THE ECONOMICS OF RADWASTE VOLUME REDUCTION STRATEGIES

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ABSTRACT

A recently concluded EPRI study has generated much of the information needed by utilities when they consider the purchase of volume reduction equipment. This paper presents some of the study's results on volume reduction economics.

The paper contains two types of results. The first is a detailed look at the economics of fourteen equipment options at a hypothetical reactor station. Costs were calculated with VRTECH, a radwaste economics computer program developed by TASC. This analysis illustrates the major points of the project conclusions. Second, the effects of the major assumptions used in the hypothetical case are examined. This analysis shows that the radwaste generation rate and the burial cost escalation rate are primary considerations when evaluating the benefit of each option.

INTRODUCTION

Reducing the volume of radioactive waste generally lowers its burial cost. In some cases the resulting savings can pay for the expenses of volume reduction, including the investment in equipment. Cost and the potential for savings are influenced by many factors. The relationships among the cost-determining variables are complicated: a small change in one can alter the interdependence of others. The intricacy of the problem increases further when uncertainties about the future are superimposed on this web of relationships. Ultimately, the projected economic benefit of a volume reduction (VR) process depends on a complex mix of facts and conjectures. Utilities must discover ways to handle these complications when deciding what, if any, VR equipment to purchase. Even when noneconomic factors are the major driving forces, the costs of the available options will influence the decision.

This paper describes the influence of several important factors on the economics of particular VR equipment options. It contains a portion of the results from a major EPRI-sponsored study of volume reduction. Other project team members have already presented their results in Waste Management '83[1,2], and the entire study is being published by EPRI[3]. A utility, when armed with these results and the techniques used to generate them, has most of the information needed to make a VR purchase decision. The other major information element in the decision process, a method for treating uncertainty, is not addressed here.

The remainder of this paper consists of two sections. The first presents the total costs to a hypothetical utility of using each of fourteen VR equipment options. Examination of these costs reveals the major benefits and liabilities of each option. In the second section, these observations are amplified based on the results from the entire EPRI study of volume reduction.

COSTS FOR A HYPOTHETICAL UTILITY

The hypothetical utility has twin boiling water reactors (BWR's) each with a deep bed condensate polishing system (CPS). Their radwaste generation rate is typical of this type of nuclear plant[4]. The radwaste is shipped 800 miles to a burial site that charges the same prices as Barnwell did on January 1, 1983. The chosen VR option will become operational on January 1, 1988, and the processed waste will be stored on-site for an additional five years before shipment. The equipment is expected to operate for thirty years. The utility is considering 14 VR equipment options, including the retention of its present system: a simple compactor, an evaporator and a solidification system that is operating well. (This latter option is referred to as the "no-VR" case.) All other options involve the purchase of new VR equipment that is either retrofitted into existing structures, or placed in a new structure. Table I describes the VR options under consideration.

The sum of all disposal costs for each option is the basis for comparison of the economic benefits. The total is difficult to calculate because various expenses occur at different times. The VRTECH computer program, developed by TASC, handles this problem for volume reduction economics by incorporating the time value of money in the calculation of VR expenses. The program calculates the total cost for each expense and expresses it in dollars at a reference date, in this case December 1982. These costs are summed to yield the present value of revenue required (PVRR) for the equipment lifetime. The total PVRR is the amount of money that would yield sufficient revenue to pay for all disposal costs during the equipment operating

TABLE I

VOLUME REDUCTION OPTIONS

100%

CASE NO.	VR TECHNOLOGY	RETROFIT OR NEW STRUCTURE	SOLIDIFICATION AGENT
0	No-VR	-	Cement
1	High-Pressure Compactor	Retrofit	-
2	Forced-Air Incinerator	New	-
3	Fluid-Bed Dryer/Incinerator (No Resin Incinerated)	New	Dow
4	Evaporator Crystallizer	Retrofit	Dow
5	Evaporator Extruder	Retrofit	Bitumen
6	Evaporator Extruder	New	Bitumen
7	FB Dryer/Incinerator plus Evaporator Crystallizer	New	Dow
8	FB Dryer/Incinerator plus Evaporator Extruder	New	Bitumen
9	FA Incinerator plus Crystallizer plus Extruder	New	Bitumen
10	Mobile Incinerator	New	-
11	Ultra High-Pressure Compactor	Retrofit	-
12	Fluid-Bed Dryer/Incinerator (Resins Incinerated)	New	Dow
13	Mobile Evaporator	New	Bitumen

life, if invested at the end of 1982, the data when the project was initiated. An option with a lower PVRR is less expensive to operate over its thirty year lifetime.

