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THE POTENTIAL FOR ENERGY FROM THE COMBUSTION OF MUNICIPAL SOLID WASTE*

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ABSTRACT

This article assesses the potential for energy from the combustion of MSW during the 1990 to 2030 time frame. Information from a variety of sources is used in a four-step process. In the first step, the total quantity of MSW is projected in five year increments. The current and future heat value of a typical pound of MSW is assessed in the second step. Step 3 addresses the total U.S. capacity to combust MSW over the projection time frame. The final step combines the results of the first three steps to formulate base, low, and high projections of energy from MSW combustion. Energy from the combustion of MSW is estimated to account for about 0.3 quads currently, or about 0.3 percent of all U.S. energy consumption. In the base case, energy from MSW combustion is projected to increase to 1.6 quads, or 1.5 percent of total U.S. consumption by 2010. In the low case, MSW combustion accounts for 0.7 quads, or 0.6 percent of total energy consumption in 2010, and in the high case MSW accounts for 2.5 quads, or 2.3 percent of the total. While not insignificant, combustion of MSW is likely to have only marginal impacts on the consumption of other energy forms. The current inability to narrow the range of MSW energy projections is due in large part to great uncertainties surrounding the future adoption of waste-to-energy facilities. The future success or failure of combustion as an MSW management option will likely depend more on that option's environmental and social acceptability, rather than the "out-of-pocket" costs of competing technical approaches. Uncertainties surrounding the quantities and heat values of current and future MSW further complicate the projection process. More refined projections must await more complete data on the quantity and composition of MSW and additional work on how and why communities adopt different management options.

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http://baywood.com

The depletion of energy resources and the management of municipal solid waste (MSW) are growing concerns of both public and private decision makers [1]. Combustion of MSW with heat recovery is often argued as a means of addressing both issues – i.e., by reducing the volume of MSW by as much as 80 percent and by producing heat energy that is normally converted to steam or electricity.

This article utilizes information from a variety of sources to address the potential for energy from the combustion of MSW during the 1990 to 2030 time frame. A four-step process is used. In the first step, the total quantity of MSW is projected in five-year increments. The current and future heat value of a typical pound of MSW is assessed in the second step. Step 3 addresses the total U.S. capacity to combust MSW over the projection time frame. The final step combines the results of the first three steps to formulate three alternative MSW energy projections.

Due to uncertainties at each step, projections presented in this article should not be interpreted necessarily as predictions, but rather as reference points and reasonable bounds. A major objective of this exercise is to illuminate our current capabilities, as well as our shortcomings, in making projections of energy from MSW combustion.

PROJECTED QUANTITY OF MSW

Background

The projection of MSW quantity is complicated by the lack of a standardized definition of what constitutes MSW and by the absence of a generally accepted methodology to collect data on MSW generation. The definition of MSW used here is consistent with definitions used by the U.S. Environmental Protection Agency (EPA) and the Office of Technology Assessment (OTA), which recently completed a major study of municipal solid waste [1]. OTA defines MSW "as post-consumer solid wastes generated at residences (e.g., single-family units and apartment buildings), commercial establishments (e.g., offices, retail shops, restaurants), and institutions (e.g., hospitals, schools, government offices)" [1, p. 74]. The OTA definition does not include so called "gray areas." For example, automobile bodies, demolition and construction debris, municipal wastewater or drinking water sludges, and ash from industrial boilers are not included. While MSW is defined to include some miscellaneous wastes from the industrial sector, such as lunchroom wastes, office paper, and corrugated boxes, MSW does not include nonhazardous industrial waste that results directly from the manufacturing process. In some cases, these omitted wastes are managed with MSW in the same facilities and can cause confusion when comparing estimates of the size of MSW from city to city. According to the EPA, about 180 million tons of MSW were produced in 1988 and about 200 million tons will be produced in 1995 [2]. For comparison purposes, OTA estimates that "at least 250 million tons of hazardous waste are generated annually and the amount of nonhazardous industrial solid waste is even greater" [1, p. 73].

The only publicly available data on MSW on a national scale are from Franklin Associates. Franklin Associates has provided a series of projections of MSW quantity, composition, and management methods at the request of the EPA. The most recent projections are available in a June 1990 EPA publication, which provides projections to the year 2010 and which updates their previous projections [3].

The model used by Franklin Associates relies on a materials flow approach. In other words, it traces the flow of materials from production, to consumption, to disposal. The model does not rely on data collected at the point of generation. OTA had argued that the Franklin approach excludes some liquids, packaging, and nondurable items [1]. OTA reported that Franklin Associates have suggested that the inclusion of these omitted waste categories might add 5 percent to the total-quantity estimates given in their earlier report.

The latest estimates from Franklin Associates [2] employ a revised methodology for calculating the quantity of MSW to address the general perception that the quantity estimates in their 1988 study were biased downward [3]. For example, the most recent report includes a more complete accounting of packaging of imported goods. While some materials remain omitted in the revised study (e.g., residues in containers, inks and pigments, staples, and adhesives), these items are likely to represent a very small percentage of the waste stream. An examination of projections from the 1988 and 1990 reports shows that quantity projections have increased for the two years common to both reports – i.e., 1995 and 2000. For 1995, quantity projections increased from 180.2 million tons in the 1988 study to 199.8 million tons in the 1990 study (a 10.9% increase). For 2000, quantity projections increased from 192.7 million tons to 216.0 million tons (a 12.1% increase).

