millions of dollars (d)

Cost Item	Estimated Costs for System Modification:								
	No-MRS Cases						MRS Cases		
CASE:	Ref.	Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Ref	Mod 1	Cost Components
Added Liability Insurance Premiums (c)									
Plant Additions				90	140	140			Increased liability premium (c)
Storage Casks	30	20	20	10	10	30	10	10	
Other liabilities		(Indeterminate)							NRC fines, adverse PUC actions, defense against intervenors, etc.
TOTALS	410	310	230-240	1160-1620	2090-2590	2150-2650	130	110	

(a) Cost ranges for estimated "average" loss of operating time. Upper-range outages could result in replacement costs of $2 billion or more.

(b) Taxes assumed to be levied annually at 40 mills (4%) per dollar of capital additions.

(c) Liability premiums based on added capital values to plant and to storage facilities as shown in Section 4. Annual premiums based on 0.45% of capital valuation.

(d) All values are rounded off to the tens-of-millions of dollars. Some columns may not sum exactly due to rounding.

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Appendix B

DESCRIPTION AND EVALUATION OF POTENTIAL MODIFICATIONS TO THE WASTE-MANAGEMENT SYSTEM

A number of questions have been raised concerning alternatives for the handling, packaging, storage and transportation of spent fuel which could be utilized in the reference no-MRS system, potentially improving the performance of that system.

The potential modifications can be grouped in four main categories:

- Expanded storage at reactor sites
- Transportation modifications
- Use of Federal Interim Storage (FIS)
- Expanded lag storage at the repository

The MRS proposal to the Congress includes a complete description and evaluation of most of the potential modifications available in the groups listed above. These descriptions and evaluations are contained in Appendix A and Appendix D to Volume II of the MRS proposal to the Congress. During the period since the preparation of the MRS proposal, additional information has become available from a number of the DOE and DOE-utility waste-management research and development programs.

This appendix reviews the potential modifications that have been described and evaluated in the MRS proposal and provides additional information that has become available on these potential options. This appendix also contains a description and evaluation of a few potential modifications that were not included in the MRS proposal.

B.1 REVIEW OF POTENTIAL MODIFICATIONS EVALUATED IN THE MRS PROPOSAL

As mentioned, Appendix A and Appendix D of Volume II of the MRS proposal evaluate many potential modifications to the waste-management system. The potential modifications that were evaluated fall into the following categories:

- Expanded lag storage at the repository to provide a buffer between waste acceptance and waste emplacement.
- Expanded storage at reactor sites, either by adding modular dry storage or in-pool consolidation of spent fuel, to provide contingency storage if repository operations were delayed.
- The use of larger shipping casks and multicask shipments, thereby increasing the tonnage per shipment and reducing the number of separate shipments.

The summary conclusions determined in the MRS proposal with respect to these potential modifications are provided below.

Expanded at-reactor storage to provide a system contingency in case of changes in the scheduled startup of the repository is a viable modification. There are two general ways that at-reactor storage can be expanded: by providing dry storage; or by consolidating the spent fuel to increase the capacity of the existing storage pool. The former is the more costly. The latter would necessitate the development and execution of contractual agreements between the DOE and each participating utility that would encompass such areas as responsibilities, liabilities, licensing, facilities, staffing, and costs. There is no assurance that any utilities will be interested or willing to participate in such arrangements.

Modifications to the transportation system (i.e., using larger casks and multicask shipments) could be implemented to reduce the number of cross-country shipments and lower overall transportation impacts because of the reduced number of shipment-miles. However, implementing some of these options would necessitate upgrading facilities and equipment at many reactors. The cost of these modifications cannot be assessed at this time because of the site-specific character of the at-reactor upgrading, and because some institutional interactions would be required for most of the modifications. Implementing multicask shipments from reactors would generally increase scheduling difficulties and transportation cost due to the increase in nontransport time for the casks.

Expansion of lag storage at the repository would provide the operational decoupling that the MRS facility provides, i.e., it would allow independent operation of acceptance and emplacement and would thus improve the reliability and efficiency of the system. It would not, however, separate the development of the waste acceptance, transportation, and packaging functions from the repository development process (site selection, characterization, licensing, and construction) since all of the repository facilities are subject to a common (10 CFR 60) license. Consequently, this option would not allow the early and increased spent-fuel receipt that the MRS facility provides. The cost of adding storage at the repository site is assumed to be identical to the cost of adding storage at the MRS site. This option would not, by itself, provide any benefits to the transportation function.

