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DETERMINATION OF COST-EFFECTIVE RECEIPT RATES FOR AN MRS AND THE REPOSITORY

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ABSTRACT

This paper describes results of a comprehensive logistics and cost analysis to determine if there are potential benefits to the U.S. high-level waste management system for spent fuel receipt rates to a Monitored Retrievable Storage (MRS) facility or the repository other than the current 3,000 MTU/yr design-basis receipt rate. Cases considering repository startup dates of 2010 and 2015 and MRS startup dates of 1998 and 3 years prior to the repository have been evaluated, and receipt rates ranging from 1,500 to 6,000 MTU/yr have been considered for both the MRS and the repository.

Higher receipt rates appear to be economically justified for both the repository and an MRS. For a repository-only system, minimum costs are found at a repository receipt rate of 6,000 MTU/yr. When a storage-only MRS is included in the system, minimum system costs are also achieved at a repository receipt rate of 6,000 MTU/yr. However, the MRS receipt rate for minimum system costs, which ranges between 3,500 and 6,000 MTU/yr, depends on both the MRS startup date and whether or not the storage capacity of the MRS is constrained. With a 1998 unconstrained MRS and a 2010 repository, the added cost of providing the MRS is offset by at-reactor storage cost reductions, and the total system cost of \$10.1 billion is only slightly higher than that for the repository-only system. If the MRS storage capacity is constrained to a maximum of 15,000 MTU, then this cost increases to \$10.4 billion.

INTRODUCTION

A comprehensive logistics and cost analysis is being carried out by Pacific Northwest Laboratory (PNL)¹ to determine if there are potential benefits to the U.S. high-level waste system for receipt rates other than the current 3,000 MTU/yr design basis

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receipt rate. The scope of the analysis includes both a Repository-Only System and a Storage-Only or Basic (MRS) System. To allow for current uncertainties in facility startup scheduling, the following combination of facility startup dates are considered:

<u>Repository Startup Year</u>	<u>MRS Startup Year</u>
2010	None
2010	1998
2010	2007
2015	None
2015	1998
2015	2012

Receipt rates ranging from 1,500 to 6,000 MTU/yr have been evaluated for both the MRS and repository facilities. The common assumption for facility design work and for system studies has been to use a 3,000 MTU/yr receipt rate for both of these facilities. There is, however, no fundamental reason for identical receipt rates, nor is there a clearly documented rationale for the 3,000 MTU/yr receipt rate. Thus, the objective of this study is to identify advantageous receipt rates and to determine if they differ over the range of conditions specified above and by how much and why.

Possible effects of both unconstrained and constrained MRS storage limits are being examined. The constrained storage limits are those specified by the Nuclear Waste Policy Amendments Act (NWPAA), i.e., 10,000 MTU of spent fuel prior to the repository startup and 15,000 MTU following the repository startup.

WASTE MANAGEMENT SYSTEM

The waste management system for this study was defined to include 1) at-reactor pool and dry storage facilities, 2) shutdown reactor facilities maintained solely for the purpose of storing spent fuel not yet delivered to DOE, 3) transportation facilities required to transport spent fuel from the reactor to either an MRS or the repository and from the MRS to the repository, 4) the MRS facility, and 5) the first

repository facility. Comprehensive system descriptions were prepared for both the Repository-Only System and the Storage-Only or Basic MRS System. These include both functional and physical facilities descriptions and have been reported separately.^(1,2)

Neither development and evaluation (D&E) nor site characterization costs have been included in this analysis. These should not be influenced by the design acceptance rates and are assumed to be constant in all cases. Only costs associated with the first 63,000 MTU of spent fuel and 7,000 MTU of high-level waste destined for the first repository are included in this analysis. At-reactor storage costs for any spent fuel either in dry storage or at shutdown reactors remaining in storage after delivery of the first 63,000 MTU are excluded from the analysis.

Repository Concept

Using information developed in the 1988-89 MRS system studies,^(3,4) separate repository waste handling building concepts were developed for four different acceptance rates - 1,500, 3,000, 4,500, and 6,000 MTU/yr. For spent fuel handling, the number of entry bays, unloading ports, hot cell facilities etc., were scaled in proportion to the cask handling, waste package handling requirements, etc. A separate hot cell was provided in all cases for handling and packaging solidified high-level waste.

One of the effects of increasing the repository receipt rate is to reduce the age of spent fuel delivered to the repository. This has the related effect of increasing the heat energy released by the spent fuel following emplacement in the repository. This, in turn, can increase the repository emplacement areas and the mining requirements. Reducing the receipt rate has the opposite effect. An analysis of spent fuel aging effects⁽⁵⁾ has shown that areal and mining requirements can be correlated with the 100-year integrated energy release from the spent fuel.

MRS Concept

Using similar information developed for a Storage-Only MRS in the 1988-89 MRS system studies,^(3,4,6) separate MRS concepts were developed for the same range of acceptance capacities. The storage facilities concept was based on use of concrete storage casks. The number of casks required and the size of the storage yard were varied according to the requirements of each case. A generic eastern location was assumed for the MRS and all spent fuel was assumed to be shipped to the MRS, placed in storage, and selected for a desired energy mix when shipped to the repository.

