PROJECTION OF FUTURE WASTE QUANTITIES IN THE MIDWEST COMPACT REGION

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ABSTRACT

An important factor in developing the Midwest Compact's management plan is how current waste generation rates will change in the future. Projections were made to the year 2015, using 1985 as a base year. Because of data limitations, waste projections were limited to waste volumes only. The data base on the nuclide content of waste generated in the Midwest Compact Region has a high degree of uncertainty, and it was decided that projections of these data would compound the uncertainty, so no estimates were made of future waste activity levels. The waste volume projections were based on three major categories of variables: (1) technical variables, (2) economic variables, and (3) institutional/social variables. Further, projections were developed for three scenarios: (1) high estimate, (2) most probable estimate, and (3) low estimate. Under the most probable scenario, in 2015 an estimated total (reactor plus non-reactor) of 220,000 cubic feet of low-level waste will be shipped. Reactor and non-reactor wastes will comprise about 71 percent and 29 percent, respectively, of the total volumes for 2015. However, beyond the year 2015 reactor decommissioning will begin to cause regional waste volumes to increase considerably.

INTRODUCTION

The Midwest Interstate Low-Level Radioactive Waste Compact region includes the states of Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. In discharging its responsibilities under the 1980 Low-Level Waste Policy Act and the 1985 Amendments, the Midwest Compact Commission developed a Regional Management Plan.

One component of that plan assessed LLW characteristics and developed waste projections to the year 2015. This 30-year period is approximately when the first regional disposal facility would be in operation (1). The methodology of developing projections and results of those projections are described in this paper. The projections here are rooted in the 1985 data base (2). At the time this paper was prepared, the Commissionsion was resurveying selected generators, which may alter these volumes and percentages.[a]

LOW-LEVEL WASTES INCLUDED IN PROJECTIONS

The universe of LLW encompasses all wastes listed in the Midwest Compact data base. Waste from commercial nuclear power plants and waste from other industries and institutions are included. Low-level wastes from commercial power plants were projected separately from wastes of non-reactor origin. In addition, LLW from decommissioning power reactors were counted. While the timing and techniques to be used in decommissioning existing commercial reactors have not been clearly defined, certain assumptions were made in the projections based on existing decommissioning literature and interviews with industry personnel.

Institutional, and industrial wastes were handled as a single group for the purpose of these projections. Wastes from Federal installations were grouped with institutional and industrial wastes because they reflect similar types of wastes, e.g., VA hospital wastes and and wastes from non-weapons research-related activities.

A number of potential LLW sources were excluded. The six former Manhattan Engineering District Atomic Energy Commission sites in the Midwest Compact region, which have been identified by the U.S. Department of Energy (DOE) under its Formerly Utilized Sites Remedial Action Program (FUSRAP), were excluded. Also, the two DOE facilities under the Surplus Facilities Management Program, which provides for decommissioning 500 DOE-owned or -operated radioactively contaminated surplus facilities, were not counted.

Another future source of LLW not included in the Compact's data base is from decommissioning of research, training, and test reactors. These reactors are much smaller than commercial power reactors and their waste quantities would not be significant on a relative basis.

Low-level wastes from future decommissioning of institutional and industrial accelerators were also excluded and are not likely to be significant in the long-term projections for the Midwest Compact region; nor are occasionally found wastes from contaminated sites where radium was used commercially.

Other possible sources of future LLW not included are two piles of radioactive materials in *Michigan* and radium-contaminated sludges that may accumulate throughout the region in conjunction with the operation of municipal and private drinking waster treatment plants.

VARIABLES AFFECTING WASTE GENERATION

The variables that will affect waste generation and shipment for disposal in the future are technical,

[a]The volume of low-level waste shipped for disposal to the three existing disposal facilities in 1986 dropped dramatically on a nationwide basis. This has raised questions as to what is happening in waste disposal, e.g., are sizable volumes of certain wastes being stored on-site? Are stronger measures of waste reduction at source and volume reduction being invoked? Are there major changes in the management of institutional wastes?

economic, institutional/regulatory, and social. Each of these had to be considered for projections of the types of waste included. Technical and economic factors are presented here in terms of reactor and non-reactor wastes. Institutional and social variables follow in a separate discussion as they apply broadly.