Base Case

The base-case methodology used here adopts Franklin's latest quantity estimates and projections for the years 1990 to 2010. For the 2015 to 2030 time frame, MSW is increased by the rate of population growth, holding MSW per capita constant at the rate calculated from the Franklin projections for 2010 – i.e., 0.887 tons per year. (The middle population growth series of the U.S. Bureau of the Census was used [4, p. 3].) The assumption of constant MSW per capita beyond 2010 reflects the source reduction efforts that are expected to be in place by that time. Note that EPA has placed source reduction at the top of its hierarchy of waste management approaches, followed by recycling and an equal preference for combustion and landfill [5]. Many states have also called for voluntary or mandatory source reduction.

Low Case

If source reduction becomes a higher priority of federal and state governments, Franklin's quantity projections are high for the 1995 to 2010 time frame. To reflect the possibility that source reduction efforts may be numerous and very successful, Franklin's updated projection for 1995 is reduced by 5 percent. Franklin's 2000 and 2010 quantity projections are reduced by 10 percent and 15 percent, respectively. For the 2015 to 2030 time frame, MSW quantity is increased by the projected rate of population growth, while holding constant per capita MSW generation at the revised rate for 2010, i.e., 0.754 tons per year.

High Case

For the high-case scenario, Franklin's updated projections are adopted to the year 2010. For the 2015 to 2030 time frame, quantity is assumed to continue to increase according to population growth, and MSW per capita rates are assumed to increase according to historical and projected trends for the 1960 to 2010 time frame. In other words, it is assumed that the per capita generation rate will continue to increase in the 2010 to 2030 time frame according to the rate of increase observed and projected over the 1960 to 2010 period. (Note that the EPA provides historical data on MSW generation to 1960 [2].) The MSW per capita rate for the high case is projected to be 1.08 tons in 2030, compared to 0.887 for the base case and 0.754 for the low case.

Table 1 summarizes MSW quantity projections for all three cases. Figure 1 presents the projections in graphical form.

Table 1. Projected Quantities of MSW (in millions of tons)

Year	Low Case	Base Case	High Case
1990	182.0	182.0	182.0
1995	189.8	199.8	199.8
2000	194.4	216.0	216.0
2005	205.28	233.0	233.0
2010	213.0	250.6	250.6
2015	217.9	256.3	268.4
2020	222.0	261.1	286.6
2025	223.9	263.4	305.8
2030	226.7	266.7	324.6

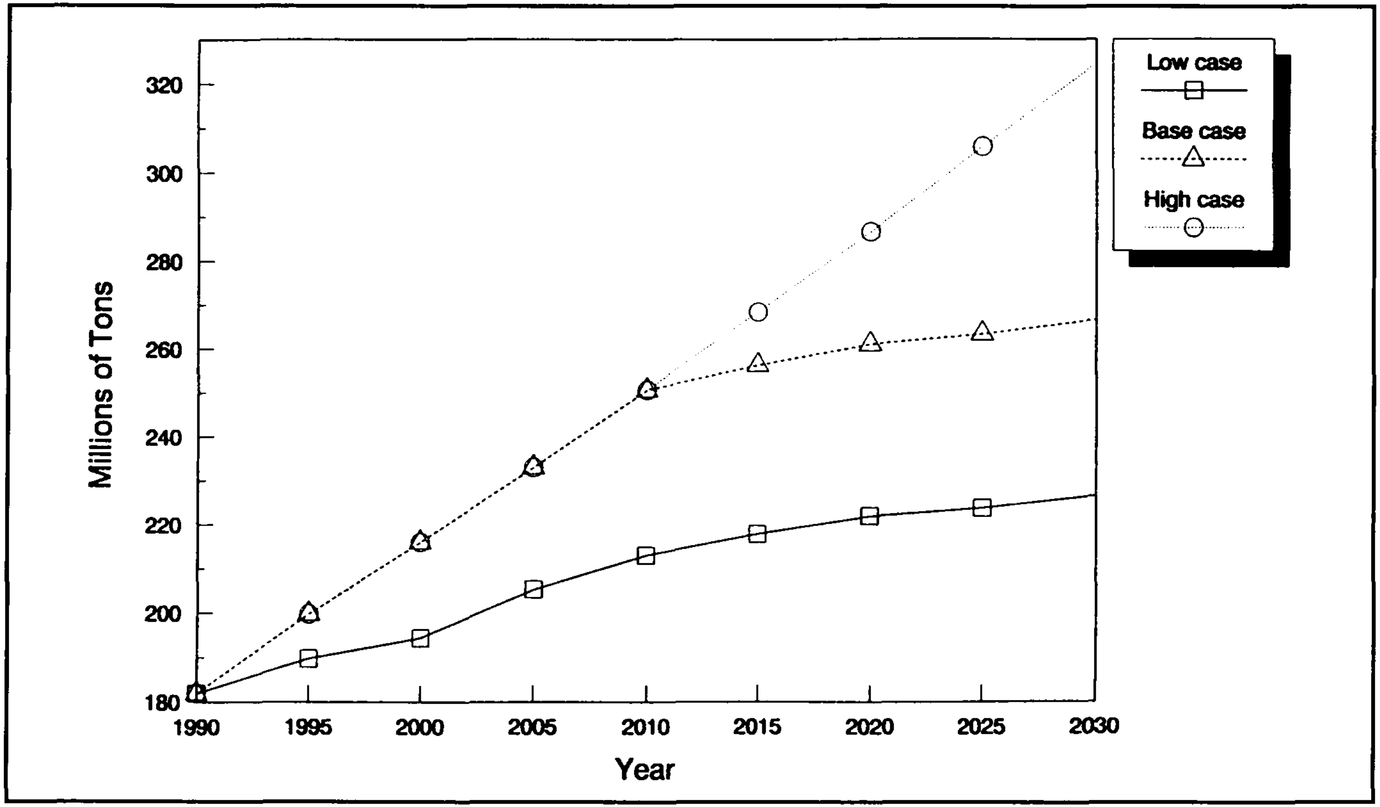

Figure 1. Projected quantities of MSW.