LOGISTICS AND COST CALCULATIONS

The WASTES model⁽⁷⁾ was used to develop spent fuel logistics and costs including at-reactor storage requirements and costs, shutdown reactor storage requirements and costs, and transportation system requirements and costs. The WASTES code models the operations with respect to spent fuel handling, storage, and shipment at each of the 100-plus reactors in the United States as well as the MRS. Delivery rights for spent fuel were assumed to be allocated on an oldest-fuel-first (OFF) basis, but the actual spent fuel delivered was not necessarily the oldest fuel. It was assumed that a constant heat-energy-levelized spent fuel mixture could be delivered to the repository each year, either directly from the reactors or from the MRS.

The ramp-up of acceptance of the MRS and repository to their respective design acceptance rates was

assumed to occur over 2 years, with the first year being one-fourth and the second year being one-half of the design acceptance rate. Operation at the full design acceptance rate was assumed in the third year.

A recently developed model named SECAM (System Engineering Cost Analysis Model)⁽⁸⁾ was used to develop MRS and repository costs. SECAM is a detailed cost accounting model that utilizes a large set of cost algorithms for scaling both capital and operating costs as functions of facility size and number of components required, as well as numbers of crews required to handle the various functions as receipt rates are varied. The basic cost data and cost scaling functions were developed from cost estimates developed during the 1988-89 MRS system studies^(3,4,6) and discussions with the Ralph M. Parsons Co., the Architect/Engineering firm responsible for the conceptual MRS design. No escalations to 1990 costs have been included.

COMPONENT COST CONSIDERATIONS

Consideration of some of the factors that influence system component costs can help in understanding the interactions and tradeoffs in the total system cost compilations.

MRS Inventories

When an unconstrained MRS starts up substantially sooner than the repository a large spent fuel inventory can accumulate at the MRS. However, when the MRS startup precedes the repository by only 3 years, only the combinations of high MRS receipt rates with low repository receipt rates result in very large MRS inventories. These peak inventory effects are illustrated in Table 1 for a 2010 repository startup. For a 1998 MRS startup with a 2015 repository, the MRS peak inventories range from 7,000 to 15,000 MTU larger than those shown in Table 1 for a 1998 MRS/2010 repository combination. The MRS peak inventories for the 2012 MRS/2015 repository case are identical to the peak inventories for the 2007 MRS/2010 repository combination.

Table 1 Peak MRS inventories with a 2010 repository startup, MTU

MRS Startup Year	MRS Receipt MTU/yr	Repository Receipt Rate, MTU/yr			
		1500	3000	4500	6000
1998	1,500	18,000	16,900	16,600	16,200
	3,000	49,100	36,000	35,000	33,800
	4,500	52,100	48,800	47,900	47,500
	6,000	52,100	48,900	48,100	47,700
2007	1,500	4,500	3,400	3,100	2,700
	3,000	35,600	9,000	8,000	6,800
	4,500	45,600	29,500	13,500	12,300
	6,000	51,300	39,700	28,200	18,000

Storage Cost Tradeoffs

The cost effect of an MRS inventory involves a tradeoff between MRS storage costs relative to at-reactor storage costs. Normal reactor pool storage costs are not considered a part of these system costs. In this analysis, it is only when pool capacity is exceeded and dry storage is required or when a reactor shuts down and storage requirements delay decommissioning that MRS storage provides a cost alternative.

The dominant cost of at-reactor dry storage is the cost of the storage casks. However, the dominant

cost of shutdown reactor storage is the annual cost of the site support facilities and operations that are necessary for maintaining the cooling requirements and security of any remaining spent fuel requiring storage either in pools or dry casks. Thus, where the unit cost of dry-cask storage is mainly a matter of cask cost and capacity, the unit cost of shutdown reactor storage depends on the total quantity of spent fuel remaining in storage at the site and the number of years of storage required. Example comparisons of the unit costs of these storage alternatives with MRS storage costs are provided in Table 2. These comparisons illustrate how a large MRS inventory can offset high MRS construction and operating costs and provide an economical alternative to either at-reactor dry casks or shutdown reactor storage costs.

Table 2 Example cost comparisons of spent fuel storage alternatives

	At-Reactor Dry Storage ¹	MRS Cask Storage ²	Shutdown Reactors ³
Site Construction (\$K/site)	1,100	353,000	
Cask Costs (\$K/cask)	880	235	
Operations/ Handling (\$K/cask stored) (\$K/site/yr)	15	335	3,670
Typical Overall Cost (\$/MTU stored)	93,000	51,000	
(\$/MTU stored/ 10 years of storage)			122,000
(\$/MTU stored/ 20 years of storage)			245,000

¹Based on an example 300 MTU peak storage at a site.

²Based on a 36,000 MTU peak inventory at the MRS.

³Assumes 300 MTU stored at a site.