Technical and Economic Factors

Reactor Wastes. The principal technical factor influencing future waste from nuclear power plants will be decommissioning. Future decisions regarding the techniques and timing of these activities will significantly impact the types and volumes of decommissioning waste requiring disposal early in the 21st century. Commercial reactors currently operate under a 40-year license from NRC. Utilities are investigating what their options might be when their operating licenses expire. Because of the large capital investments required to build today's reactors, utilities may elect to retrofit rather than decommission. Such decisions will obviously be based on considerations other than technical factors, including the demand for power and economic analyses.

Decommissioning waste volumes prior to the year 2000 will be minimal, based on current forecasts. Commercial reactors in the region that could be candidates for decommissioning before the year 2000 are small reactors (less than 100 net MW). The impact of LLW from these reactors should be small compared to waste volumes generated during commercial power production over this time period.

After the year 2000, assumptions regarding the techniques used to decommission plants, i.e., Immediate Dismantlement (DECOM) or Safety Storage Deferred Dismantlement (SAFSTOR), and the timing of these activities are critical variables that will influence waste projections.

Other technical factors that will influence future reactor waste generation and shipment include source reduction practices and installation of advanced volume reduction technologies such as supercompaction and incineration.

Economic considerations are a key variable in forecasting future waste generation from power reactors. Especially in the area of decommissioning, economic factors will play a major role regarding both the timing and techniques used to decommission commercial reactors. Other areas where economic factors may influence waste generation rates include the costs associated with the various waste management options versus measures to reduce waste generation.

Non-Reactor Wastes. Technical factors influencing generation of LLW from industrial, institutional and government activities are associated with three primary methods to minimize the amount of radioactivity and the volume of the wastes: source reduction; storage for decay, and volume reduction.

Source reduction procedures and techniques for minimizing waste generation include:

- o Minimizing the quantities of radionuclides purchased
- o Substitution of short-lived radionuclides
- o Decontamination and recycling (vs. disposal of contaminated equipment)

Waste contaminated with isotopes having short half-lives which can be safely stored for decay can ultimately be disposed of as non-radioactive waste. Storing of suitable radionuclides for ten to twenty half-lives reduces their activity to very low levels. In the medical field, radionuclides are suitable for storage for decay.

Once waste has been generated, procedures and techniques can be employed to minimize the volume requiring disposal; major ones are:

- o Segregation of uncontaminated waste from radioactive waste.
- o Incineration of suitable wastes particularly low activity, high-volume wastes.
- o Mechanical compaction of wastes.

The costs of waste management in the non-reactor sector are becoming more important by influencing waste volumes shipped for off-site disposal. Traditionally in institutional settings, waste management costs have been absorbed as overhead. However, some institutions in the Midwest Compact region are currently passing these costs directly on to the project or department that generates the waste.

Low-level waste generation from industrial, institutional and government sectors will depend on economic growth in general and, more specifically, the growth rate in research and services.

Institutional/Social Factors

Factors of an institutional and/or social nature will also affect the quantities, types and activity levels of future waste streams from all sources within the region. Analyzing these variables, however, is of necessity quite subjective and judgmental. These factors are highlighted below.

Definition of LLW. Low-level radioactive waste continues to elude a definition that is completely acceptable to the public. A redefinition of LLW at the federal level could have a significant impact on future waste types and quantities, but is not factored into present projections.

The Future of Nuclear Power. In making assumptions for the projection of reactor LLW, the issue of the future of nuclear power inevitably arises. A report of the Congressional Office of Technology Assessment (Ref. 3) concluded that unless public trust is restored, nuclear power will not be a credible future energy option. Others, including some leaders in the nuclear industry itself, have voiced similar setiments (4).

What might eventually occur in this scenario will be driven primarily by social, institutional and political attitudes at the time, though technology and economics will be vital ingredients. However, trying to forecast what might occur between 1985-2015 in this area would be highly speculative.

Continual Pressures for Volume Reduction. In technical and economic terms, volume reduction may have a limited influence on continued changes in the amounts and activity of waste generated in the Compact due to extensive volume reduction practices anticipated to be in place by the late 1980s. However, social and institutional factors will continue to exert pressure on generators to further reduce waste by any means available.

Waste Reclassification or Declassification. Waste reclassification or declassification is another institutional factor that always remains a future option for changing waste quantities requiring disposal in a low-level waste facility. The NRC's amendment of 10 CFR 20 in 1981, allowing generators to dispose of specified concentrations of biomedical wastes, ^{14}C and ^{3}H (tritium), as other than LLW was a notable instance which declared certain wastes as below regulatory concern. This change resulted in a substantial reduction of certain biomedical waste streams as LLW.