B.1.1 Expanded Storage at Reactor Sites

Expanding storage capacity at reactor sites could provide the contingency storage that would be needed if the repository is delayed. Three methods for expanding storage capacity at reactors are available: reracking for high-density storage, fuel consolidation, and dry storage. The first two involve expanding in-pool capacity, while the last requires storage outside of the pool. For this analysis, it is assumed that all reactors have been reracked to the maximum extent possible. Consequently, this option will not be discussed further.

B.1.1.1 Modular Dry Storage

Spent fuel that exceeds in-pool capacity could be stored in dry storage modules that are kept at the reactor site. Dry storage methods include metal casks, drywells, silos, and vaults. These methods are described in Appendix D of Volume II of the MRS proposal together with their relative costs. Typically, dry-storage methods at reactors are more costly on a per-kilogram of contained uranium (kgU) basis than in-pool consolidation.

B.1.1.2 Spent-Fuel Consolidation and Canistering

Spent-fuel consolidation is the process of separating the fuel-bearing components (spent-fuel rods) from the nonfuel-bearing components (assembly hardware) and placing the rods into a canister in a more compact array, thus reducing the space required to store spent-fuel rods by about one-half. Consolidation can also be used to provide a more compact waste form for dry storage (e.g., casks) as well. At-reactor consolidation is generally considered as a means to alleviate the spent-fuel storage problem at reactor sites; however, it has also been suggested as an alternative to consolidation in the federal portion of the waste-management system. There are three alternatives for at-reactor consolidation and canistering:

- At-reactor consolidation into a utility-selected canister.
- At-reactor consolidation into a repository-specific canister.
- At-reactor consolidation into a repository-compatible canister that is also compatible with reactor pool racks.

The utility-selected canister could, and likely would, be different in size from reactor to reactor, resulting in a variety of canisters that would not fit together well within the repository-specific disposal container. The repository-specific canister may not be identified until after a significant amount of spent fuel will have been consolidated to meet storage needs. This material might then have to be recanistered. Only the third alternative would actually permit canistering activities to proceed without the risk of the produced canisters being incompatible with the final repository-specific disposal container.

Each of the alternatives requires the utilities to perform the initial preparation and packaging of spent fuel, a responsibility assigned to the DOE by the Nuclear Waste Policy Act. The DOE could contract with utilities to perform this function, which could include some arrangement to appropriately reimburse the utilities. The reimbursement should be related to the costs avoided by the DOE when the utility provides canisters of consolidated spent fuel instead of intact fuel assemblies. The maximum avoided cost would occur when all utilities perform the consolidation function, thus eliminating the need for such a facility at the repository. However, there is no assurance that all utilities would be willing or able to perform this function. The feasibility of performing the consolidation function and storing consolidated fuel in a particular spent-fuel storage pool depends on structural, thermal, and seismic constraints for that pool. In addition, consolidating spent fuel in a reactor pool creates the potential for degrading the water quality for the reactor pool, and adding to the background radiation level of the pool. It is unlikely that consolidation would be a feasible or attractive option for all utilities.

Each of the alternatives for consolidating spent fuel at reactor sites would shift the location of this spent-fuel preparation step from the federal government site (either the MRS facility or the repository) to the utility sites. This shift creates several important tradeoffs that are common to each of the above alternatives.

Each of the alternatives for at-reactor consolidation and canistering are described in more detail below.

At-Reactor Consolidation into Utility-Selected Canisters

Utilities would most likely select a canister for consolidated fuel that would be compatible with their existing pool storage racks. Typically, each canister would hold the equivalent of two intact assemblies but would fit into the same rack space as a single intact assembly. The hardware from the disassembly process would most likely by compacted into a similarly-sized canister and also stored in the pool racks. Thus, a variety of reactor-specific canisters would be created which would not necessarily fit well together in the repository's disposal container. In addition, these canisters would probably not be sealed and inerted because systems capable of evacuating, backfilling with an inert gas, and seal-welding canisters underwater in the storage pools have not yet been demonstrated. These latter functions would probably have to be performed at the repository or the canister removed and discarded. Working over storage pools, consolidation workers would receive higher radiation doses than would be received at an MRS facility because of higher radiation levels over the pools.