VRTECH requires two kinds of inputs before it can determine the PVRR. The first describes the costs and operating characteristics of the VR equipment. This information was developed by Burns and Roe, Inc. for the EPRI project. It also requires economic inputs. For the hypothetical case, the inflation rate is 8.5%; all costs except burial escalate at that rate. The escalation rate for burial is 15%. The cost of money to the utility is 12.5%, and its fixed charge rate is 0.2.

Table II shows the total PVRR and its major components for the 14 VR options at the hypothetical utility. The table displays the costs for: operations which includes the labor and consumables necessary to operate and maintain the equipment, and to drum the processed waste; transportation which includes trucks, vans and casks; burial including dry and wet wastes; total operating expenses which are the sum of the operating, transportation and storage costs; and the capital expenditures for the storage facility, as well as for all capital needed to purchase, engineer and house the VR equipment. These latter capital expenditures are labelled "construction" in the table.

The no-VR case sets the context for the analysis: 75% of the total cost is for burial of the waste, with 45% being for wet waste and 30% for dry. Reductions in burial costs are obviously the major opportunity for savings.

In Case 1, the high-pressure compactor can be retrofitted into the plants inexpensively. The resulting savings of $10M are more than forty times its cost. The reductions in operations, storage or dry-waste burial are each more than sufficient to repay the investment. This option carries a very low risk: the technology is relatively simple and dependable. Moreover, savings in the first year of operation are enough to cover the capital requirements.

The forced-air incinerator (Case 2) burns compactible trash; the waste volume reduction is much better than with the high-pressure compactor. It produces savings of $24M at the burial site, and $2M in storage costs. However, the incinerator is expensive to purchase and install. Consequently, the compactor has a smaller PVRR.

The fluid bed dryer/incinerator is considered in both Case 3 and Case 12. In the former, it incinerates compactible trash and dries concentrated liquids; in the latter, it incinerates resins as well. The projected economic performance is better when resins are also processed. In either case, the technology

TABLE II

COSTS FOR TWIN BWRs
(HYPOTHETICAL CASE)

PRESENT VALUE OF COSTS (MILLIONS OF DEC. 1982 DOLLARS)

VR CASE	TOTAL OPERATING COSTS	TRANSPORTATION COSTS	BURIAL COSTS			TOTAL EXPENSES	CAPITAL COSTS		TOTAL PVRR
			DRY WASTE	WET WASTE	TOTAL		STORAGE	CONSTRUCTION	
0. No-VR	17.6	30.2	69.1	108.3	177.3	225.1	10.2	0	235.2
1. Compactor (R)	16.5	30.1	60.6	108.3	168.8	215.4	9.5	0.2	225.1
2. Incinerator	18.6	29.6	45.0	108.3	153.3	201.4	8.1	19.0	228.5
3. FB Incinerator	21.5	27.2	45.0	80.1	125.1	173.8	6.5	33.5	213.8
4. Evap Cryst (R)	22.8	29.4	69.1	90.7	159.8	212.0	9.1	6.0	227.0
5. Evap Extr (R)	15.7	22.3	69.1	49.9	119.0	157.0	7.1	11.9	175.9
6. Evap Extr	15.7	22.3	69.1	49.9	119.0	157.0	7.1	13.6	177.6
7. FB Inc + Evap Cryst	22.7	27.2	45.0	80.1	125.1	174.9	6.5	40.4	221.8
8. FB Inc + Evap Extr	17.9	21.7	45.2	49.9	95.1	134.7	5.0	35.5	175.2
9. Incin, Cryst + Extr	16.1	21.7	45.2	49.9	95.1	132.9	5.0	40.3	178.3
10. Mobile Incinerator	15.8	29.6	44.6	108.3	152.9	198.3	8.0	3.7	210.0
11. Super Compactor (R)	14.4	24.6	32.9	108.3	141.2	180.2	8.2	5.2	193.6
12. FB Resin Incin	21.8	23.6	45.0	64.3	109.3	154.7	5.8	36.1	196.6
13. Mobile Evaporator	18.9	26.9	69.1	79.9	148.9	194.7	8.4	5.2	208.3

