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Assessment of Municipal Solid Waste for Energy Production in the Western United States

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Preface

This report was prepared for the Western Area Power Administration (WAPA). WAPA manages the Western Regional Biomass Energy Program (WRBEP) for the U.S. Department of Energy. WRBEP established an Ad Hoc Resource Committee to determine the most appropriate feedstocks to be considered for energy production in the 13-state western region. This report is designed to provide the committee members with information to assist them in making this determination.

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1.0 INTRODUCTION

Approximately 250 million tons of municipal solid waste (MSW) are generated by the residential, institutional, and industrial sectors of this country each year. Every individual in the United States produces approximately 3.5-5.0 lb of MSW daily. This represents a significant national environmental problem, but also a potentially valuable resource for renewable energy production. Aside from industrial discards, the Environmental Protection Agency (EPA) estimates that residential and commercial wastes account for approximately 160 million tons. This amount is constantly increasing; the figure is projected to reach about 198 million tons by the year 2000.

The Western Area Power Administration (WAPA) manages the Western Regional Biomass Energy Program (WRBEP) for the U. S. Department of Energy. The western region encompasses Arizona, California, Colorado, Kansas, Nebraska, Nevada, New Mexico, Oklahoma, North Dakota, South Dakota, Texas, Utah, and Wyoming. To determine the most appropriate feedstocks to be considered for energy production in this 13-state region, WRBEP established an Ad Hoc Resource Committee. At their meeting, the committee members requested information on the status of MSW in these states, including economic and environmental issues. This report is designed to provide the committee members with data to assist them in determining the potential for using MSW to produce energy in this region.

The background section covers general information on MSW. Section 3.0 gives data on population and population density for each of the 13 states, as well as information on the economy of these states. Data on the amount of MSW generated in each state and information on each state's landfills are included in Section 4.0. Section 5.0 discusses options for energy recovery from MSW and current waste-to-energy facilities in this region. Environmental issues, including federal regulations, state regulations (where available), and public opinion, are discussed in Section 6.0. Specific conclusions and/or recommendations are not made in this report, as the intent of this document was simply to provide the Ad Hoc Committee with information. However, some general trends are noted in Section 7.0. Appendix A provides names, addresses, and phone numbers for the Ad Hoc Committee members contacted in compiling this report. Federal and state government agencies involved in waste to energy are listed in Appendix B. Appendix C lists system vendors/operators and equipment manufacturers. Engineering, management, and technical consultants in the municipal waste field are listed in Appendix D. A paper describing U.S. regulatory, research, and legislative activities related to municipal waste combustion facilities is included as Appendix E. Appendix F is a bibliography of resources used in preparing this report.

2.0 BACKGROUND

Information regarding the quantities and composition of MSW is required for appropriate solid waste management. There is no "typical" composition of MSW because it varies from season to season, location to location, and day to day. However, historical and projected quantities of materials in the U.S. municipal waste stream have been provided by Franklin Associates, Limited, and are shown in Table 2-1 below.

Table 2-1. Materials Discarded into the U.S. Municipal Waste Stream 1970-2000*
(in millions of tons)

	1970		1986		2000	
	Million ton/yr	%	Million ton/yr	%	Million ton/yr	%
Paper and paperboard	36.5	32.4	50.1	35.6	66.0	39.1
Glass	12.5	11.1	11.8	8.4	12.0	7.1
Metals	13.5	12.0	12.6	8.9	14.4	8.5
Plastics	3.0	2.7	10.3	7.3	15.6	9.2
Rubber and leather	3.0	2.7	3.9	2.8	3.8	2.3
Textiles	2.0	1.8	2.8	2.0	3.3	2.0
Wood	4.0	3.6	5.8	4.1	6.1	3.6
Other	0.1	--	0.1	--	0.1	--
Food Waste	12.8	11.4	12.5	8.9	12.3	7.3
Yard Waste	32.2	20.6	28.3	20.1	32.0	19.0
Miscellaneous inorganics	1.9	1.7	2.6	1.8	3.2	1.9
Total	**112.5**	**100.0**	**140.8**	**100.0**	**168.8**	**100.0**

*Wastes discarded after materials recovery and before energy recovery.

The relative magnitude of the various materials in the municipal waste stream is illustrated in Figure 2-1. The largest fraction of MSW is paper and paperboard, followed by yard waste. The next most significant component, called "other," varies greatly depending on the source of the MSW and the season. Food waste and metals are approximately the same percentage of MSW, followed by glass, plastics, and miscellaneous inorganic materials. A few comments on each of the materials follow.