At-Reactor Consolidation into a Repository-Specific Canister

In this alternative, the utilities would have to load the consolidated fuel roads into a repository-specific canister, which would be designed to fit efficiently into the repository's disposal container. The dimensions of the canister and the internal loading arrangements will be governed by the nature of the disposal medium and, therefore, may not be defined sufficiently early for the utility to provide an appropriate canister. An incorrect choice could result in the early-design canisters having to be repackaged. In addition, a repository-specific canister could be much larger in dimension and in total weight than would be a canister that fits within the pool storage racks. As a result, some new racks specifically designed for the canisters would have to be installed in the pool, and additional procedures and equipment would have to be put in place to ensure the safe handling and criticality safety of the large canisters.

At-Reactor Consolidation into a Repository-Compatible Canister That Is Also Compatible with Reactor Pool Racks

With this alternative, the utilities would consolidate fuel rods into canisters that are compatible with proposed repository disposal containers. The canister sizes also would allow the disposal package characteristics to be changed without requiring repackaging as knowledge of the disposal medium improves and requires such changes. One such canister concept considered for this alternative is the square/half-square configuration as proposed by NUS Corporation in its PRDA studies, where two assemblies are consolidated into a full-square canister and one assembly is consolidated into a half-square canister. One canister size would be used for pressurized water reactor (PWR) assemblies and a smaller canister size would be used for boiling water reactor (BWR) assemblies. Two half-square canisters would occupy approximately the same space as a single full-square canister, permitting a variety of geometric arrangements and improving the packing efficiency of the canisters within the repository disposal container.

B.1.2 Transportation Modifications in the No-MRS System

A series of changes to the transportation system were evaluated that would provide benefits similar to the MRS system by reducing the number of discrete shipments moving through the system. This reduction would be achieved by (1) using larger casks, and (2) combining casks into multicask shipments. The primary effect of these modifications would be to improve the degree of control that could be exercised over the transportation system, i.e., by reducing the number of cross-country shipments to the repository.

Implementing these modifications could reduce the total shipment-miles in the no-MRS system. These modifications will generally require use of new cask or handling technology, facilities such as marshalling yards, investments at utilities to improve existing reactor facilities, and some additional handling of spent fuel outside of contained areas. The total cost implications of these options have not been evaluated at this time, as most have not yet been designed in detail.

All of these modifications to the transportation system could be implemented in the MRS system and could lead to further reductions in transportation impacts for that system as well as the no-MRS system.

Each of the modifications is described below, along with preliminary information on the potential feasibility and reductions in transportation impacts (cask-miles and shipment-miles), costs, and radiation dose effects.

B.1.2.1 Increased Use of Rail Transport

Recent studies of cask-handling capability at existing reactors have shown that many reactors are limited in their ability to handle large rail casks. These limitations stem from such factors as inadequate crane lifting capacity, lack of a rail sur onto the site or into the reactor building, and structural limitations of the storage pool.

Two methods for increasing the use of rail transport for shipments originating from reactors are discussed in this section:

- Upgrade reactor facilities to provide direct rail access (e.g., by adding rail spurs and modifying crane capacity).

- Transfer spent fuel to large rail casks outside the pool using smaller transfer casks loaded in the storage pool and, if necessary, transport the large casks by truck ("heavy-haul") to the nearest rail access point.

Of these alternatives, the first can be accomplished without new technology development or application. Upgrading reactor-handling capabilities would require retrofitting or recertifying present equipment to handle heavier rail casks. Also, reactors that do not have rail service into the reactor site would need that service. The second alternative would require dry-cask transfer methods to be developed and certified. This technology is currently being investigated, especially for its use as a method to load storage units that could be used at reactor sites. The cost, risk, and feasibility of this alternative are uncertain at this time. "Heavy-haul" has been used many times to move heavy components such as reactor vessels onto sites without rail access, but has not yet been used for spent-fuel shipments. Each alternative is discussed in more detail below.

Upgrade Reactor Sites To Provide Direct Rail Access

A recent study has estimated that 41 of 127 reactors do not have active rail lines or do not have the capability to receive, handle, and load a rail cask. Of these 41 plants, 12 plants would require extensive structural modifications within the reactor or fuel-handling buildings to upgrade rail capability. The remaining 29 reactors are limited to truck shipping because they are not provided with rail access to the site. These plants would require rail spurs to be built between the reactor site and the nearest rail point, distances ranging from 1 to 50 miles. Seventeen of these reactors were judged to be the most likely candidates for upgrades because they would require less than 10 miles of new rail spur construction and have no known requirements for constructing bridges or tunnels. In many of these cases, additional studies would be required to assess the structural sufficiency of the pools, cranes and cask-handling areas before the first rail-cask handling sequence could commence.