PROJECTED HEAT VALUE OF MSW

Background

The heat value of a typical pound of MSW is widely quoted to be between about 4,000 and 6,000 Btus (see, for example, [1, 6-10]). The heat value of MSW is close to the value of wood and about one-third the value of coal. Opinions about the heat value of future MSW differ depending on the source. Kolb and Wilkes state that "MSW fuel value is believed to be increasing slowly from an increasing fraction of plastics. One source estimated that the heating value would increase at an average rate of 0.5 percent per year" [11, p. 14].

The future heat value of MSW will depend on its composition. OTA states that [1, p. 85]:

> The organic fraction of MSW was estimated to be about 81 percent in 1986. It appears to be growing slowly, primarily because the portions of paper and plastics in MSW also are growing. . . . Removing particular materials from MSW prior to incineration can affect combustibility. For example, removing yard wastes and inorganic recyclables such as glass and metals can reduce moisture and increase average HHV (higher heating value). In contrast, removing paper and plastics lowers HHV and increases moisture constant. The net effect will depend on what is removed.

Table 2 provides information from EPA on the composition of MSW for selected years between 1960 and 2010 [2]. In percentage terms, note that large increases have been observed and are expected to continue for plastics and paper, i.e., two high-Btu components of MSW. While recycling trends and composting programs may alter the heat value of MSW entering combustion facilities, those changes are assumed to be small and are not considered here. Table 3 combines information from OTA [1] on the heat values of MSW components with information in Table 2 to estimate and project the average heat value of MSW in selected years. Heat value increases from 3,774 Btus per pound in 1960, to 4,457 Btus per pound in 1980, to 5,745 Btus per pound in 2010.

Base Case

The base case adopts the projected Btu values from Table 3 for the time period 1990 to 2010. From that statistical relationship, estimates and projections were derived for the years for which no MSW composition information is available from the EPA [2] – i.e., 1990 and 2005. For 2015 to 2030, it is assumed that Btu values continue to increase according to historical trends.

Low Case

For the entire projection time frame, the base-case Btu values are decreased by 10 percent. Note that this reduction lowers the 1990 estimate to close to the commonly quoted 4,500 Btus per pound.

Table 2. The Composition of MSW: 1960 to 2010

	Composition of MSW (in percent)						
Material	1960	1970	1980	1988	1995	2000	2010
Paper and paperboard	34.1	36.3	36.6	40.0	42.8	44.5	48.4
Glass	7.6	10.4	10.0	7.0	5.6	4.8	3.8
Metals	12.0	11.6	9.7	8.5	8.1	7.8	7.0
Plastics	0.5	2.5	5.2	8.0	9.3	9.8	10.3
Rubber and leather	2.3	2.6	2.9	2.5	2.4	2.5	2.3
Textiles	1.9	1.6	1.7	2.1	2.0	2.0	1.8
Wood	3.4	3.3	3.3	3.6	3.7	3.9	4.1
Food waste	13.9	10.5	8.8	7.4	6.6	6.2	5.5
Yard waste	22.8	19.0	18.4	17.6	16.5	15.9	14.4
Other organics	0.1	1.5	1.5	1.5	1.4	1.3	1.2
Other inorganics	1.5	1.5	1.5	1.5	1.4	1.3	1.2
Total[a]	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: U.S. Environmental Protection Agency [2].

[a] May not sum to 100 because of rounding.

High Case

For the entire projection time frame, the base-case Btu values are increased by 10 percent. This adjustment increases the 1990 estimate to about 5,500 Btus per pound (i.e., the high end of current estimates). Table 4 and Figure 2 summarize MSW heat-value projections for all three cases.

PROJECTED PERCENTAGE OF MSW COMBUSTED FOR ENERGY PRODUCTION

Background

Several sources of information currently exist to estimate the current U.S. capacity to combust MSW and project combustion capacity to about 1995. Those courses include databases maintained by Donald Walter, Director, Biofuels and Municipal Waste Technology, U.S. Department of Energy; Steven Levy, U.S.

Table 3. The Estimated and Projected Heat Value of MSW: 1960 to 2010

Material	Estimated Btus per Pound*	Estimated MSW Heat Value (Btus per pound)						
		1960	1970	1980	1988	1995	2000	2010
Paper and paperboard	6500	2216.5	2359.5	2379	2600	2782	2892.5	3146
Glass	0	0	0	0	0	0	0	0
Metals	0	0	0	0	0	0	0	0
Plastics	14000	70	350	728	1120	1302	1372	1442
Rubber and leather	9500	218.5	247	275.5	237.5	228	237.5	218.5
Textiles	6800	129.5	108.8	115.6	142.8	136	136	122.4
Wood	6500	221	214.5	214.5	234	240.5	253.5	266.5
Food Waste	2000	278	210	176	148	132	124	110
Yard waste	2800	638.4	532	515.2	492.8	462	445.2	403.2
Other organics	2800	2.8	19.6	53.2	47.6	42	39.2	36.4
Other inorganics	0	0	0	0	0	0	0	0
Total		3774.4	4041.4	4457	5022.7	5324.5	5499.9	5745

Source: Information on Btus in specific materials: OTA [1].