Transportation Costs

The cost of transporting spent fuel is not a major system cost. Likewise, the tradeoff between the cost of transporting spent fuel directly to the repository compared with transporting to the MRS plus MRS to repository is not particularly significant. Transport to and from the MRS adds only about 15% to the total transportation costs, e.g., \$1.02 versus \$0.88 billion.

MRS and Repository Capital Costs

The initial MRS and repository facility construction costs increase as the receipt rate capability is increased. Example initial facility costs as calculated by SECAM are summarized in Table 3.

MRS and Repository Operating Costs

Example operating costs are also presented in Table 3 and are shown to be significantly larger than the construction costs. The MRS operating costs

Table 3 Example MRS and repository costs, \$ millions¹

	Design Receipt Rate, MTU/yr			
	1500	3000	4500	6000
MRS Construction	315	353	394	433
Repository Construction	1096	1143	1206	1262
MRS Operations ²	1363	880	721	637
Repository Operations	6385	5490	5069	4940

¹Example costs are based on a 1998 MRS and a 2010 repository.

²Total does not include storage cask costs which vary with peak storage requirements.

decline as the receipt rate increases. This is primarily because the MRS site support costs are the major cost component, and these decline in proportion to the operating period as the receipt rate is increased. Not included in this calculation are the storage cask costs which vary with peak inventory requirements.

The repository operating costs at a 1,500 MTU/yr receipt rate are about evenly divided between surface operations, underground operations, and site support operations. Surface facility operations costs decline as the receipt rate increases because facility support costs decline. Site support operations also decline as the operating period is reduced with higher receipt rates. There are counteracting effects, however, with respect to the underground operations. Mining costs tend to be increased as the receipt rate increases because younger and hotter wastes are received and these require more mined area for heat dispersal. However, mining costs tend to fluctuate as the receipt rate increases because of varying utilization efficiency of operating crews; i.e., it depends on where the break points occur when the number of operating shifts need to be increased.

REPOSITORY-ONLY SYSTEM RESULTS

For a Repository-Only System starting up in the year 2010, the total system costs decline continuously up to a receipt rate of 6,000 MTU/yr. There is no identifiable minimum-cost receipt rate, although the rate of cost decline is quite steep up to 4,500 MTU/yr and relatively modest between 4,500 MTU/yr, where the total system cost is \$10.6 billion, and 6,000 MTU/yr, where the total system cost is \$10.0 billion. Cost reduction prospects for receipt rates above 6,000 MTU/yr appear to be small.

These results are plotted in Figure 1, which also shows how the component costs change with receipt rates. The cost of maintaining storage at shutdown reactors is the major influence on the overall total system cost trend. The repository costs are reduced from \$7.6 billion at a 1,500 MTU rate to \$6.4 billion at 4,500 and to \$6.3 billion at 6,000 MTU/yr. The principal reason for this reduction is reduced site support costs resulting from a shorter operating period at the higher rates. At-reactor dry storage costs are reduced only slightly at the higher rates, \$1.3 billion at a receipt rate of 6,000 MTU/yr compared to \$1.4 billion at 1,500 MTU/yr. This cost is reduced only minimally because dry storage requirements at most reactors are maximized if acceptance is delayed beyond 2010, leaving very little room for higher

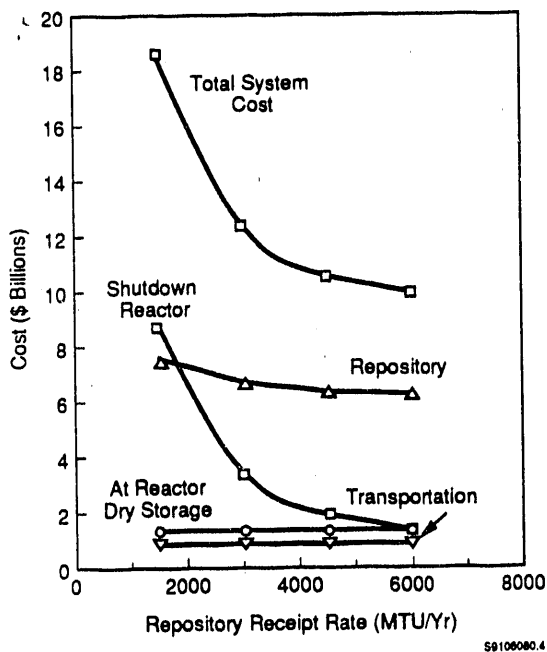


Fig. 1 System costs for a 2010 repository-only system (costs are in undiscounted 1990 dollars)

acceptance rates to reduce these requirements. Transportation costs increase from \$860 million at 1,500 MTU/yr to \$960 million at 6,000 MTU/yr, due to the cost of buying and maintaining larger transport cask fleets as the receipt rate is increased.

For a repository startup in 2015 compared to 2010, the principal change is a \$1.0 to \$1.3 billion increase in the cost of maintaining storage at shutdown reactors. The reduction in total system costs between 4,500 MTU and 6,000 MTU/yr is increased to approximately \$0.8 billion, thus increasing the incentive for the higher rate and giving a stronger indication of possible cost incentives for even higher rates. At-reactor dry storage costs are increased slightly, but transportation and repository costs are essentially the same as for the 2010 startup case.