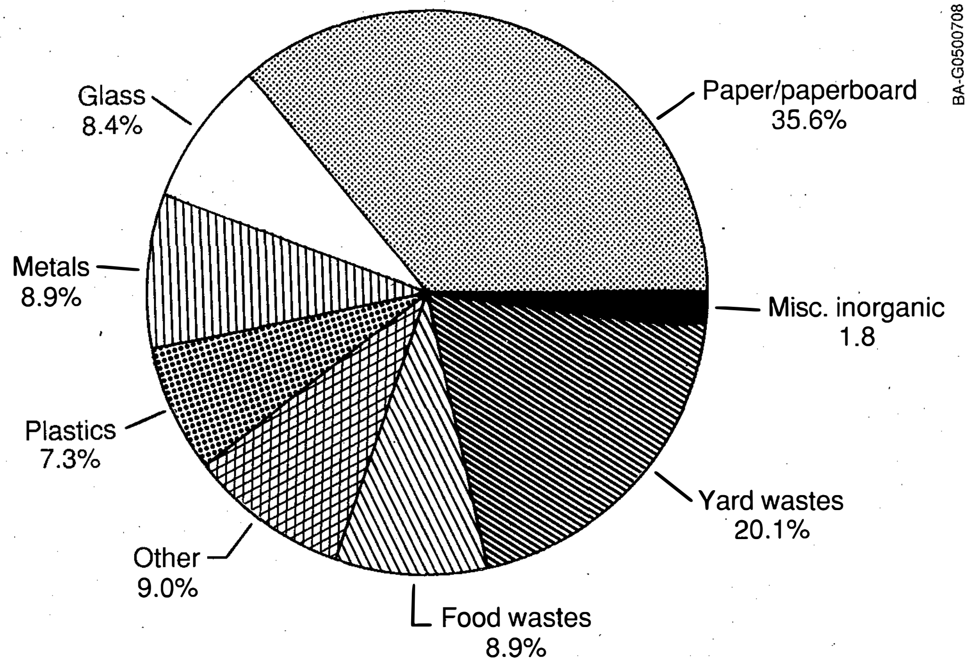


Figure 2-1. Materials discarded into the municipal waste stream in 1986 (percentage of total)

Paper and Paperboard. Paper and paperboard make up the largest category of MSW, ranging from 24.5 million tons disposed in 1960 to 50 million tons disposed in 1986. Paper and paperboard discards are projected to reach 66 million tons by 2000. Paper's share of municipal waste stream discards has ranged from 30% to 35% over the past quarter of a century. The upward trend is projected to continue.

Glass. The percentage of tons of glass (mostly containers) in the waste stream increased steadily until the early 1980s, then began to fall slowly. Glass comprised 8% in 1960, rising to more than 11% in the early 1980s, then falling to 8% in 1986. The percentage of glass in the waste stream is projected to fall to under 8% by 2000 because of increased recycling efforts and the increased use of plastic containers.

Ferrous Metals. Currently, ferrous metals total about 11 million tons in the waste stream. The ferrous metals tonnage has remained fairly constant over the years; thus, as a percentage of the total, ferrous metals have decreased. This trend is projected to continue.

Aluminum. Aluminum in the municipal waste stream has increased steadily, but the tonnage of this light metal is still very small -- only 1.7 million tons in 1986. In percentage, aluminum has grown from less than ½ of 1% in 1960 to just over 1% in 1986. This trend is expected to continue, possibly because of effective recycling efforts for this material.

Other Nonferrous Metals. Metals such as copper and brass comprise a very small share of the municipal waste stream -- less than 1%. Their tonnage has been about 300,000 tons in recent years; this is projected to increase to 400,000 tons by 2000.

Plastics. Plastics in the waste stream have increased steadily, from approximately one-half million tons in 1960 to more than 10 million tons in 1986. This trend is expected to increase to 15.6 million tons in 2000.

Rubber and Leather. This category, which includes rubber tires, grew in tonnage from 1.7 million tons in 1960 to 4.1 million tons in 1981. Since then, tonnage has been declining, and any growth is expected to be very slow. Rubber and leather have ranged from 2.1% to 3.2% of the waste stream, and the percentage is projected to remain fairly constant at about 3%.