Utility and industrial generators of LLW also have been urging the NRC to declare certain other waste streams with low concentrations of radionuclides as being below regulatory concern.

Reclassification could change the volume of LLW to be disposed of in the future. However, to attempt to make any meaningful predictions at this time would be premature.

Another regulatory variable involves mixed wastes. The management of these wastes is currently the subject of a jurisdictional dispute between DOE, the NRC, and EPA, and in the Congress over who is to regulate their disposal. Any suitable projection of their characteristics for future disposal in the region's Management Plan should logically await the resolution of the current dispute.

SELECTED WASTE PROJECTION VARIABLES

The previous section outlined the variables that could reasonably be expected to influence future generation of LLW in the Midwest Compact Region. Those variables that will have maximum impact on future projections were selected for use in the waste projections.

Reactor Wastes. As previously noted, decommissioning of commercial reactors will be the biggest contribution to future waste generation. The volume of LLW generated by the decommissioning of a single reactor, comparable in size to the "reference" power reactor could, under the immediate dismantlement option, generate about 635 cubic feet of radioactive waste. For the reference boiling waster reactor approximately 620,000 cubic feet of radioactive waste would be generated. Therefore, decommissioning of a single commercial nuclear reactor could double the volume of radioactive waste generated in the Midwest Compact Region in a single year.

There is a consensus in the nuclear power industry that most reactors will not be decommissioned upon expiration of their present licenses, but will be retrofitted to operate for up to an additional 20 years.

For the purposes of waste projections in this study, the most probable scenario assumes that currently operating reactors, with the exception of Big Rock Point (63 MW) and La Crosse (50 MW), will operate for 60 years beyond the date of initial full-power operation. It was assumed that the two small reactors noted will be decommissioned at the end of their current license.

Non-Reactor Wastes. Projections of non-reactor wastes were based on four factors:

- o Industry segment growth
- o Volume reduction
- o Storage for decay
- o Regulatory changes

Non-reactor wastes in the Midwest Compact region are generated primarily from institutional and industrial segments of the economy. Data indicate that the institutional and industrial sectors generate 14 percent and 12 percent, respectively, of the LLW. Generation of LLW from these industry segments will be based, in part, on the growth rate in research and services. While growth in the institutional and industrial sectors of the economy is the driving force for increased generation of LLW at the source, other factors will moderate this increasing growth in waste volume.

Volume reduction through incineration and mechanical compaction techniques will be the major factor moderating the growth in non-reactor waste. In 1985, the volume of LLW incinerated in the Midwest Compact region was not significant but increased use of incineration would account for substantial reduction in volume.

The effects of mechanical compaction on future volume reduction of non-reactor waste are not as dramatic as incineration might be. This is because major generators of compactible waste in the non-reactor sector are already compacting their waste. If compaction is continued, even with supercompaction, the net reduction is estimated to be less than 2,500 cubic feet/yr. (This assumes that wastes which are also incinerable would be managed by incineration.)

Storage for decay represents another factor that may influence future generation of LLW. Information indicates that for non-reactor wastes the potential for additional benefits realized in terms of volume reduction will be minimal; an upper bound on the volume of waste that may potentially be suitable for storage for decay is about 17,000 cubic feet/yr. However, the generators of these wastes also report long-lived nuclides in their shipped waste. Therefore, the total volume reduction from decay for storage is probably a small fraction of the 17,000 cubic feet/yr.

WASTE PROJECTION SCENARIOS

Three sets of assumptions or scenarios were developed as a basis for the waste projections. The high estimate scenarios represents the set of assumptions that yield the largest volume of waste shipped, the medium estimate represents a most probable scenario and ERM-Midwest's best estimate of future generation, while the low estimate scenario represents the set of assumptions yielding the least volume requiring management. The scenario structure for reactor and non-reactor wastes is as follows.

Reactor Wastes. All three scenarios for future quantities of reactor waste have two major assumptions in common: (1) waste generation will continue at present volumes and, (2) no additional reactors will be built in the Midwest Compact region for the 30-year projection period.