Because the expenditures for this system are incurred over about an 80-year period, it is of interest to consider the present worth of these costs. A calculation of real yield (net after inflation) on government securities over the period from 1962 to 1986⁽⁹⁾ has shown annual real interest rates ranging from less than -3% to greater than 8% depending on the time period and the length of investments. When averaged over the entire 25-year time period, however, the average annual yield ranges between 1% and 2%. For this reason, the conclusions of this study are, for the most part, based on undiscounted costs. Discount rates of 3% and 5% were used here to illustrate 1) the effect of calculating present-worth system costs discounted to 1990 and 2) the effect on the cost trends of using yields greater than the historical average. A single "correct" discount rate cannot be defined, but in evaluating results of this analysis the effect of discounting should be considered.

The present-worth total system costs for the 2010 repository-only case are compared in Figure 2 to the undiscounted total system costs. This shows the cost curve to be significantly flattened because the shutdown reactor costs occur relatively later than most other costs.

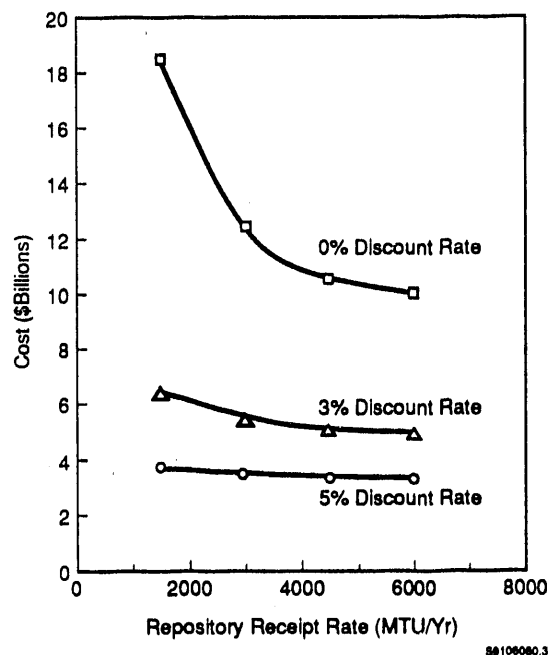


Fig. 2 Effect of discounting on total system costs for 2010 repository-only system

The 2015 repository-only total system costs are \$1.0 to \$1.4 billion higher than the 2010 case due to increased reactor shutdown storage costs. However, discounted costs are about the same or slightly lower (up to \$200 million) since the cost savings from delaying the repository 5 years offset the added shutdown reactor costs when costs are discounted.

SYSTEM COSTS WITH AN UNCONSTRAINED-STORAGE MRS

Analysis of the cost trends in the MRS System is a more complex task than the repository-only system. System costs were first determined over the four MRS receipt rates for each repository receipt rate separately. The minimum system cost at each of the four separate repository receipt rates was then plotted against repository receipt rate to select the overall minimum system cost and associated MRS and repository receipt rates.

Not all combinations of MRS and repository receipt rates can be sustained for delivery of the entire 63,000 MTU of spent fuel because of either reactor or MRS inventory limitations. With a 1998 MRS startup, a receipt rate higher than 3,500 MTU/yr cannot be sustained because it is limited by the availability of eligible 5-year-old spent fuel stored at the reactors. This limits inventory accumulation at the MRS to about the same quantity as with a 3,500 MTU/yr rate. This in turn prevents achieving further benefit from a higher MRS receipt rate, i.e., further reductions in reactor storage requirements cannot be realized. When deliveries to the MRS are stretched out due to reactor inventory limitations, this does not increase the operating life or operating costs of the MRS because these are limited by the removal rate to the repository. In contrast, when the repository receipt rate is limited by available MRS inventory, this lengthens the operating life of both the MRS and the repository and consequently increases the life-cycle operating costs of both facilities.

An example plot of the MRS system costs for a 1998 MRS and 2010 repository case is shown in Figure 3 for a repository receipt rate of 3,000 MTU/yr.

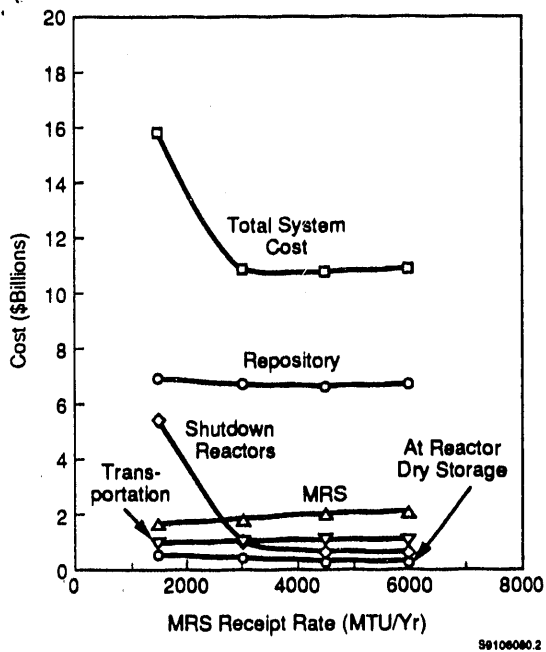


Fig. 3 MRS system costs for a 1998 MRS with a 2010 repository at a 3000 MTU/yr repository receipt rate