Table 4. Projected Heat Value of MSW (in BTUs per pound)

Year	Low Case	Base Case	High Case
1990	4,503	5,004	5,504
1995	4,792	5,325	5,857
2000	4,950	5,500	6,050
2005	5,084	5,649	6,214
2010	5,171	5,745	6,320
2015	5,471	6,079	6,687
2020	5,664	6,294	6,923
2025	5,858	6,509	7,160
2030	6,051	6,724	7,396

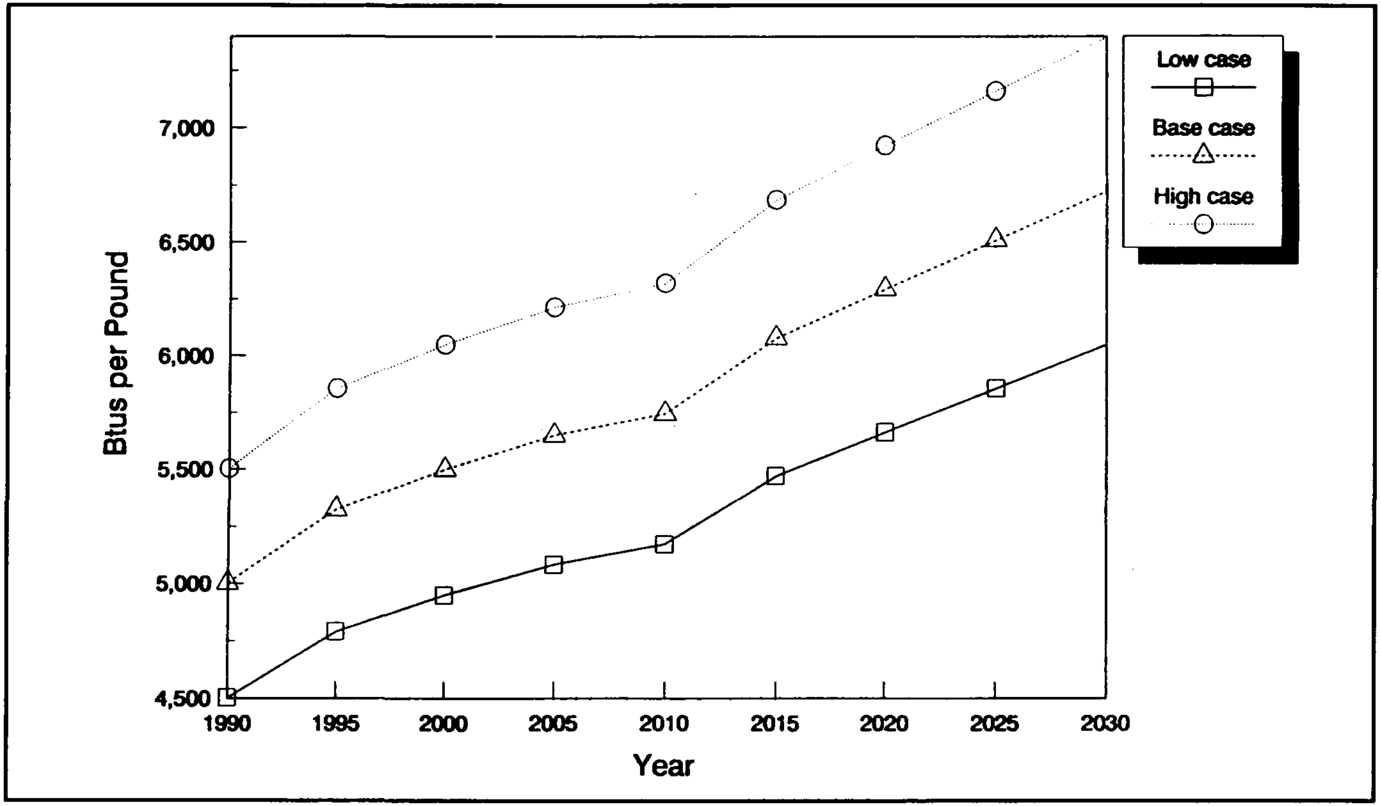

Figure 2. Projected heat value of MSW.

Environmental Protection Agency; the National Solid Waste Management Association (NSWMA); and Governmental Advisory Associates. However, beyond 1995 there is very little information on which to base projections.

OTA estimates that in 1988 combustion accounted for about 15 percent of MSW management in the United States [1]. In 1988 existing facilities numbered 160 with a total capacity of about 70,000 tons per day. OTA goes on to report that about 23,000 tons per day of new capacity is expected to become operational between 1990 and 1992.

Steven Levy of the EPA estimates that existing combustion capacity totals 91,705 tons per day at 167 facilities, or about 16.7 percent of current MSW management, given an estimated MSW quantity of 182 million tons per year and 90 percent capacity utilization [12]. Levy estimates that total 1992 capacity will equal 132,291 tons per day at 206 facilities. An additional sixty-three facilities are planned for the post-1992 time frame with a total capacity of 56,086 tons per day, or 18.42 million tons per year at 90 percent capacity. If we assume that all the planned facilities in Levy's data base are completed by 1995 and we assume MSW equals our 1995 base-case quantity (199.8 million tons), incineration with heat recovery will account for about 31 percent of the total waste stream in 1995.

Governmental Advisory Associates reports that at the time of publication about 15.9 million tons of MSW were combusted per year [8]. When all facilities in what they term the "advanced planned" phase are completed, a total of about 44.0 million tons of MSW will be combusted per year. They suggest that about 31 percent of all MSW will be disposed of in resource recovery projects once all planned facilities are fully operational.

Combustion with energy recovery is estimated to have accounted for 2.5 percent of MSW management in 1985 and 13.6 percent in 1988, according to the EPA [2]. Franklin Associates project that nearly 23 percent of MSW will be combusted in 1995 and about 26 percent will be combusted in 2000. All major MSW combustion facilities are projected to have energy recovery capabilities in the future.

Note that the quantity of MSW combusted in the United States is low relative to Japan and many European countries. It is difficult to compare estimates of incineration with heat recovery from different countries because of varying definitions of MSW. Combustion rates in the 30 percent to 50 percent range are, however, generally accepted for countries such as Japan, Denmark, France, Netherlands, Sweden, Switzerland, and West Germany.