Note: (R) denotes retrofit.

is expensive to install, and it increases operational costs. Transportation and storage costs are reduced, but the greatest savings occur in burial. In both cases, dry-waste burial costs are reduced by $24M, wet-waste costs are lowered by $44M if resins are burned, and $28M if they are not. If resins are processed, the expected savings over the no-VR case approaches the purchase price, but most of these savings accrue near the end of the equipment lifetime.

Only concentrated liquids are processed with the evaporator crystallizer, Case 4. The volume reduction ratio is relatively low, and the product is solidified with DOW binder which is very expensive ($260/drum). Consequently, the crystallizer has the highest inplant costs of all the options. Nevertheless, it produces an overall savings of $8M by lowering the burial costs by $18M. If a less expensive binder were used, this option might appear more economically attractive even with smaller waste loadings.

The evaporator extruder is considered twice: as a retrofit in Case 5, and in a new structure in Case 6. The added cost of the new structure is approximately $2M. The extruder processes resins, liquids and sludges. It produces substantial savings in all expense categories, and is the only option that can totally pay for itself with savings in operations, transportation and storage. $58M is saved at the burial site. The extruder has the smallest total PVRR of all the options considered; it returns its investment within two years.

The mobile incinerator, Case 10, is used to burn compactible trash. It combines the excellent volume reduction of the other incineration systems with a low purchase price. Burial costs are reduced by $16M at an initial cost of only $4M. The payback period on this equipment is fairly short, and for this reason the mobile incinerator is a very attractive option.

The super compactor, Case 11, is the only equipment that processes both compactible and non-compactible trash. Consequently, it has the lowest dry-waste burial cost of any of the VR options. Like the mobile incinerator, the initial investment is fairly low, and the payback period is short.

Case 13 is the mobile evaporator which processes resins and concentrated liquids. The $5M initial investment is the smallest of the wet-waste processors. Although burial cost reductions are almost six times the purchase price, total savings are substantially less than for the extruder.

Cases 7 through 9 are equipment combinations. The two options with extrusion of the wet waste are economically very beneficial. But in each case, the combination is less attractive than the extruder alone because the incinerators are too expensive to be used for trash only. The combination of the extruder and one of the compactors would be much more economically attractive.

In summary, four of the VR options process dry waste only: the super compactor reduces the volumes of both compactible and non-compactible trash; the high-pressure compactor, the forced-air incinerator and the mobile incinerator operate on compactible trash only. The forced-air incinerator is much more expensive than the other dry-waste technologies, and cannot produce enough savings to overcome this disadvantage. The high-pressure compactor produces much smaller savings than the others, but it is so inexpensive to purchase that it becomes a low-risk choice. The mobile incinerator costs about $4M, but produces $25M in savings. The super compactor is even better: it saves $42M at a cost of only $5M. The economics of the incinerators would likely improve if the combustible portion of the non-compactible trash were segregated and then incinerated.

Four options process only wet wastes: the two extruder configurations, the crystallizer and the mobile evaporator. They are the most economical group because the wet waste burial costs are the largest single expense in the no-VR case. The extruder and the mobile evaporator are more economical than the crystallizer. The latter suffers in comparison because it works on only one waste stream, reduces the volume less well, and uses the more expensive DOW binder. The extruder generates large savings at very modest costs.

The five remaining technologies are used on both dry and wet wastes. The two combination technologies with the extruder perform most economically. However, neither are as good as the extruder alone because the incinerator technologies are too expensive to be limited to processing trash. The crystallizer combination does less well. The fluid-bed dryer/incinerator is most economical when resins are incinerated in addition to the processing of trash and liquids. Pairing an extruder with one of the inexpensive dry-waste options would give better results than any of the options considered.

VOLUME REDUCTION ECONOMICS IN A BROADER CONTEXT

All of the VR options are economically beneficial in the hypothetical case. The EPRI study[3] reveals that VR performs less well in other situations.