Results appear similar to the repository-only system plot except that MRS costs have been added and the total system cost curve flattens out beyond about 3,500 MTU/yr. This is because both the reactor dry storage and the shutdown reactor inventories have reached a minimum while the MRS costs are gradually increasing due to increasing storage inventory and scaled-up capital costs. Both dry storage and shutdown reactor storage costs are reduced more than for the repository-only case.

The total system costs over the MRS receipt rate range for each of the four repository receipt rates are plotted in Figure 4. At each of the four repository receipt rates, minimum system costs are achieved at about a 3,500 MTU/yr rate to the MRS for the reasons discussed above. This same figure also shows the total system costs for the repository-only system from Figure 1. It is of interest to note that the minimum cost 1998 MRS/2010 repository system case achieves almost the same total system cost (\$10.1 billion) as that achieved in the minimum cost 2010 repository-only case (\$9.96 billion). This demonstrates how the more economical spent fuel storage achieved with a large MRS inventory can offset the added transportation and MRS costs when an MRS with unconstrained storage limits is included in the waste management system.

The minimum total system costs from Figure 4 are plotted in Figure 5 and show the lowest costs at a repository receipt rate of 6,000 MTU/yr. Once again, MRS-repository systems are shown to have lower total system costs, for the most part, than repository-only systems across the range of receipt rates. Discounted total system costs at 3% and 5% discount rates are also shown in Figure 5 and indicate that system costs are slightly lower for the repository-only system (about \$0.3 billion) at the minimum-cost 6,000 MTU/yr receipt rate. However, the substantial relief to at-reactor storage requirements provided by an MRS would more than compensate for this slightly higher cost.

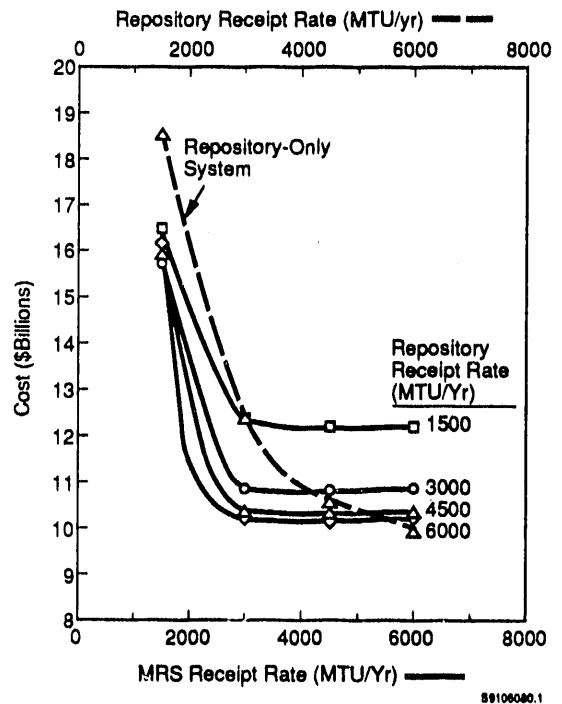


Fig. 4 Total system costs for a 1988 MRS and a 2010 repository as a function of both MRS and repository receipt rates

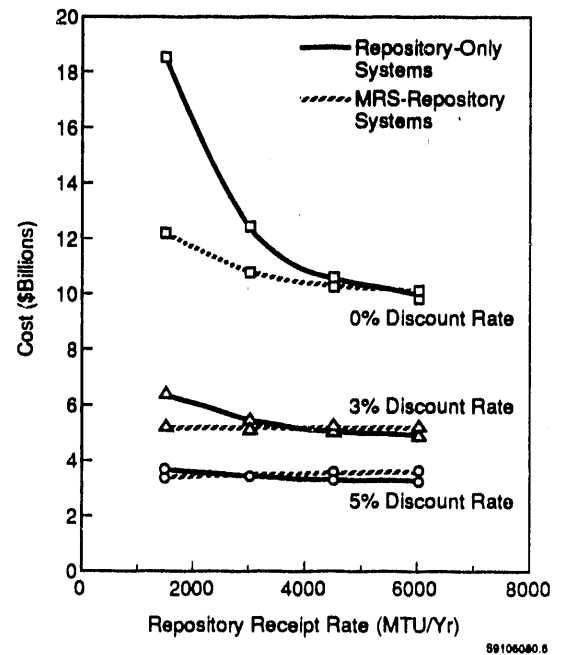


Fig. 5 Minimum total system costs at three discount rates for a 1998 MRS and a 2010 repository

In the case of a 1998 MRS and a 2015 repository (i.e., repository startup delayed 5 years), the system costs and cost trends are very similar to the 1998 MRS/2010 repository cases. Costs are a little higher (\$0.2 to \$0.4 billion) because a somewhat larger inventory accumulates at the MRS without an offsetting reduction in at-reactor storage costs. Minimum costs as before are achieved at an MRS rate of about 3,500 MTU/yr and a repository rate of 6,000 MTU/yr. The discounted costs are a little lower (\$0.2 to

\$0.3 billion) because of the present-worth cost advantages gained from delaying the repository by 5 years.