Combustion Technology and Energy Potential

Before addressing the factors that will determine future combustion capacity, it is appropriate to consider the effects that the type of combustion capacity may have on energy potential. Governmental Advisory Associates reports that 47 percent of the 202 existing and advanced-planned facilities employ mass burning

Table 5. Net System Energy Output per Unit Input of MSW (in Btus per pound)

	Waterwall Incineration of Raw Refuse (Btu/lb)	Modular Incineration (Btu/lb)	RDF[a] Typical (Btu/lb)	RDF[a] Enhanced (Btu/lb)
Input	4500	4500	4500	4500
Front-end facility:				
Energy requirements			70	70
Losses			586	1688
Combustion facility:				
Energy requirements	150	173	50	40
Losses	1850	1754	1214	591
Output	2500	2573	2580	2111

Source: Diaz, Savage, and Golueke [6, p. 12].

[a] Does not consider transportartion of RDF.

technology, 34.2 percent utilize modular incineration, and 17.8 percent are refuse-derived-fuel plants (RDF) [8]. Of the conceptually designed facilities that have decided to employ specific technologies, 58.6 percent will use mass burning waterwall incineration, 15.5 percent mass burning modular equipment, 8.6 percent RDF, 6.9 percent mass burning rotary combustors, and 10.3 percent other technologies. The relative proportion of combustion facilities has shifted gradually away from the modular and RDF processes and toward the larger mass burn facilities. However, between 1986 and 1988 the average design capacity of existing and advanced-planned facilities decreased by 7.2 percent, which suggests a possible market saturation of larger scale facilities.

Most experts conclude that combustion technology will have little impact on the energy that may be retrieved from MSW combustion. For example, Table 5 presents information from Diaz, Savage, and Golueke on the net system energy output per unit input of MSW for different types of combustion [6]. Note that the outputs for all combustion technologies are very close. If transportation energy is considered, RDF may be at a slight disadvantage. For the purpose of this study, it is assumed that the selection of combustion technology is not essential to projecting energy from MSW combustion.

FUTURE LANDFILL AND RECYCLING RATES

A strong argument can be made that the current interest in MSW combustion reflects recent sharp reductions in landfill capacity and the current advantages that combustion holds in terms of regulatory preference – in particular, regulations under the Public Utilities Regulatory Policies Act (PURPA) that give preferential treatment to electricity produced at MSW combustion facilities. (PURPA also gives preference to other generating facilities employing cogeneration or using renewable fuels.) While 72.7 percent of the MSW was managed in landfills in 1988, landfill capacity is decreasing at an alarming rate [2]. OTA reports that 3,332 landfills are expected to be operational in 1993, while only 1,234 will be operational in 2008 [1]. EPA projects that landfill will account for 53.1 percent of all MSW in 1995 [2], as environmental regulations further restrict the design and operation of landfills. In addition, siting of new landfills is difficult because of public opposition. The current problems with landfills have led many communities to consider combustion, even though in most locations the combustion option is currently more expensive than landfill.

The percentage of MSW that is recycled in the United States increased from 10.1 percent in 1985 to 12.9 percent in 1988, and by 1995 a projected 19.4 percent will be recycled [2]. Recent regulatory actions may spur additional recycling. In addition to extensive pro-recycling legislation at the state and local level, the U.S. EPA proposed a rule in 1989 that would allow permits to be issued to incineration facilities only if 25 percent of the incoming waste stream is separated for recycling. The 25 percent recycling requirement was part of a proposed EPA rule on air emission guidelines for municipal waste combustors.[1] Although the 25 percent recycling rule was dropped before the rule became final, it is likely that similar measures will be put forth when the Resource Conservation and Recovery Act (RCRA) comes up for reauthorization. While it is difficult to speculate about what components of MSW will see higher recycling rates in future years, it is widely believed that the overall MSW recycling rate will increase from its current level.

The Social Acceptability of Combustion

The social acceptability of combustion will be key in determining the future use of the waste-to-energy option. Of primary concern are 1) the toxicity, regulatory classification, and disposal and recycling options for incinerator ash and 2) air emissions from combustion facilities – in particular, furans, dioxins, and heavy metals (see, e.g., [13-16]). OTA reports that "Public opposition and uncertainties regarding emissions and ash management have slowed projects and probably will continue to cause some cancellations and delays. In addition, the nature of financing (including bond status, tax changes, and PURPA) is changing and could affect future use of this MSW management method" [1, p. 222].

[1] See *Federal Register*, Vol. 54, No. 243, December 20, 1989, pp. 52,209-52,304. The President's Council on Competitiveness, headed by Vice President Quayle, persuaded EPA Administrator Reilly to drop the provision. The Council claimed that recycling requirements were not appropriate in a rule to control air pollution. The Council further argued that any recycling requirements should be part of the upcoming reauthorization of the Resource Conservation and Recovery Act (RCRA).

There are, however, recent indications that incineration is becoming more acceptable, while retaining a primarily negative image. For example, a recent poll by the National Solid Waste Management Association found that 44 percent of respondents said "yes" when asked if they would support siting a combustion facility in their community. This response was up from 36 percent in the 1988 survey. Only 36 percent said they would oppose a facility, down from 47 percent in 1988. About 49 percent had a concern that ash residue poses an environmental threat, compared to 54 percent in 1988. Some 61 percent viewed air emissions from combustors as an environmental threat. However, this number is down from 72 percent in the 1988 survey.

Base Case

In the base case, it is assumed that 16 percent of MSW was combusted in 1990 and will increase to 30 percent by 1995. These estimates are consistent with the majority opinion about capacity and capacity utilization during this time frame and the base-case MSW quantity projections given in Table 1. Combustion is assumed to account for 40 percent of MSW in 2000, increase to 50 percent in 2005, and level out at 55 percent in 2010. Combustion with heat recovery is assumed to remain at 55 percent for the remainder of the projection time period.