The estimates assume that any increase in volume will be mitigated by more aggressive volume reduction practices. Additional assumptions used for distinguishing among each of the scenarios are as follows:

Low Estimate
- o Decommissioning takes place 40 years from commercial operation
- o Decommissioning by deferred dismantlement

Most Probable Estimate
- o All commercial reactors except Big Rock Point and La Crosse are retrofitted after 40 years of commercial operation and relicensed for at least 20 additional years
- o Big Rock Point and La Crosse decommissioned 40 years from commercial operation
- o Decommissioning by immediate dismantlement

High Estimate
- o Decommissioning of commercial reactors takes place 40 years from commercial operation
- o Decommissioning by immediate dismantlement

Non-Reactor Wastes. Assumptions for the non-reactor waste scenarios are as follows:

Low Estimate

- o Very aggressive source/volume reduction
- o Improved separation of wastes
- o Incineration of all compatible wastes including compacted trash
- o Increased use of storage for decay

Most Probable Estimate

- o Moderate growth in research and services
- o Increased emphasis on volume reduction techniques
- o Incineration of liquid scintillation vials and other highly combustible wastes

High Estimate

- o Status quo source/volume reduction
- o No incineration of low-level wastes
- o Higher industry segment growth than the most probable scenario

QUANTIFICATION OF PROJECTION FACTORS

For each of the variables and scenarios discussed earlier, projection factors were utilized to project future waste quantities. All of these factors have a subjective element and reflect a large degree of professional judgment tempered by interviews with knowledgeable individuals, reviews of relevant literature, and data from the assessment of waste characterisitcs management and practices for the Midwest Compact Region.

Reactor Wastes. The major consideration of projecting future waste quantities involved scaling the decommissioning waste volume estimates provided for the reference pressurized and boiling water reactors. These reactors have 1175 MW and 1155 MW generating capacity, respectively, while many of the power reactors in the Midwest Region have lower generation capacity. NRC documents provide scaling factors for decommissioning costs (but not volumes). Overall scaling factors (for cost estimates) are provided in NRC Document NUREG/CR-0130 for four PWRs (5):

- o Yankee Rowe (185 MW)
- o R. E. Ginna (420 MW)
- o Turkey Point (728 MW)
- o Trojan (1175 MW)

These data were utilized to develop waste generation scaling factors for the size plants operating in the Midwest Compact region. Decommissioning volume estimates for the reference reactors for a desired decommissioning mode, i.e., DECON or SAFSTOR, were multiplied by the scaling factor to arrive at a volume estimate for any given reactor.

Reactor waste volume projections for the three scenarios for the period 1985 to 2015 are presented in Fig. 1, where the cumulative effect of decommissioning reactors in the Midwest Compact is clearly evident. For the purposes of this graph, projections were extended to 2030, since this could represent a period of very high waste generation under the high-estimate scenarios.

Under the high-estimate scenarios, waste generation from the utilities would remain fairly flat from 1985 to 2030 except for two minor surges caused by the decommissioning of the region's two smallest reactors. However, under the most-probable-estimate scenario, the dramatic increases seen in the high-estimate scenario are only delayed by 20 years. Beginning in the year 2030, if reactors are immediately dismantled under a DECON mode, then the same peaks in waste volume generation will be evident even under a most-probable-estimate scenario.

The low-estimate scenario shows a flat waste generation curve up to about the year 2015 when waste generation begins a gradual decline to the year 2030. This scenario assumes decommissioning by SAFSTOR with a storage period of at least 30 years.

Non-Reactor Wastes. Projection factors of industry segment growth, volume reduction, storage for decay and regulatory changes were used in projecting non-reactor waste quantities. For each of the four factors a "multiplier" was developed to transform the 1985 data into future period estimates for the three scenarios. A composite projection factor for each scenario and time period was obtained by multiplying the individual multipliers for each of the four individual factors. All factors for 1985 (present) were set or normalized at 1.0.

Industry segment growth was estimated at 1.5 percent increase per year for the low-estimate scenario, 2.5 percent per year for the most-probable estimate and 3.5 percent per year for high-estimate scenario. While some industry contacts suggested annual industry segment growth may approach 5 to 10 percent per year for institutional LLW generation based on recent trends, such growth would not likely be sustained for a number of years.