A comparison of the 1998 MRS/2015 repository systems with the 2015 repository-only systems reveals that the MRS-repository systems are now lower cost throughout the range of receipt rates. In fact, the minimum cost systems, in which the repository receipt rate is 6,000 MTU/yr, shows that the total system cost for the MRS-repository system is about \$0.6 billion less than that for the corresponding repository-only system. Once again, this trend is reversed when costs are discounted. As mentioned previously, however, the benefits that an MRS provides in terms of reduced at-reactor storage requirements would compensate for this slightly higher cost.

Delayed MRS Startup

When the MRS startup is delayed until 3 years before the repository startup, a major portion of the storage cost benefits are forfeited. This delay would allow for the construction licensing of the repository prior to MRS startup as required by the Waste Policy Amendments Act of 1987. Two cases were evaluated, a 2007 MRS/2010 repository combination and a 2012 MRS/2015 repository combination.

In these cases, the lowest costs result when both the MRS and the repository operate at 6,000 MTU/yr. There is less reduction in at-reactor dry storage costs compared to a 2010 repository-only system for a 2007 MRS/2010 repository and essentially no reduction in at-reactor dry storage costs compared to a 2015 repository-only system for a 2012 MRS/2015 repository. Shutdown reactor costs are reduced substantially compared to the repository-only cases but do not reach the same minimum costs as do the 1998 MRS cases. An example plot of the 2007 MRS/2010 repository system cost components and total system costs is shown in Figure 6 as a function of MRS receipt rates for a 6,000 MTU/yr repository receipt rate.

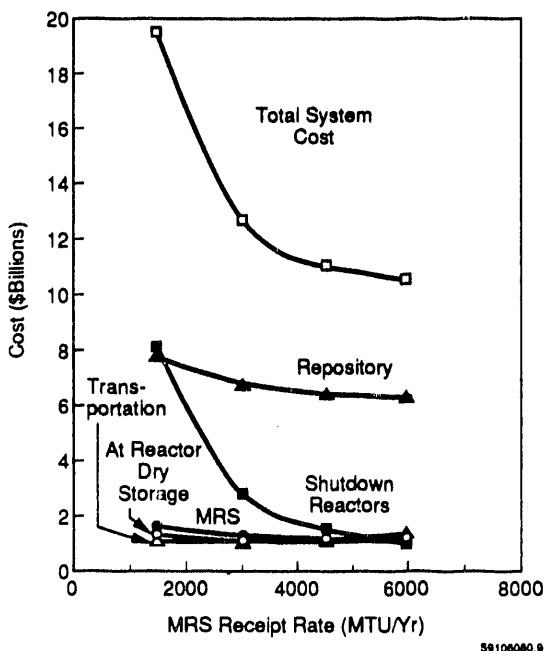


Fig. 6 MRS system costs for a 2007 MRS with a 2010 repository at a 6,000 MTU/yr repository receipt rate

The total system costs as a function of MRS receipt rates are plotted for the 2007 MRS/2010 repository case in Figure 7 for all four repository receipt rates. In all cases, the lowest costs are indicated at a 6,000 MTU/yr MRS receipt rate and the 6,000 MTU/yr repository receipt rate shows the lowest overall costs. This figure also shows the 2010 repository-only system cost curve for comparison. In this instance, the repository-only system has lower total system costs than the MRS-repository systems throughout the entire range of receipt rates. This suggests that if the startup of the MRS is delayed until 2007, there is little advantage to including an MRS in the system. Discounting the costs further widens this disadvantage.

Total system costs for the 2012 MRS/2015 repository (i.e., repository and MRS both delayed 5 years) are between \$1.2 and \$1.7 billion higher than for the 2007 MRS/2010 repository primarily because shutdown reactor costs are not reduced as much.

Total MRS System Cost Comparisons

As a final summary comparison of the unconstrained-storage MRS system costs, the total system costs for each of the four MRS/repository startup combinations for a 6,000 MTU/yr repository receipt rate are plotted as a function of MRS receipt rate in Figure 8. Also included in the lower portion of the figure is a plot of peak MRS inventory for each case which indicates how the MRS inventory influences the total system cost curve.

SYSTEM COSTS WITH A CONSTRAINED-STORAGE MRS

Analysis of the cost trends for the constrained-storage MRS configuration used the same approach as was used for the unconstrained-storage MRS configuration. Constrained, in this instance, refers to a storage-capacity constrained MRS as per the NWPAA.