Dry-Cask Transfer and Heavy-Haul Methods

This alternative involves the transfer of spent fuel between casks in a dry environment and/or transfers of loaded spent-fuel casks between transport vehicles. Spent fuel from reactors not having rail cask receiving and loading capability could be loaded into a transfer cask (about the size of a truck cask) in the reactor pool using conventional methods. This loaded transfer cask would be removed from the reactor building and the spent fuel could be transferred directly (in a dry environment) to a large rail cask. Several transfer cask loads would be required to fill the rail cask. If there is not rail access at the reactor site, this rail cask would be heavy-hauled by truck to a nearby rail access point where it would be transferred onto a rail car. Some reactors could load the rail casks in their existing pool, but may not have onsite rail access. For these reactors, the rail transport cask would be heavy-hauled by special truck to a nearby rail access point where it would be transferred into a rail car.

The overall result of this alternative would be a shift from truck to rail transport. This shift would decrease the number of shipments and cask-miles, but require additional spent-fuel handling and transfer activities at or near the reactor facility.

B.1.2.2 Use of Extra-Large Rail Casks

The use of extra-large rail casks (125 to 150 tons loaded) in the no-MRS system would significantly reduce the total cask-miles traveled as well as the total number of shipments required. The actual percentage reduction that may be obtained in cask-miles and in the number of shipments is directly proportional to the relative cask capacities. The majority of reactors that are currently listed as having rail-cask-handling capabilities can handle rail casks having a loaded weight between 100 and 125 tons. As a result, the use of these casks would be limited, or their widespread use would require modifications to rail-cask-handling capabiliti[illegible] or the implementation of dry-cask transfers at most of the reactors currently in operation in the United States.

B.1.2.3 Multicask Shipments

The total number of shipments and shipment-miles in the waste-management system can be reduced by combining single-cask shipments into larger multicask shipments.

Several alternatives for combining shipments were considered and are briefly described below.

Truck Convoys

This method of combining shipments would require individual truck shipments of spent fuel to be marshalled at either individual reactors or a centralized yard. The combined shipments would then travel as a convoy to the repository. This marshalling of truck shipments would, in effect, reduce the number of separate shipments of spent fuel on the highways.

Combining Rail Shipments at Marshalling Yards

Individual rail shipments from reactors could be combined into fewer, larger shipments to the repository by coordinating shipments from reactors near centralized marshalling yards. This would allow an opportunity for combining individual shipments into a single train and would minimize the total waiting time of casks at the marshalling yard.

Scheduling Multicask Shipments from Reactors

By scheduling to receive more than one cask of spent fuel at a time from each reactor and by combining the multiple casks in a single shipment, the number of separate shipments could be reduced.

Inherent in each of these options is the added amount of nontransport time that occurs for individual casks. This increased nontransport time is incurred either at the reactor, where loaded casks are idle while awaiting the loading of subsequent casks, or at the marshalling yards, where early arriving casks remain idle while awaiting the arrival of other casks to be added to the shipment. This increased nontransport time lengthens the average total time required for a trip for casks and requires that more casks be added to the cask fleet to ship the same amount of spent fuel in an equivalent time. These extra casks will add to the overall cost (capital and maintenance) of shipping the spent fuel.

All of these alternatives require differing degrees of planning, scheduling, and control of operational parameters. No new technology is required for the implementation of any of these options.

B.1.2.4 Use of Overweight Truck Shipments

The capacities of truck casks are generally limited by the gross vehicle weight limits rather than by physical volume constraints. Thus, the size of truck shipments could be increased, with corresponding reductions in the number of such shipments, by using overweight rather than legal-weight shipments.

One complication with this alternative is that the regulations and statutes governing overweight truck shipments are not consistent throughout the United States, but vary from State to State. This results in more complex scheduling and interactions to ensure that the overweight shipments are consistent with the regulations of the various States along the routes. Overweight shipments might also be constrained to operate only during certain times of the day or at reduced speeds, resulting in a net reduction in shipment speed. Some States also do not allow overweight truck shipments during the winter months because of possible damage to highways. The DOE is continuing to investigate and refine the scheduling and regulatory compliance issues associated with this option.

B.1.3 Expanded Lag Storage at the Repository

Lag storage capability could be added to the first respository to provide some of the same benefits that are provided by the MRS system. For example, the waste-acceptance process would be insulated from disruptions in repository emplacement. If the storage capability were licensed separately from the underground portion of the repository, spent fuel could also be received earlier and contingency storage could be provided in case of some types of delays in repository startup or diminished emplacement capability. Present designs of repository surface facilities include a 3-month operational buffer (750 MTU), which is sufficient to ensure smooth functioning during normal emplacement operations, to unload the transportation system during slowdowns or brief stoppages in emplacement activities, and to maintain emplacement operations during brief disruptions of the transportation system.