Effects of volume reduction for 1990 and beyond was estimated at 50 percent reduction (compared to 1985) for the low-estimate scenario to reflect the potential for volume reduction from incineration of all incinerable wastes; a 25 percent reduction was estimated for the most-probable-estimate scenario to reflect incineration of the more combustible low-level wastes, e.g. liquid scintillation cocktails, and 5 percent reduction was estimated for the high-estimate scenario to reflect a status quo condition, i.e., continued compaction and no incineration.

Storage for decay will have a minimal effect on waste shipped. The low-estimate scenario was set a 6 percent reduction, the most-probable was set at 2 percent reduction and the high reflects no changes, all referenced to 1985.

Regulatory changes have the potential to influence waste projections. The multipliers used for this factor assume that political forces will be reflected in regulatory changes that exert a downward pressure on waste volumes. The multipliers for this factor were set at 20, 10, and 5 percent reduction for the low-, most probable-, and high-estimate scenarios, respectively.

Non-reactor waste volume projections for the three scenarios for the period 1985 to 2015 are presented in Fig. 2. Using this projection methodology for individual state wastes would yield curves that exhibit the same shape, the difference being a lower volume to start from.

Total Waste Volume Projections. Total waste volume projections for 1985 to 2015 are presented in Table 1. These data represent the total waste volume (i.e., both reactor and non-reactor waste) for the Midwest Compact region for the three scenarios described.

Regional projections of total waste volume for the most probable scenario are presented in Fig. 3, which shows the relationship among reactor, non-reactor, and total volume estimates.

SUMMARY

Based on 1986 data, LLW from nuclear power plants constitute approximately 75 percent of the total waste volume shipped in the Midwest Compact region with non-reactor wastes accounting for the remainder.

TABLE I

Total LLW Projections (1985-2015)

(Cubic Feet Per Year)

STATE	SCENARIO	1985	1990	1995	2000	2005	2010	2015
Iowa	Low	20,931	20,306	20,336	20,365	20,395	20,424	8,811
	Most Probable	20,931	20,663	20,749	20,836	20,923	21,010	21,096
	High	20,931	20,994	21,160	21,326	21,491	21,657	129,763
Indiana	Low	4,711	1,904	2,037	2,170	2,303	2,436	2,568
	Most Probable	4,711	3,506	3,895	4,285	4,674	5,064	5,454
	High	4,711	4,996	5,740	6,484	7,228	7,972	8,716
Michigan	Low	52,275	65,908	66,205	66,502	64,049	64,346	49,433
	Most Probable	52,275	69,494	70,366	71,238	93,282	70,231	71,104
	High	52,275	72,829	74,495	76,161	98,999	76,742	330,988
Minnesota	Low	47,182	34,596	35,191	35,787	36,383	36,979	20,651
	Most Probable	47,182	41,778	43,525	45,272	47,018	48,765	50,512
	High	47,182	48,459	51,795	55,132	58,468	61,804	250,944
Missouri	Low	18,140	11,519	11,832	12,146	12,459	12,772	13,086
	Most Probable	18,140	15,297	16,216	17,135	18,054	18,973	19,892
	High	18,140	18,812	20,567	22,322	24,077	25,832	27,587
Ohio	Low	9,669	36,394	36,561	36,729	36,896	37,064	37,231
	Most Probable	9,669	38,413	38,905	39,396	39,887	40,378	40,869
	High	9,669	40,292	41,230	42,168	43,106	44,045	44,983
Wisconsin	Low	12,461	11,977	12,000	12,023	12,046	14,137	2,726
	Most Probable	12,461	12,253	12,320	12,388	12,455	59,434	11,568
	High	12,461	12,510	12,638	12,767	12,895	59,935	213,362
TOTAL	Low	165,369	182,603	184,163	185,722	184,531	188,159	134,507
	Most Probable	165,369	201,404	205,977	210,549	236,293	263,855	220,494
	High	165,369	218,892	227,626	236,359	266,264	297,988	1,006,344