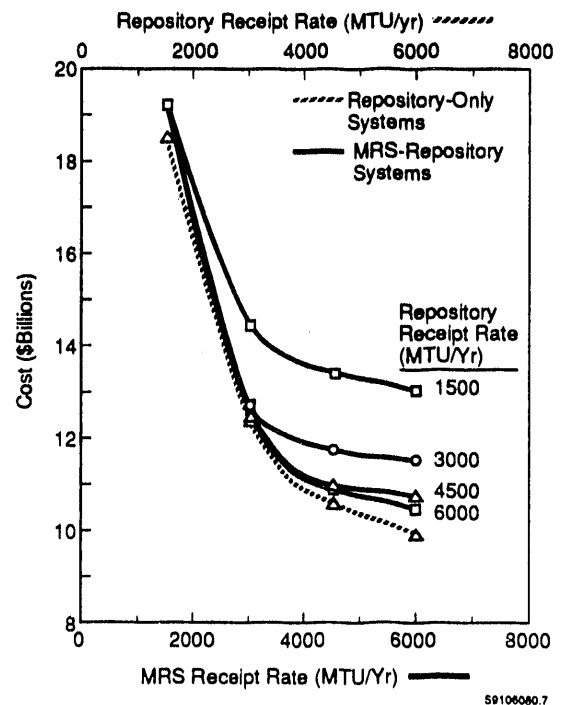


Fig. 7 Total system costs for a 2007 MRS and a 2010 repository as a function of both MRS and repository receipt rates

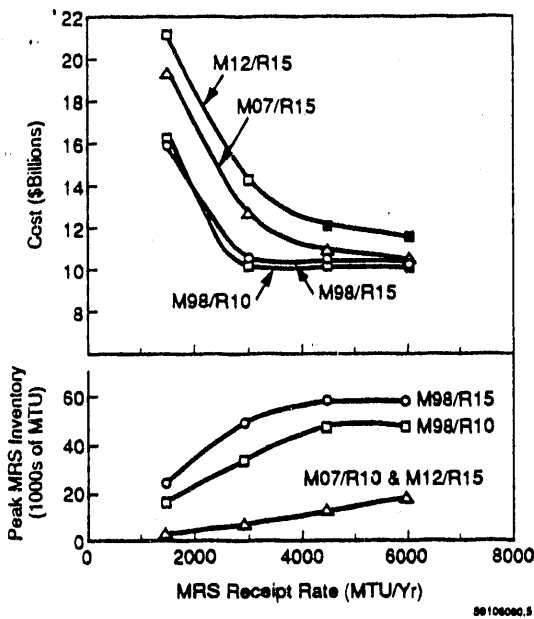


Fig. 8 Total system costs and peak MRS inventories for four MRS system cases

System costs were first determined over the four MRS receipt rates for each repository receipt rate separately. The minimum system cost of each of the four separate repository receipt rates was then plotted against repository receipt rate to select the overall minimum system cost and associated MRS and repository receipt rates. As with the unconstrained MRS configuration, this procedure was conducted for a 1998 MRS, 2010 repository system and then repeated for systems in which the MRS was delayed to 2007 and 2012 and for systems in which the repository was delayed to 2015.

The results of this analysis indicate that with constrained storage the minimum cost system, for all combinations of receipt rates, is one in which both the MRS and repository operate at 6,000 MTU/yr. The total system cost for the corresponding 1998 MRS/2010 repository system is about \$0.4 billion higher than the minimum cost 2010 repository-only system.

Results from the constrained MRS cases with repository delay are similar to those for the unconstrained MRS cases and are not presented here.

OVERALL SUMMARY COMPARISONS

An overall summary comparison of results for a repository-only system with both a storage-constrained and unconstrained MRS system is shown in Table 4 for a 2010 repository and 1998 MRS startup conditions. Results are compared in terms of peak at-reactor storage requirements and overall system costs. The upper half of the table shows results at minimum cost receipt rates, and the lower half shows results obtained when receipt rates at both the MRS and repository are fixed at this current design basis 3000 MTU/yr.

This table shows that the constrained-storage MRS provides a substantial reduction in both peak at-reactor day storage requirements and peak shutdown reactor storage requirements at a net system cost increase of approximately \$0.4 billion. This savings in at-reactor storage requirements is even larger with an unconstrained MRS at a net system cost increase of only about \$0.1 billion. The table also shows that

Table 4 Comparison of at-reactor storage requirements and system costs for 1998 MRS and 2010 repository systems

Scenario Assumption	Peak At-Reactor Dry Storage Inventory (MTU)	Peak Shutdown Reactor Storage Inventory (MTU)	Total System Cost (\$10 ⁹)
Comparisons at Minimum-Cost Receipt Rates			
Without an MRS	13,300	13,000	10.0
With an MRS; With Storage Constraints	7,000	8,500	10.4
With an MRS; Without Storage Constraints	2,500	2,800	10.1
Comparisons at 3000 MTU/yr Receipt Rates			
Without an MRS	14,000	18,500	12.4
With an MRS; With Storage Constraints	7,200	13,200	12.3
With an MRS; Without Storage Constraints	2,800	5,700	10.9

both at-reactor storage requirements and total system costs are significantly lower for all three system configurations when operated at the higher minimum-cost receipt rates compared to operating at the current design basis 3000 MTU/yr.