To accelerate the initial spent-fuel-acceptance rates in the no-MRS system, expanded lag (buffer) storage at the repository could be provided. The spent-fuel acceptance rate at the repository during the first 5 years of operation is controlled by the rate at which the underground emplacement excavations and operations progress after NRC licensing. (Completion of repository surface facilities also affects the lower acceptance rate but to a lesser degree.) The amount of storage that could be provided to accelerate the acceptance of spent fuel while not impeding repository construction cannot be predicted at this time. The licensability of such storage prior to repository operating approval could also be a major obstacle to its implementation, considering the constraints incorporated into the Nuclear Waste Policy Act. The Act prohibits the construction and operation of an MRS facility or FIS in a State in which a repository site is located. Also, to avoid characterization as a separate facility, the lag storage would have to be licensed in the same action as the repository. Thus, fuel acceptance in meaningful quantities could not begin much in advance of repository disposal activities; in other words, lag storage could not effectively separate the DOE's acceptance of spent fuel from the schedule of spent-fuel acceptance at the repository.

B.2 ADDITIONAL INFORMATION ON POTENTIAL MODIFICATIONS EVALUATED IN THE MRS PROPOSAL

During the period since the preparation of the MRS proposal, additional information on the potential modifications evaluated in the MRS proposal has become available from a number of DOE and DOE-utility programs on waste-management research and development. The additional information is in two general areas: at-reactor consolidation and transportation modifications. This section reviews the developments in these areas.

B.2.1 Additional Information on At-Reactor Consolidation

The consolidation of spent fuel in reactor pools has been proposed as a feasible and cost-effective means to increase pool storage capability. Recent small-scale demonstrations indicate that consolidation may be both feasible and economically attractive; however, the experience at present is too small to confidently estimate either the cost or the feasibility of large-scale applications of the process. Confident estimates will require data from larger-scale projects.

The experience to date with in-pool demonstrations has been variable. Five companies have designed in-pool consolidation equipment, and each has teamed up with one or more utilities to test and refine the systems. All of the development and experience has focused on PWR fuel consolidation--no efforts to consolidate BWR fuel have been made. The demonstration programs that have been performed to date can be summarized as follows:

- The Westinghouse Electric Corporation has designed an automatic system that pulls all rods from an assembly at once, and it has worked with the Duke Power Company on four PWR assemblies at the Oconee plant in November 1982. Westinghouse now has a contract with the Northern States Power Company to consolidate about 40 PWR assemblies at the Prairie Island plant. This "hot" demonstration program is reported to have been initiated in October 1987.

- Combustion Engineering (C-E) has an automated system that pulls one rod at a time or one row at a time. A cold demonstration of the equipment was completed in December 1986. C-E completed a "hot" demonstration program at the spent-fuel pool of the Millstone 2 plant (Northeast Utilities). Six PWR assemblies were consolidated, with a 2:1 compaction ratio achieved for each assembly. Northeast Utilities has a goal of eventually consolidating the entire pool inventory if approval from the NRC is obtained. C-E also has a contract with the Virginia Power Company to consolidate about 48 PWR assemblies at the Surry plant.

- The Nuclear Assurance Corporation (NAC) uses an elevator in the fuel pool to raise and lower assemblies and canisters, and rods are pulled one at a time. NAC worked with the Rochester Gas and Electric Corporation (RG&E) on six PWR assemblies from the Ginna plant at West Valley in December 1985 and February 1986. NAC and the Tennessee Valley Authority had planned a rod-consolidation demonstration of about 12 BWR assemblies at Browns Ferry, but this has been deferred indefinitely.

- The U.S. Tool & Die Company (UST&D) has designed a system using a funnel to guide and control the path of each fuel rod as it is drawn from the assembly into the storage canister. UST&D worked with RG&E to complete consolidation of the PWR assemblies from Ginna at Battelle Columbus Laboratories in October 1985.

- The Proto-Power Corporation uses a computer-controlled indexing system and a single rod transfer system and has worked with the Maine Yankee Atomic Power Company to refine the equipment. A "cold" test of the equipment has been done, but Maine Yankee has no plans for a "hot" demonstration in the near term.

In 1986, General Electric also indicated it might be considering rod consolidation at its Morris spent-fuel storage facility. GE has done fuel reconstitution and has talked to the NRC staff about consolidation at Morris. The future of GE's plans is uncertain, however, because of the company's decision in October 1986 to pull out of the waste-services business.