Textiles. Textiles have stayed at a fairly constant 2% of the municipal waste stream. Tonnage has ranged between 2 million and 3.4 million tons.

Wood. Wood in the municipal waste stream was estimated at 3 million tons in 1960, increasing to 5 million tons in the early 1980s, and continuing to grow slowly to 6 million tons in 2000. The percentage of wood has been about 4% or slightly less of the total.

Food Wastes. Disposal of food wastes in the United States is poorly documented compared to other product wastes. However, food wastes are estimated to have increased from 12.2 million tons in 1960 to 13.4 million tons in 1975. Thereafter, food wastes are estimated to show a slightly decreasing tonnage, to 12.3 million tons by 2000. In terms of percentage of net discards in the waste stream, food wastes are estimated to have fallen from nearly 15% in 1960 to about 9% in 1986. They are projected to decrease to about 7% in 2000, mainly because of increased home garbage disposal use.

Yard Wastes. Like food wastes, yard wastes are not well documented, and they vary widely from region to region. Based on previous work and sampling studies, yard wastes are estimated to have been 20 million tons in 1960, increasing to 28.3 million tons in 1986. They are projected to reach 32 million tons by 2000. Percentage of total decreased from about 24% in 1960 to about 20% in 1986.

Miscellaneous Inorganic Wastes. This category, composed mostly of stones and dirt, is also poorly documented. The tonnage increased slowly from 1.3 million tons in 1960 to 2.6 million tons in 1986, with a slow increase thereafter, to 3.2 million tons. This category represents less than 2% of the municipal waste stream.

3.0 ECONOMY AND POPULATION OF THE REGION

The feasibility of using MSW for energy production depends on a number of factors including the economy of the area, population, and land availability. These factors for the 13-state region encompassed by WRBEP are highly variable. A brief description of the economy of each of the 13 states follows.

Arizona. Arizona's economy is sometimes characterized by the five "C's" - copper, cotton, cattle, climate, and citrus. This characterization, however, omits a vital and growing element -- manufacturing.

Income from crops usually makes up somewhat more than half the total farm income. Cotton is the largest cash crop with hay, sorghum, grain, barley, corn, vegetables, and citrus fruits also contributing to the farm economy. In the livestock and livestock products category, cattle bring the largest proportion of the cash income with dairy products ranking second.

Since the 1900s, Arizona has led the United States in the production of copper. Its mines yield just over half the U.S. total. Other than copper, the metals with greatest production value are molybdenum, silver, gold, zinc, lead, and uranium. The most valuable nonmetals are sand and gravel.

Most of Arizona's economic growth since the 1950s has been in manufacturing. Important categories of manufacturing include electrical machinery, primary metals, food and food products, lumber, and wood products.

National parks and monuments attract many visitors; however, the bulk of Arizona's tourist business is centered in Phoenix and Tucson.

California. California's economy benefits from its many natural resources as well as from a mounting population. These resources have enabled the state to lead the nation in agriculture and fisheries and have placed it near the top in manufacturing, mineral and lumber production, and tourism.

Employment in manufacturing industries is the leading source of personal income in California with services, government, and wholesale and retail trade following in that order. California's favorable climate permits crops to be grown over longer periods than elsewhere. Mechanization and irrigation are widespread with many farms specializing in only one or two crops. The range of products is wide, including livestock, feed crops, food grains, cotton, vegetables, fruits, and nuts. California leads in canning, freezing, and drying of foods. It also produces approximately 85% of the nation's wines. It is the leading state in commercial fishing and fish canning and is second to Oregon in lumber production.

Engineering and production of aircraft, missiles, and television and communications equipment also contribute to California's economy. Recycling of packaging and waste materials is also an economically important activity.

Research and development as well as mining and minerals extraction contribute to California's economy. California provides the only domestic source of boron minerals and compounds and is also the leading world supplier for these materials. The entertainment and associated industries contribute significantly to California's economy.

Manufacturing, governmental activities, trade, and services dominate Colorado's economy, but agriculture and mining are also important. Two-fifths of Colorado's land is devoted to farming, with cattle being the primary livestock and winter wheat the most valuable single crop.

Mining and mineral extraction are important to this state's economy with petroleum being the primary fuel and molybdenum the principal metal.