The 55 percent figure represents underlying assumptions about landfill and recycling. It is assumed that the 25 percent recycling target of many states will be met by 2010 and that landfill will account for only 20 percent of MSW by that time. It is suggested that landfill is unlikely to go below 20 percent (not counting the disposal of incinerator ash) in the projection time frame because of the geographical distribution of the U.S. population. Population density and transportation costs are likely to limit the viability of combustion with heat recovery in many areas.

Low Case

In the low case, combustion percentage for 1990 is the same as in the base case. It is assumed that the percentage of MSW combusted is 23 percent in 1995 and 26 percent in 2000, corresponding to projections from EPA [2], which are lower than other available projections. For the period 2005 to 2030, it is assumed that combustion facilities continue to account for only 30 percent of MSW. This scenario suggests that recycling will be much more successful than in the base case. An ultimate recycling rate of 50 percent in combination with a landfill rate of 20 percent would imply a combustion rate of 30 percent.

High Case

As in the base case, combustion is assumed to account for 16 percent and 30 percent of MSW in 1990 and 1995, respectively. Between 1995 and 2010, it is

Table 6. Projected Percentage of MSW Combusted with Heat Recovery

Year	Low Case	Base Case	High Case
1990	16	16	16
1995	23	30	30
2000	26	40	47
2005	30	50	63
2010	30	55	80
2015	30	55	80
2020	30	55	80
2025	30	55	80
2030	30	55	80

assumed that combustion capacity increases progressively such that in 2010 combustion accounts for 80 percent of all MSW. This very optimistic scenario for combustion reflects the case where both landfill and recycling are found to be non-viable options when compared to combustion.

Table 6 summarizes projections of MSW to be combusted with heat recovery. Figure 3 presents the same information in graphical form.

PROJECTED ENERGY FROM THE COMBUSTION OF MSW

Table 7 combines information from Tables 1, 4, and 6 to calculate total energy available from the combustion of MSW in the base, low, and high cases. Figure 4 presents those projections in graphical form. In the base-case projections, energy increases from 0.29 quadrillion Btus (quads) in 1990 to 1.97 quads in 2030. In the low-case scenario, energy is projected to increase from 0.26 quads in 1990 to 0.82 quads in 2030. In the high-case, energy is projected to increase from 0.32 quads in 1990 to 3.84 quads in 2030.

Table 8 compares these projections to other published MSW energy projections. Figure 5 compares the base case to those other projections in graphical form. Note that the base case projections are higher than each of the projections put forth in Solar Energy Research Institute [17]. Further note that the base case exceeds the projection from Klass for the year 2000 [18]. MSW is but one of several renewable energy sources evaluated in both the Klass and SERI studies; and underlying assumptions are not explained sufficiently in either study to pinpoint the sources of the differences in MSW energy projections. Several explanations are possible. For example, Klass assumes a MSW heat value of between 3,500 and 4,500 Btus