In each of these cases, the vendor's equipment has been designed for an optimum 2:1 compaction, but most efforts have so far had mixed success. Where 2:1 consolidation has been achieved, the tradeoffs have been low production rates, substantial man-hours, or high costs. Vendors agree that there is still a good bit or work needed to optimize the systems. The more recent demonstration by C-E was encouraging: a 2:1 consolidation ratio was achieved with reasonable production rates. The experience to date on achieving the desired compaction ratio is summarized below.

- At Oconee in 1982, two assemblies containing 208 rods each were consolidated into one canister. The other two assemblies (which were the first two worked on), however, were not successfully loaded into one canister: there were 33 stray rods because of a malfunction with one of the machines.

- NAC only succeeded in consolidating six Ginna assemblies into five canisters at West Valley. Only 109 of the 179 rods in the first assembly were loaded into the first canister. The next three canisters were loaded with 251, 251, and 276 rods, however, for a consolidation of about 1.4:1. The fifth canister was loaded with 187 rods but was not completely loaded. According to NAC, the loading of the fourth canister--with 276 rods--was equivalent to a consolidation of 1.8:1 because of the space taken up by thermocouplers and other instrumenting devices.

- UST&D succeeded in consolidating five Ginna assemblies into two-and-a-half canisters at Battelle Columbus Laboratories' West Jefferson facilities.

- C-E succeeded in consolidating six PWR assemblies into three canisters at Northeast Utilities' Millstone 2 plant.

Several utilities are considering fuel consolidation, and a recent limited study by NAC of utility preferences showed that utilities are willing to consider consolidation to meet their own storage requirements prior to the inception of Federal acceptance of spent fuel. Although the limited NAC study indicated a willingness among utilities to consolidate to relieve their own storage problems, it also indicated strong objections to voluntary consolidation to achieve benefits elsewhere in the waste system, even if substantial incentives were provided.

The interest of the nuclear utility industry in in-pool consolidation is isolated to specific operating units as follows:

- The Duke Power Company is primarily considering dry storage to meet short-term needs for Oconee in mid-1989 but is also investigating consolidation technologies.

- The Consumers Power Company plans to rerack the spent-fuel pool at the Palisades plant and has indicated plans to seek a license amendment to store consolidated fuel. Consumers will need additional storage space at Palisades in 1989.

Other utilities potentially interested in at rod-consolidation projects are the Wisconsin Electric Power Company, Baltimore Gas & Electric Company, Florida Power & Light Company, New York Power Authority, and Philadelphia Electric Company.

The utility licensing situation with the NRC is an evolving one. No generic or vendor-specific topical report has been submitted to the NRC for in-pool consolidation equipment. The position taken by the utilities--and so far not disputed by the NRC--is that consolidation itself does not need to be licensed by the NRC because the operations involved would be within utilities' technical specifications in most cases. Unless a change in technical specifications is required, it appears that consolidation is allowed under 10 CFR 50.59.

However, a license amendment is required if a utility will be increasing its in-pool storage capacity through consolidation. Since this is the primary reason for undertaking at-reactor consolidation, a utility's decision to consolidate will have to include an assessment of the factors associated with an operating license amendment. The experiences of Maine Yankee Atomic Power Company in attempting to attain a license amendment for this purpose are not encouraging. A summary of their efforts is provided below.

- In 1979, Maine Yankee submitted to the NRC a detailed safety analysis and application for approval. A local antinuclear group petitioned for leave to intervene and was admitted.

- In 1980, the necessary supplements were filed. At that point, the State of Maine also petitioned for leave to intervene and was admitted.

- By mid-1983, Maine Yankee could see no end to the licensing process--a trial date had not been set.

Maine Yankee currently has no plans to pursue consolidation, although it believes that consolidation and in-pool storage of consolidated fuel is technically and economically viable. Similarly, Northeast Utilities applied to the NRC for a license to consolidate (and store in the spent-fuel pool) the entire spent-fuel inventory at its Millstone 2 plant. The NRC, however, granted this utility the very limited authority to consolidate (and store) only up to 10 assemblies. The licensing problems encountered by Maine Yankee and Northeast Utilities are probably not unique.

B.2.2 Additional Information on Transportation Modifications

Since the preparation of the MRS proposal, a number of additional potential transportation modifications have been developed through various DOE programs. These potential modifications are described and evaluated below.