CONCLUSIONS

Receipt rates higher than the current 3,000 MTU/yr planning base appear to be economically justified for both the repository and an MRS.

For a repository-only system, assuming the system to include just the at-reactor dry storage requirements, the transportation facilities, and the repository, a modest cost advantage of approximately \$0.4 billion is indicated for increasing receipt rates from 3,000 to 6,000 MTU/yr. However, when the costs of maintaining spent fuel storage at shutdown reactors are also included as a part of the system costs, the cost reduction is increased to \$2.4 billion for a 2010 startup and to \$2.8 billion for a 2015 startup. Since costs are still declining at a 6,000 MTU/yr receipt rate, a minimum-cost receipt rate was not identified. However, the shape of the cost curve indicates relatively modest cost reductions for receipt rates above 6,000 MTU/yr.

When a storage-only MRS is included in the system, minimum system costs are also achieved at a repository receipt rate of 6,000 MTU/yr. However, the MRS receipt rate for minimum system costs depends on both the MRS startup date and whether or not the storage capacity of the MRS is constrained.

When an unconstrained MRS is started up in 1998, this provides an opportunity for acceptance of

substantial quantities of spent fuel prior to repository startup and for greater reductions in both at-reactor dry storage and shutdown-reactor storage requirements. The minimum-cost receipt rate for either a 2010 or a 2015 repository is about 3,500 MTU/yr. Higher receipt rates cannot be sustained because of limited availability of 5-yr-old spent fuel at the reactors. Although the cost of providing higher receipt rate capability at the MRS is not large, there appears to be no advantage in providing for it for a 1998 startup.

With a 1998 unconstrained MRS receiving spent fuel at 3,500 MTU/yr and a 2010 repository receiving spent fuel at 6,000 MTU/yr, the peak MRS inventory is about 40,000 MTU. This provides economical replacement storage for both at-reactor dry storage requirements and shutdown-reactor storage requirements. For this reason, the added cost of providing the MRS is offset by at-reactor storage cost reductions and the total system cost of \$10.1 billion is only slightly higher than the repository-only system cost of \$10.0 billion.

If repository startup is delayed until 2015 with a 1998 unconstrained MRS, minimum costs are also found at an MRS receipt rate of 3,500 MTU/yr and a repository receipt rate of 6,000 MTU/yr. The peak MRS inventory is increased to about 57,000 MTU. The total system cost of \$10.4 billion is about a \$0.6 billion savings compared with the \$11.0 billion cost for the repository-only system with a 2015 repository startup.

When the MRS startup is delayed until 3 years before the repository, spent fuel availability from the reactors is not a limitation and receipt rates up to 6,000 MTU/yr can be maintained without any problem. Minimum costs are achieved with a 6,000 MTU/yr receipt rate at both the unconstrained MRS and the repository. With only a 3-year lead on the repository startup, the peak inventory in this case is limited to 18,000 MTU. Thus, the storage cost savings compared with the repository-only cases are significantly reduced. A large part of the MRS construction and operation costs is, however, offset by storage cost savings. The minimum cost for a 2007 MRS/2010 repository combination is \$10.5 billion and for a 2012 MRS/2015 repository combination is \$11.6 billion.

If the MRS storage capacity is constrained according to the NWPAA, the MRS storage inventory is restricted to a maximum of 15,000 MTU. This reduces but does not eliminate the advantages of having an MRS in the system. The minimum-cost receipt rate for both the MRS and repository is 6,000 MTU/yr. The total system cost for a 1998 constrained MRS/2010 repository system is about \$10.4 billion. This is about \$0.3 billion higher than the corresponding 1998 unconstrained MRS/2010 repository system and about \$0.4 billion higher than the 2010 repository-only system.

These conclusions have been based on undiscounted costs. When costs are compared on a discounted present-worth basis, the cost advantage of higher rates tends to be diminished. However, since the long-term inflation adjusted cost of money to the government has historically been only on the order of 1% to 2% per year, it is not clear how much significance should be attached to this result. Even if there are zero cost advantages for higher receipt rates, there is still the advantage of a substantial reduction in at-reactor storage requirements with

increased receipt rates. Furthermore, the initial construction cost to provide higher receipt rate capability is relatively small (see Table 3). The major MRS facility costs result from storage cask purchases and these are purchased as needed. Thus, there is not a large initial investment cost consideration.

The economic benefits indicated here for an MRS and for increased receipt rates are dependent on projected storage costs at shutdown reactors. If reactors are granted life extensions by the NRC, these costs would not develop until much later. However, if these higher rates are utilized, results of this analysis indicate relatively small or no cost penalties if shutdown reactor storage costs do not materialize and large savings if they do materialize. Thus, increased facility capacities can probably be justified on the basis of added flexibility.

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