For example, Table III displays the present value of costs when twin PWRs replace the BWRs in the hypothetical case. PWRs produce significantly less waste than BWRs: dry-waste volumes are lower by a factor of two; the wet-waste volumes by a factor of seven. As a result, wet-waste burial costs are less than one-half of the dry-waste burial costs. In this case the super compactor is the only option that yields a saving greatly exceeding its purchase price, and the high-pressure compactor is the only option that repays its purchase price within ten years.

The wet-waste technologies are even less economical. The extruder remains excellent at reducing burial costs, but the saving is only approximately equal to its purchase price. Its payback period is more than ten years. The mobile evaporator is the most economical option because of its lower purchase price and its efficiency in handling the boric acid wastes from PWRs.

The highly priced technologies all produce approximately $25M in burial cost savings. Unfortunately, this sum is only a portion of their installed cost.

It is clear from this example that the waste generation rate sets a limit on the economic effectiveness of VR equipment by controlling the potential for savings at the burial site. The burial escalation rate has a similar effect on the potential for savings.

As the burial escalation rate changes, the operations, transportation, and storage costs are unaffected, but the burial costs are altered, often greatly. Figure 1 illustrates this point. It depicts the component costs of the total PVRR for the no-VR case with twin PWRs as the escalation rate varies. The burial

TABLE III

COSTS FOR TWIN PWRs

PRESENT VALUE OF COSTS (MILLIONS OF DEC. 1982 DOLLARS)

VR CASE	TOTAL OPERATING COSTS	TRANSPORTATION COSTS	BURIAL COSTS			TOTAL EXPENSES	CAPITAL COSTS		TOTAL PVRR
			DRY WASTE	WET WASTE	TOTAL		STORAGE	CONSTRUCTION	
0. No-VR	7.8	6.8	35.1	16.2	51.3	65.9	5.0	0.0	70.9
1. Compactor (R)	7.5	6.8	31.2	16.2	47.4	61.7	4.8	0.2	66.7
2. Incinerator	10.2	6.7	23.8	16.2	40.0	56.9	4.4	19.0	80.2
3. FB Incinerator	11.6	6.3	23.8	5.0	28.8	46.7	3.7	33.5	83.9
4. Evap Cryst (R)	8.7	6.7	35.1	7.1	42.4	57.7	4.5	6.0	68.1
5. Evap Extr (R)	9.0	6.2	35.1	3.9	39.0	70.3	4.2	11.9	70.3
6. Evap Extr	9.0	6.2	35.1	3.9	39.0	70.3	4.2	13.6	72.1
7. FB Inc + Evap Cryst	12.4	6.3	23.8	5.0	28.8	47.6	3.7	40.4	91.7
8. FB Inc + Evap Extr	12.2	6.1	24.0	3.9	27.8	46.1	3.6	35.5	85.1
9. Incin, Cryst + Extr	11.7	6.1	24.0	3.9	27.8	45.6	3.6	40.3	89.5
10. Mobile Incinerator	8.4	6.7	23.6	16.2	39.7	54.7	3.7	4.3	62.7
11. Super Compactor (R)	7.0	3.7	15.2	16.2	31.4	42.1	4.2	5.2	51.5
12. FB Resin Incin	11.9	6.1	23.8	2.6	26.4	44.4	3.4	36.1	83.9
13. Mobile Evaporator	8.2	6.6	35.1	5.4	40.6	55.4	4.3	5.2	64.9

Note: (R) denotes retrofit.

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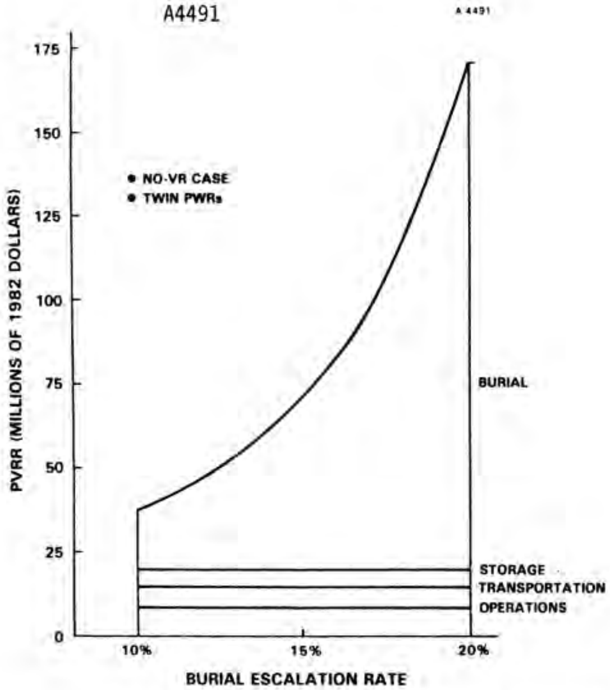