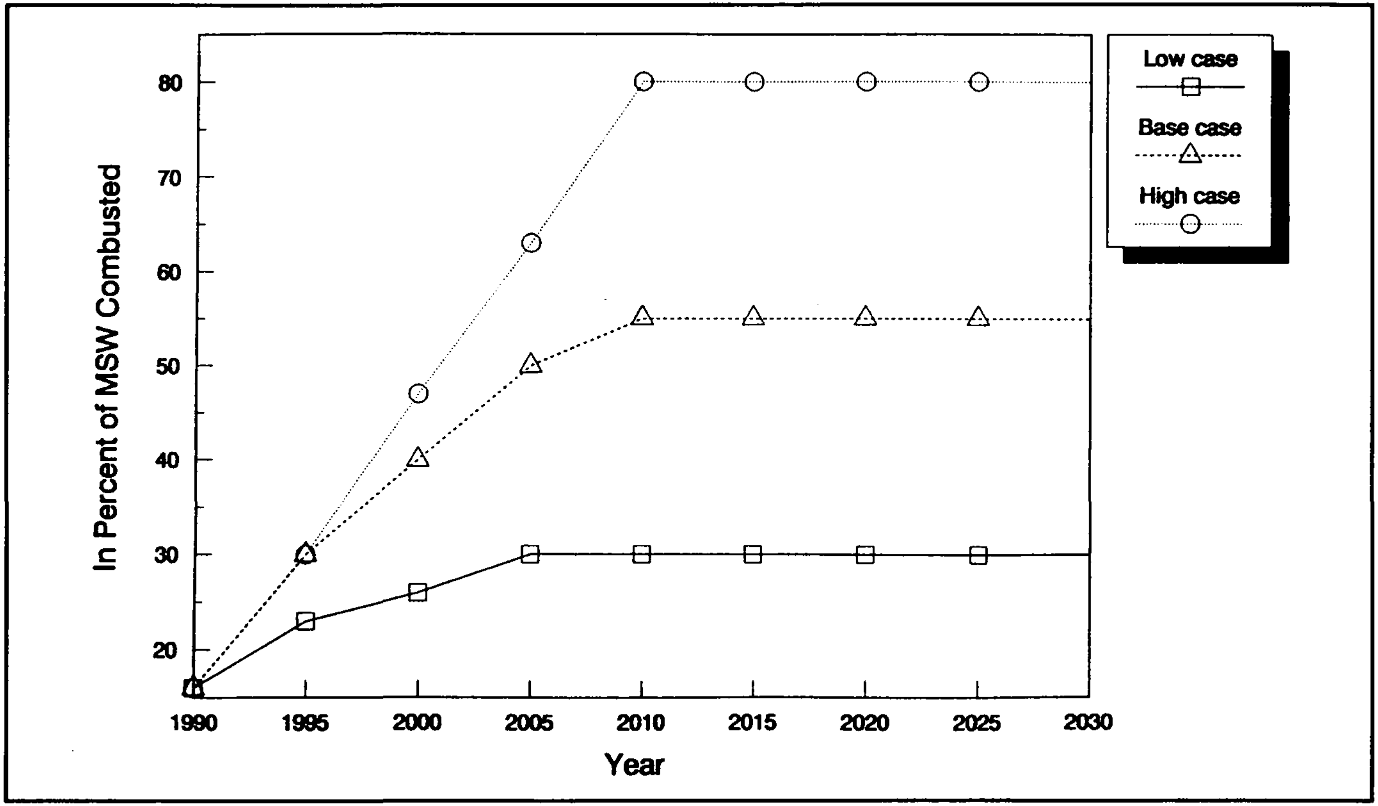

Figure 3. Projected percentage of MSW combusted with heat recovery.

Table 7. Projected Energy from the Combustion of MSW (in 10^{15} Btus or Quads)

Year	Low Case	Base Case	High Case
1990	0.26	0.29	0.32
1995	0.42	0.64	0.70
2000	0.50	0.95	1.22
2005	0.63	1.32	1.82
2010	0.66	1.58	2.53
2015	0.72	1.71	2.87
2020	0.75	1.81	3.17
2025	0.79	1.89	3.50
2030	0.82	1.97	3.84

Table 8. A Comparison with Other Projections of Energy from the Combustion of MSW (in 10^{15} Btus or Quads)

Year	Low Case	Base Case	High Case	SERI[a] Business As Usual	SERI[a] R&D Intensification Scenario	SERI[a] National Premiums Scenario	Klass[b]
1990	0.26	0.29	0.32				
1995	0.42	0.64	0.70				
2000	0.50	0.95	1.22	0.20	0.26	0.34	0.60
2005	0.63	1.32	1.82				
2010	0.66	1.58	2.53	0.45	0.57	0.84	
2015	0.72	1.71	2.87				
2020	0.75	1.81	3.17	0.66	0.89	1.00	
2025	0.79	1.89	3.50				
2030	0.82	1.97	3.84	0.87	1.20	1.17	

[a] **Source:** Solar Energy Research Institute [17].
[b] **Source:** Klass [18].

per pound, which is below this study's assumed 5,500 Btus per pound for the year 2000 in the base case. Klass also assumes a lower total quantity of MSW – 164 million tons compared to this study's estimate of 182 million tons for 1990. The relatively low estimates in the SERI study may be explained by lower assumed combustion capacity and/or utilization. For example, SERI estimated that the total recoverable energy from MSW combustion and landfill methane in 2000 will be

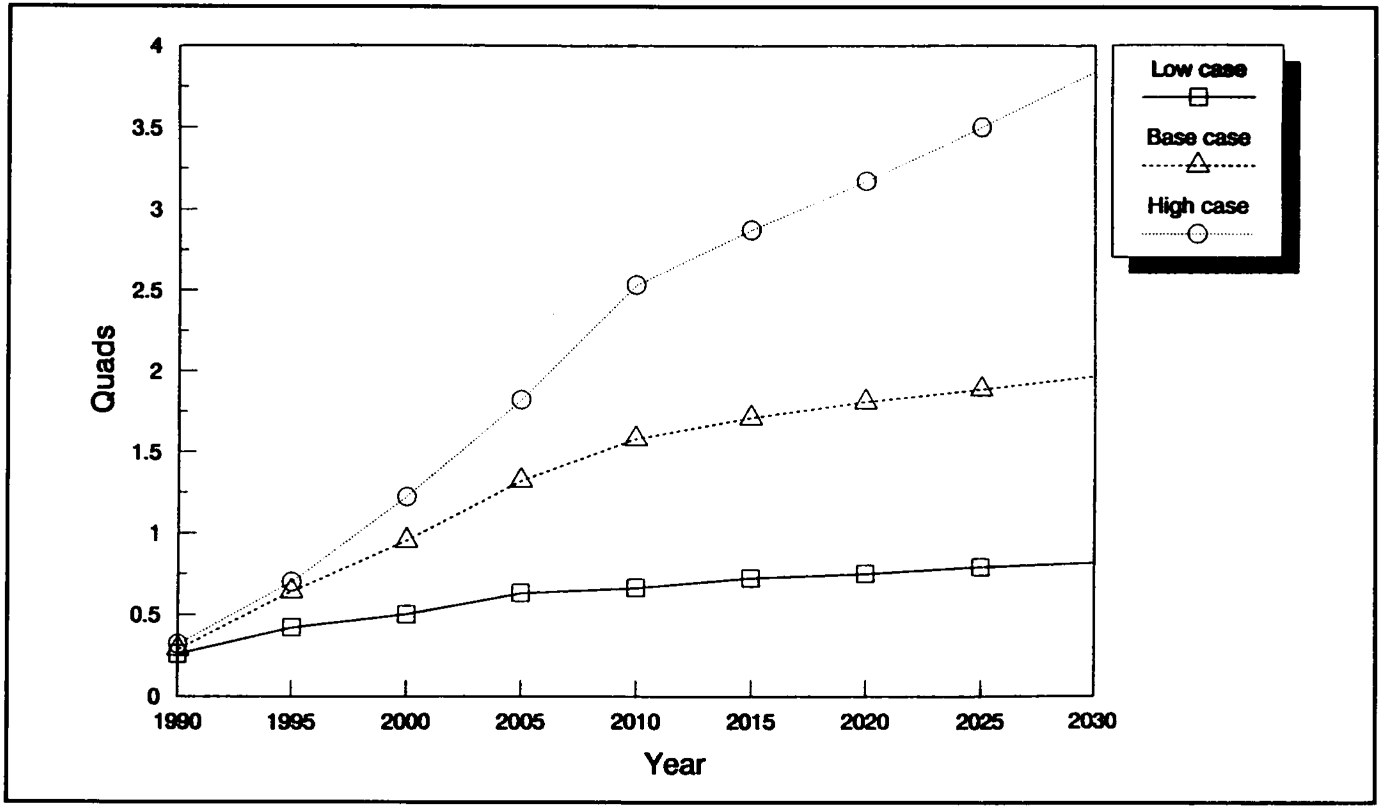

Figure 4. Projected energy from the combustion of MSW.