B.2.2.1 Larger-Capacity Standard Casks

Responses from commercial vendors to the recent request for proposals (RFP) for cask designs have confirmed that it is possible to design a new generation of truck and train casks that would have a much higher capacity than previous designs of the same weight and size. The train cask used in the MRS proposal was assumed to have a capacity of 14 PWR or 36 PWR spent-fuel assemblies, and the reference truck cask was assumed to have a capacity of 2 PWR or 5 PWR assemblies. The recent RFP responses, however, have suggested that new-generation cask capacities would be 21/48 for train and 3/7 for truck. These larger-capacity standard casks would significantly affect system development. A smaller cask fleet would be needed, and the design and operation of receiving facilities could potentially be based on handling fewer cask arrivals. It is important to recognize that the benefits of most other potential modifications to the transportation system would be reduced by the use of larger-capacity casks because the number of casks and cask shipments would be lower.

System operations would be simplified because fewer cask trips would be required. System costs would be reduced because fewer casks would be acquired, maintained, and decommissioned, and fewer casks would be transported, resulting in lower transportation costs.

System risks would be greatly reduced. Most radiation exposure is incurred in cask loading and maintenance operations. Far fewer handlings would be necessary with the larger-capacity standard casks. The risk of radiation exposure of the public would also be reduced by the smaller number of casks being shipped.

Preliminary analyses have shown these casks to be technically feasible, and no obstructions to institutional acceptance have been identified.

B.2.2.2 Dedicated Trains from Reactors

Rail shipments could be made in dedicated trains that would carry no other commodity. These trains would operate directly from a reactor to the repository. The dedicated-train alternative should not be confused with the multicask alternative. Multicask shipments are characterized by a number of casks moving as a set, which could move by either general freight or dedicated trains.

Dedicated trains would have a moderate effect on system development, with primary benefits coming from a greater control over the arrival and departure schedules, which would allow receiving facilities at the repository to be designed for a lower "surge" rate and for greater predictability and control of routing, which would allow institutional efforts to be focussed on fewer geographical areas. Dedicated trains would simplify system operations by allowing the scheduling and routing of trains to meet the DOE's needs rather than the railroads' convenience.

System costs might be slightly increased by dedicated trains, although the higher over-the-road cost of dedicated trains could be partially balanced by significantly higher over-the-road speeds and reduced stopped times. The greater control over the arrival and departure of trains would allow the receiving facilities to be designed for lower surge capacity.

System risks would be reduced by dedicated trains, for both occupational and nonoccupational radiological risks. Occupational and nonoccupational nonradiological risks may be slightly increased, reflecting the presence of additional trains (as compared to the presence of just additional cars if regular trains were used) on the rail network.

Dedicated trains are technically feasible and are in everyday use in the railroad industry for certain commodities and equipment types. A specialized form of dedicated train, called a "special train," has been used in various nuclear fuel shipments, notably for the Cooper and the Monticello plants. Dedicated trains are assumed to provide all transportation from the MRS facility to the repository.

B.2.2.3 Pick-Up Trains

Pick-up trains could pick up casks from two or more reactors before proceeding to a repository. This contrasts with the reference no-MRS system, where it is expected that shipments to a repository will be composed of casks from only one reactor site, except for those instances where railroads, by coincidence or for their own operational purposes, might combine the shipments on a single train.

A pick-up train is a form of "dedicated train". Pick-up trains could allow some of the benefits of dedicated trains by providing greater control over the shipments, and of multicask shipments by providing economies of scale and reducing shipment miles, without incurring waiting time at a single reactor site while several casks are loaded consecutively.

The effects of pick-up trains on system development would be mostly limited to the resolution of institutional considerations. Since pick-up trains require a gathering of casks from several or more reactors, most casks would not be moved by the shortest or the most-direct route to the repository and would incur some waiting time at another reactor while the next cask is added to the train. Public opposition to the increase in cask-miles could be expected, as could utility opposition to the requirement to "store" another utility's fuel during the time that the train is being made up. In fact, the NRC might require an amendment to each utility's license to allow it to temporarily "store" the spent fuel from other utilities that is in the casks. A recent survey of utility managers indicates strong opposition to the use of pick-up trains for these reasons.

System operations would be greatly complicated by the use of pick-up trains, as very precise scheduling and coordinating of shipments would be required so that shipment problems affecting one utility would not affect the others. Successful application would require precise scheduling many months ahead, the unfailing ability of utilities to ready shipments for pickup, and perfect coordination and cooperation between utilities, railroads, and the DOE.