Colorado is not heavily industrialized; however, manufacturing is the foundation of its well-being, and food processing is one of Colorado's major industries. Manufacture of machinery is also an important industry. Research and development and tourism also contribute to this state's economy.

Kansas. The economy of Kansas is diversified, with the largest number of people employed in wholesale and retail trade, followed by manufacturing, government, and service industries. Transportation equipment industries are the leading employers, and aircraft companies dominate that sector. Meat packing and milling are also important industries.

Kansas is first in wheat production and among the leaders in production of sorghum, beef, and alfalfa. The livestock industry is also of economic importance throughout the state.

Valuable deposits of petroleum, natural gas, and coal exist in Kansas.

Nebraska. Throughout its history, Nebraska has been primarily an agricultural state. In recent years, however, agricultural employment has declined and manufacturing activities have increased. More than half of Nebraska's farm income comes from the sale of livestock and livestock products. Corn is the leading crop grown in the state. Other important crops include wheat, soybeans, sorghum, and hay. Leading manufacturing industries include production of printed materials and instruments. Mining plays a relatively small role in the state's economy. Petroleum is the major mineral product of commercial importance.

Nebraska is unique among the states in that all electric utilities are publicly owned. Most electricity is produced and supplied by public power districts governed by popularly elected boards of directors.

Nevada. Tourism is the leading economic activity in Nevada, producing more than 50% of the income generated in the state. Nevada's most important agricultural activity is the raising of livestock, especially cattle and sheep. About 85% of all farm income is derived from livestock raising and feeding. Fruits and vegetables account for 11%.

Minerals produced include gold, copper, silver, mercury, molybdenum, lead lithium, and tungsten. Nonmetallic minerals include barite, sand, cement, gypsum, and stone.

Nevada is one of the leading industrialized states. Important industries include food processing, printing and publishing, metal item fabrication, and chemical production. Ore smelting is also an important activity.

New Mexico. Farming was the dominant economic activity in New Mexico until the 1940s, when it was surpassed by mining, now the foremost economic activity. Natural gas and petroleum are the state's most valuable minerals. Coal production is also important. New Mexico has about 40% of the nation's total reserves of uranium. Copper, molybdenum, potash, gold, and silver are also mined.

There are more ranches than farms in New Mexico, and cattle are the main livestock. Hay and wheat are the leading cash crops.

North Dakota. Agriculture is the basis of North Dakota's economy; however, mining, manufacturing, and tourism are also important. North Dakota ranks first among the states in production of spring wheat, durum wheat, barley, sunflower seed, and flaxseed. Many North Dakota farmers gain additional income by raising hogs and sheep.

Lignite coal is North Dakota's most valuable mineral resource. Petroleum and natural gas also contribute to the mining income of the state.

Oklahoma. Oklahoma's economy is a balance of agriculture, mining, and manufacturing. Livestock is responsible for the greatest portion of farm income in Oklahoma; winter wheat is second. Minerals and mining are focused on oil and natural gas. Other than fuels, important minerals include cement, stone, sand, and gravel. The most important industries today are the manufacture of nonelectrical machinery, fabricated metals, rubber and plastic products, petroleum and coal products, and electrical equipment.

South Dakota. Agriculture is the economic mainstay of South Dakota with manufacturing, tourism, and mining contributing a lesser, but significant, share. Approximately 70% of all farm receipts comes from the sale of livestock and livestock products. Only 20% comes from the sale of crops.

Meat-packing and processing industries have grown in South Dakota. Mining operations also contribute to the economy with gold being the most profitable.

Texas. Texas traditionally leads the nation in production of livestock, cotton, and grain sorghum. The quality of its beef cattle is renowned. The state ranks first in value of mineral production, and its petroleum-related industries continue to grow.

Texas ranks fourth in the nation in total farm income with almost 85% of the land used for farms and ranches. Agricultural income is equally divided between livestock, poultry, and crop production.

More than 90% of the total value of the state's mineral production is from mineral fuels such as petroleum and natural gas. Texas is also one of the leading states in the production of sulfur, helium, salt, and cement.

Manufacturing varies in Texas from processing of natural resources and agricultural products to machinery manufacturing. Tourism has also become a major source of income for Texas.

Utah. Beef and dairy products are important in Utah. Hay, winter wheat, and barley are Utah's chief crops. Mink raising in Utah ranks third in the nation.

Utah's most important industrial activity is the manufacture of electrical machinery. Other leading industries include the manufacture of guided missiles and space vehicles, food processing, and the production of electrical equipment.