Figure 1 Effect of Burial Escalation Rate on Total PVRR

costs are less than one-half of the total for a 10% escalation; they grow to almost nine-tenths of the total for a 20% rate.

Table IV displays the total PVRR for all of the VR options in the twin PWR case for burial escalation rates of 10, 15 and 20 percent. With a 10% escalation rate, the no-VR case is very nearly the least expensive, and only the super compactor generates an appreciable saving. At 15%, about one-half of the VR technologies produce savings; for three of them the cost

TABLE IV

VARIATION OF DISPOSAL COSTS WITH THE BURIAL ESCALATION (TWIN PWRs)

VR CASE	TOTAL PVRR (MILLIONS OF DEC. 1982 DOLLARS) ESCALATION RATE		
	10%	15%	20%
0. No-VR	38.1	70.9	170.0
1. HP Compactor	36.4	66.7	157.9
2. FA Incinerator	54.6	80.2	157.1
3. FB Dryer/Incinerator	65.5	83.9	139.3
4. Evaporator Crystallizer	41.0	68.1	149.6
5. Evaporator Extruder	45.3	70.3	145.3
6. Evaporator Extender	47.1	72.1	147.1
7. FB Dry/Incinerator plus Crystallizer	73.3	91.7	147.1
8. FB Dry/Incinerator plus Extruder	67.3	85.1	138.5
9. FA Incinerator plus Crystallizer plus Extruder	71.7	89.5	142.9
10. Mobile Incinerator	37.3	62.7	139.0
11. Super Compactor	31.4	51.5	111.9
12. Resin Incinerator	67.0	83.9	134.6
13. Mobile Evaporator	38.9	64.9	143.3

reductions are large enough to make purchase a reasonable action. When the escalation rate increases to 20%, the PVRR of every technology option is at least $12M lower than that of the no-VR case.

The critical importance of the burial escalation rate is troublesome to utilities when they attempt to make decisions about what, if any, VR option to purchase. Prediction of the future is always difficult, especially when one must account for complex interactions among all levels of government, the public at large, and private business concerns. Eventually, a utility must deal with this uncertainty both to make a decision and to defend the inclusion of the costs in the rate base.

The EPRI volume reduction study confirms the importance of the waste generation rate and the burial escalation rate in VR economics. In general, these two factors control burial costs, and thereby determine how effective VR can be at reducing expenses. Whenever large volumes of waste are generated, or the costs of burial are rising quickly, volume reduction is likely to produce substantial savings.

However, when waste volume is lower or the escalation rate is smaller, other variables can become important. In particular, some options can effect large enough reductions in the costs of operations, transportation or storage to repay a large portion of their purchase price (for example the extruder in the hypothetical case). Additionally, when burial costs are reasonably low, general economic conditions such as the cost of money to the utility or the general inflation rate assume increased importance. The EPRI study[3] contains complete details of the sensitivity of VR economics to changes in these variables.

In summary, when a utility attempts to decide whether to buy volume reduction equipment, it must consider a mix of fact and conjecture that leads to an estimate of the economic consequences of purchase. The information assembled by the EPRI project can assist in this task. In addition to creating an equipment data base and specialized economic computer programs, the project has also examined the major variables that affect the calculations, and has identified the most important variables in the decision process. The radwaste generation rate and the burial escalation rate are the dominant variables in VR economics because they jointly determine the cost of waste burial, the largest element in disposal expenses. If burial costs are small, then savings in operation, transportation or storage costs, as well as the general economic conditions assume greater importance in making VR purchase decisions.

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