Pick-up trains would probably have a higher system cost than regular or dedicated-train shipments from a single reactor because of operating inefficiencies such as numerous short rail hauls and time spent waiting for other casks. Some savings would be realized for reducing waiting time as compared to assembling an equal number of loaded casks at a single reactor site.

B.3 EVALUATION OF POTENTIAL MODIFICATIONS NOT INCLUDED IN THE MRS PROPOSAL

Two potential modifications to the waste-management system that were not evaluated in the MRS proposal are Federal interim storage (FIS) and the use of dual-purpose (transportable-storage) casks. This section describes and evaluates these alternatives.

B.3.1 Federal Interim Storage (FIS)

There are provisions in the Nuclear Waste Policy Act to assist the commercial nuclear power reactors that are unable to reasonably provide adequate storage capacity on site when needed to ensure the continued, orderly operation of such reactors. This Federal storage capability is limited to 1900 MTU.

The Act makes it clear, however, that the primary responsibility for providing interim storage for spent nuclear fuel rests with the individual utility owning reactors by maximizing, to the extent practical, the effective use of existing storage facilities at the site and by adding new on-site storage capacity in a timely manner where practical. For those commercial nuclear power reactors that have pursued all alternatives for additional spent-fuel storage without solving their storage difficulties, applications can be made to transfer spent nuclear fuel to Federal storage facilities. Such arrangements in the form of contracts with the DOE are required to be enacted not later than January 1, 1990. There is no evidence at this time that any utility plans to make an application for FIS. It should be noted that, before applying for transfer of fuel to FIS, the utility must request and receive from the NRC a determination that it has exhausted all other spent-fuel storage options.

The impacts of FIS on the total DOE spent-fuel storage requirements would be minimal in terms of system operations advantages. FIS must be fully supported by assessments against utilities using the services. Costs will depend heavily on factors such as the site and the storage technology. The use of Federal storage would introduce additional handling and transportation costs resulting from spent-fuel movement from reactors, to Federal storage facilities, and finally to the repository.

There are potentials for marginally increasing public risk due to the increase in transportation cask miles and also some increase in occupational worker radiation exposure due to additional handling of spent fuel in an uncanistered form.

There are no technical limitations in the transfer of spent fuel to licensed Federal storage facilities. There could be some institutional difficulties from State, Indian Tribes, and local groups because of additional transportation and storage activities. There is a restraint within the Act (Section 135(a)(2) that precludes Federal storage in any State in which there is a candidate site for a repository.

In summary, there does not appear to be any evidence that utilities owning civilian nuclear power reactors are considering Federal interim storage as a means of solving on-site spent-fuel storage shortfalls. It should be recognized that this storage concept is only a near-term stop-gap measure and was proposed pending the development and demonstration of new technologies; that is, it was never intended as a long-term safety valve.

B.3.2 Dual-Purpose Casks

The concept of the dual-purpose storage cask, which has been under study by the DOE for several years, is a variant of the metal storage cask alternative in which the same cask in which spent fuel is stored is later used to transport the fuel directly from the storage field to the MRS facility or the repository. In essence this arrangement amounts to storage in a metal storage cask, and, if needed, the cask could then be placed in service as part of the transportation fleet or serve as lag storage at the repository.

The system impacts of the dual-purpose cask are in many instances identical with those of the metal storage-only cask. The potential additional services of the dual-purpose cask, however, generate unique impacts.

The basic feasibility of the dual-purpose cask concept depends on its certification for transportation use after extended periods in storage. Current NRC interpretations of their regulations could preclude certification under those circumstances. There is currently no evidence as to whether such certification could be expected in the future with any degree of confidence.

Dual-purpose casks could either be furnished to utilities by the DOE or purchased by the utilities and later repurchased by the DOE. Several related concerns of equity, quality control, and records pertaining to certification would be involved in these proceedings.

The dual-purpose casks under consideration would weigh about 125 tons and have a capacity of 24 PWR or 60 BWR integral assemblies or 40 PWR or 96 BWR consolidated assemblies.

System development would be affected by the adoption of the dual-purpose cask as design and engineering of the casks would have to be accelerated to ensure that the casks are available to meet near-term storage needs while maintaining compatibility with the transportation and repository systems that are still being developed. Additionally, to gain full benefit from the use of these casks in the regular transportation fleet, their development would need to preempt the acquisition of most of the transportation-only cask fleet.

Dual-purpose casks would offer a minor reduction in the occupational and public risk of radiation exposure as a result of eliminating the rehandling of fuel at the reactors and the slight increase in cask capacity resulting in fewer shipments.