Petroleum is Utah's most valuable mineral followed by coal, copper, and natural gas. Gold, silver, and salt are also produced in significant quantities.

Tourism also contributes to the state's economy.

Wyoming. Wyoming is the least industrialized state in the nation. Mining is the most important industry, and petroleum is its major product. Wyoming is the nation's leader in uranium production. Coal production is a rapidly expanding industry. Ranching is the state's second most important industry. Principal crops are beans, sugar beets, alfalfa, hay, oats, barley, corn, and potatoes. Almost all the manufacturing is related to petroleum, uranium, and coal processing. Food processing and manufacture of flight equipment also contribute to the economy.

Because the economy of this region is so diverse, generalizations about similarities within the waste stream are difficult to make. However, agriculture, manufacturing, mining, and tourism appear to be the most important in this region. The number of people in a given area closely correlates to the amount of municipal waste generated. Figure 3-1 shows population data for each of the 13 states encompassed by WRBEP. It is interesting to note that in this region the states with the largest populations tend to be the states with the largest area, in contrast to the situation in the Northeast. This may be why we have not seen as much attention being given to waste-to-energy projects in the western United States as in the Northeast.

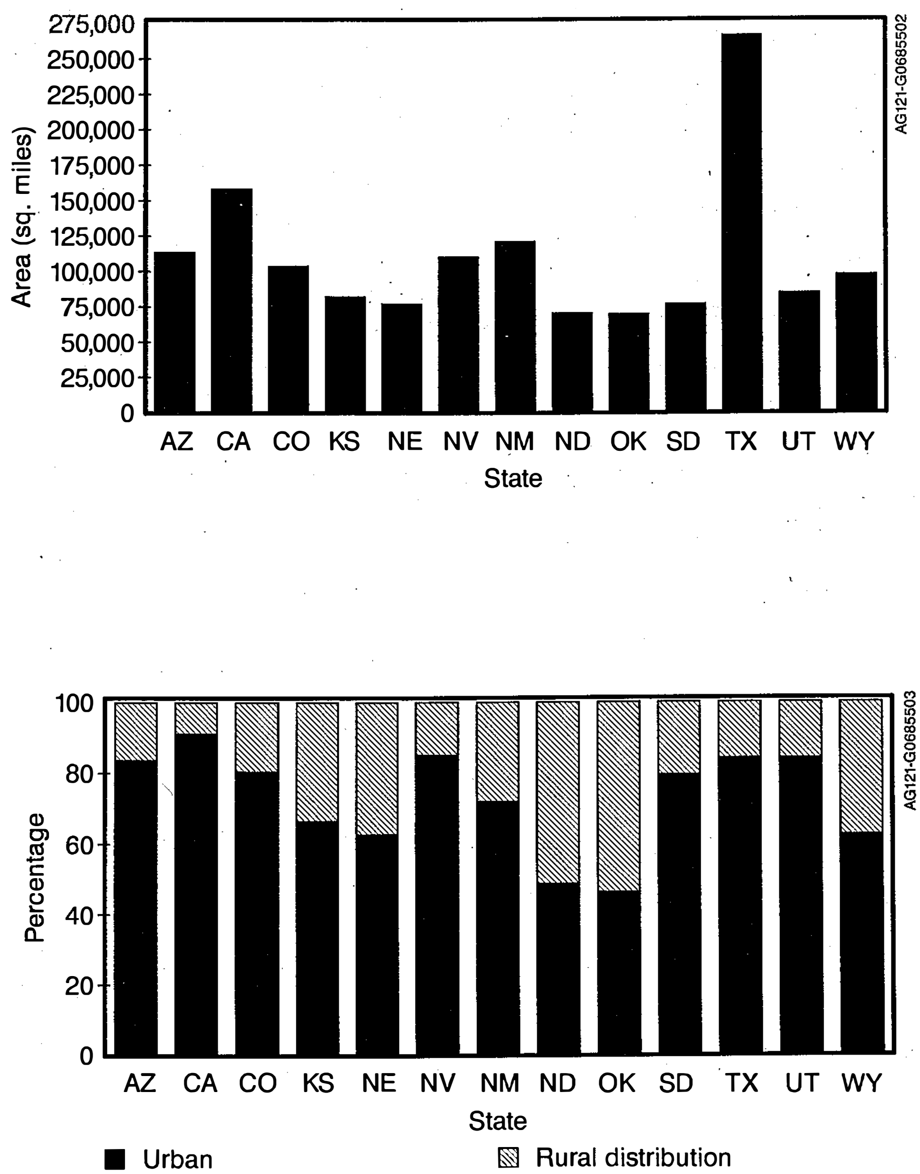


Figure 3-1. Population data for region

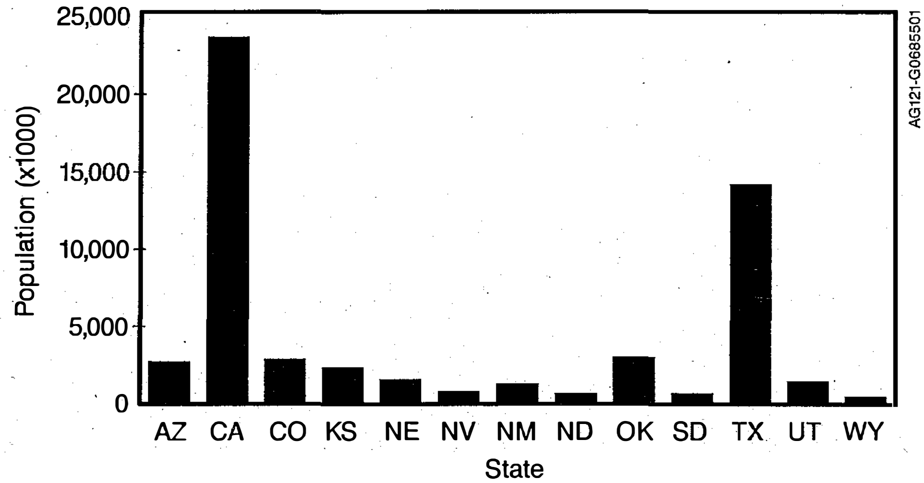


Figure 3-1. Population data for region (Concluded)

4.0 GENERATION & LANDFILL CAPACITY

According to the National Solid Waste Management Association (NSWMA) Annual Tipping Fill Survey, the 1988 average at landfills was $26.93 per ton, up 32.3% from the 1987 figure. At waste-to-energy facilities, this average was $39.86 per ton. Based on discussions with the members of the Ad Hoc Committee for WRBEP and information available in the literature, Table 4-1 was compiled. It summarizes the amount of MSW generated per day for each of the 13 states, assuming an average production of 4.0 lb per person per day, along with the average or range of tipping fee and cost of electricity for each state.