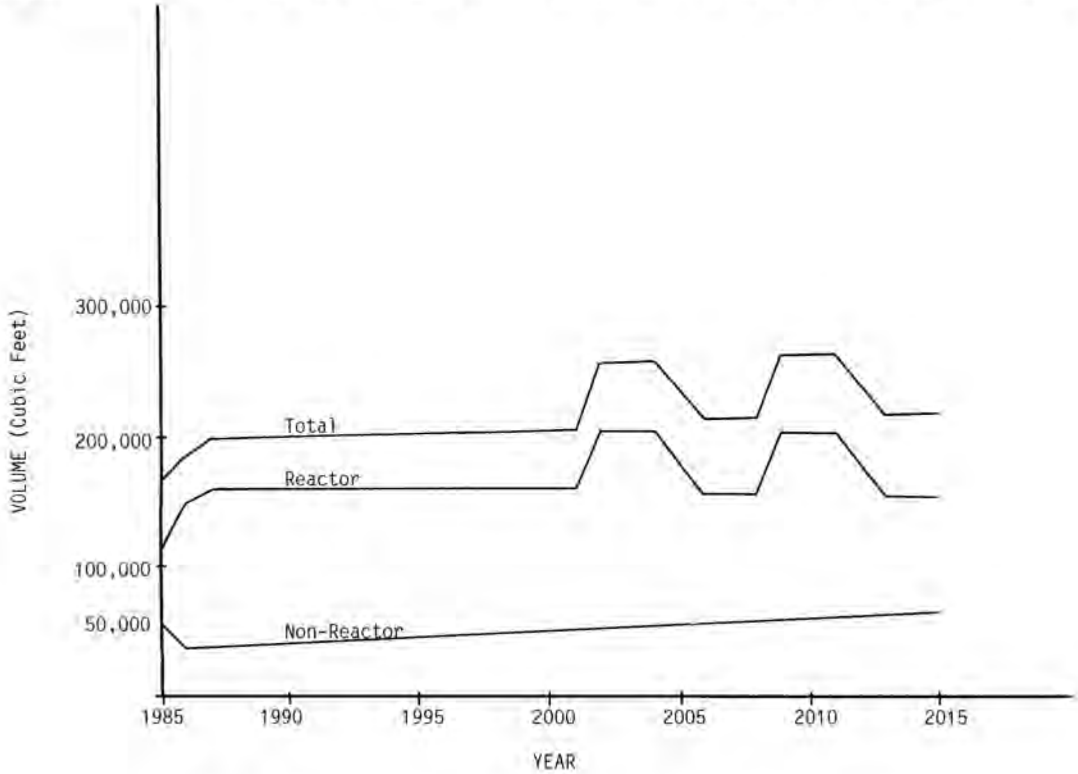

Fig. 3. Total LLW Volume Projections (Most Probable Scenario).

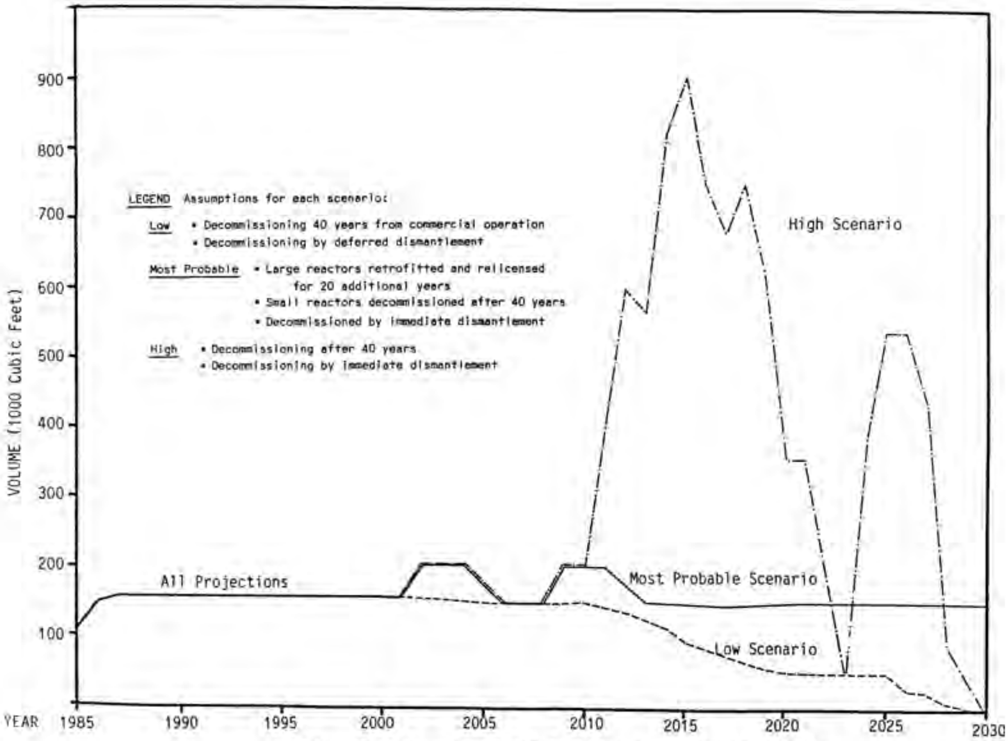

Fig. 1. Reactor LLW Projections (1985-2030).