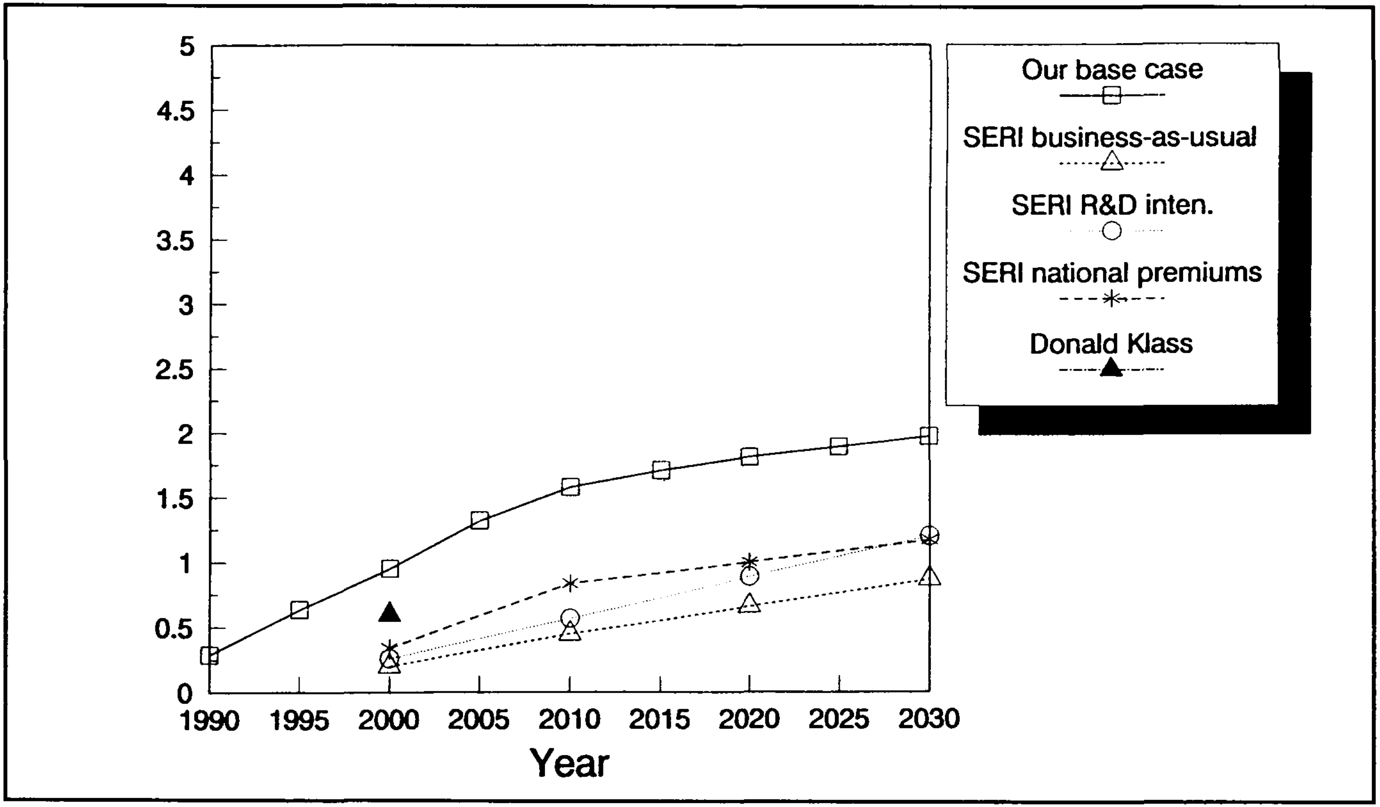

Figure 5. Base case comparison with other projections of energy from MSW combustion.

2.0 quads (1.8 from combustion and 0.2 from methane). However, in the business-as-usual scenario SERI estimates that only 0.2 quads will be produced from MSW combustion, or only 10 percent of their estimated total potential. This study estimates that in 2000 combustion with heat recovery will claim 40 percent of the potential 2.37 quads that could be produced if all MSW enters waste-to-energy facilities.

CONCLUSIONS

Total energy consumption in the United States was 83.4 quads in 1988 and is projected to increase to 97.4 quads in 2000 and to 108.4 quads in 2010 [19]. Therefore, energy from the combustion of MSW currently accounts for about 0.3 percent of all U.S. energy consumption. In the base-case scenario, energy from MSW combustion is projected to increase to 1.5 percent of total U.S. consumption by 2010. In the low case, MSW combustion accounts for 0.6 percent of total energy consumption in 2010 and accounts for 2.3 percent in the high case. While not insignificant, combustion of MSW is likely to have only marginal impacts on the consumption of other energy forms.

The current inability to narrow the range of MSW energy projections is due in large part to great uncertainties surrounding the future adoption of combustion with energy recovery as a method to manage MSW. The future success or failure of combustion as a management option will likely depend more on that option's environmental and social acceptability, rather than the "out-of-pocket" costs of the competing technical approaches. Uncertainties surrounding the quantities and heat values of current and future MSW further complicate the projection process. More refined projections must await more complete and defensible data on the quantity and composition of MSW and additional work on how and why communities adopt different management options.

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