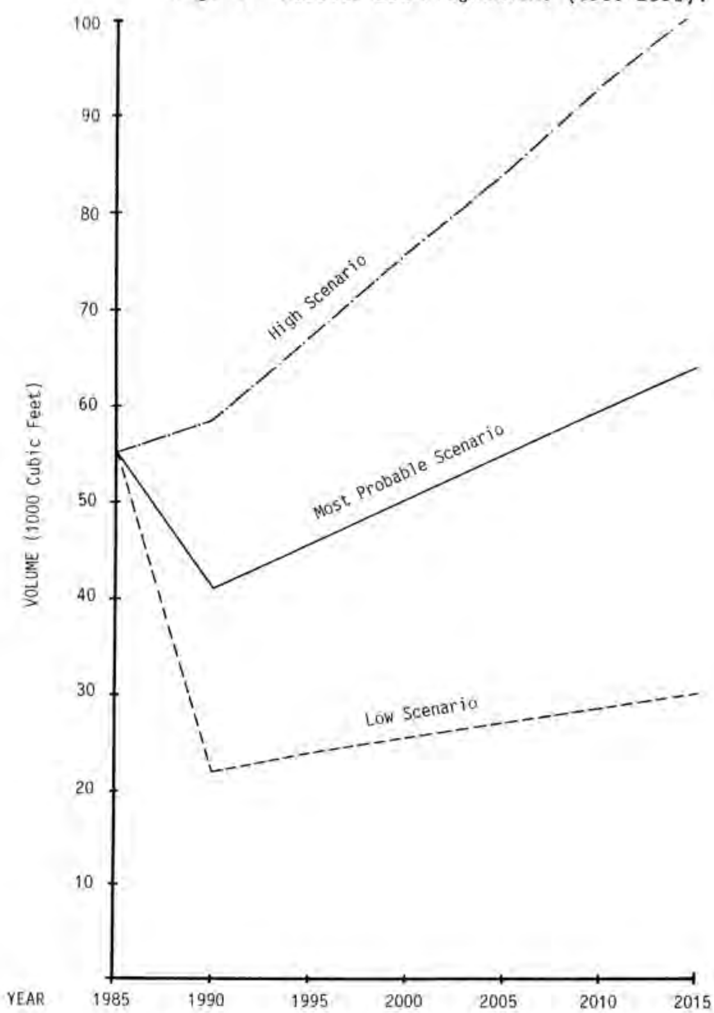

Fig. 2. Total Non-Reactor LLW Projections (1985-2015).

Volumes from utilities are projected to remain at fairly constant levels over the 1985 to 2015 planning period. Non-reactor waste volumes will drop sharply in the next five years under the most probable scenario and then maintain a moderate rate of increase over the remaining 25 years.

Under the most probable scenario, in 2015 an estimated total (reactor plus non-reactor) of 210,000 cubic feet of low-level waste will be shipped. Reactor and non-reactor wastes will make up about 71 percent and 29 percent, respectively, of the total volumes for 2015.

Reactor low-level waste projections show two small surges under the most probable scenario. These temporary increases of volume will be caused by decommissioning of the two small reactors in the Compact region. Following decommissioning of these two reactors, waste volumes from reactors would again return to fairly constant levels until the next group of reactors are decommissioned. Under the most probable scenario, the next group of reactors will be decommissioned starting in 2031. The dramatic increase in reactor wastes exhibited under the high scenario are only delayed for 20 years under the most probable scenario and would likely occur post-2030.

Non-reactor waste volumes drop approximately 25 percent over the next five years under the most probable scenario. This sharp decrease will be driven primarily by volume reduction efforts in the form of compaction and incineration. The increasing waste volumes predicted over the remainder of the projection time period are due to industry segment growth. The net effect of the factors influencing non-reactor wastes will be an increase by 2015 of 15 percent over 1985 waste volume estimates.

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