Table 4-1. MSW Generation, Tipping Fee, and Electricity Cost for Region

State	MSW Generation (tons/day)	Tipping Fee ($/ton)	Cost of Electricity (¢/kwh)
Arizona	5,433	7-25	9-10
California	47,336	3-20	N/A
Colorado	5,779	2-14	6.5
Kansas	4,728	3-17	7.5
Nebraska	3,140	5-13	4-7
Nevada	1,601	10	5-8
New Mexico	2,607	0-12	10
North Dakota	1,305	N/A	N/A
Oklahoma	6,051	20	N/A
South Dakota	1,382	0-10	3-7
Texas	28,451	6-15	8
Utah	2,922	6-35	6-8
Wyoming	939	1	3

According to the EPA's latest calculations, half our nation's landfills will be closing by 1995, leaving large amounts of refuse without local disposal options. Current construction rates are expected to add only about four million tons per year of new capacity, which may force many communities to ship their waste to distant sites at large costs. Table 4-2 shows EPA's projection for landfill closings for 1988 to 2000.

Currently, 75% of our garbage is deposited in landfills, while 11% is recycled and 13% is burned in waste-to-energy plants. Table 4-3 shows historical and projected trends in solid waste management as given by Governmental Advisory Associates.

Americans are putting increased emphasis on source reduction, recycling, and resource recovery. Source reduction is an attempt to reduce the volume of trash before it is produced. In addition, problematic materials such as lead and cadmium need to be minimized in manufacturing processes to decrease threats to groundwater when discarded.

Table 4-2. Projected Landfill Closings, 1988-2000

Year	Operating Landfills	Annual Intake* (millions of tons)
1988	5,499	187
1993	3,332	131
1998	2,720	94
2000	2,157	76

*Includes industrial and other wastes deposited in solid waste landfills.

Table 4-3. U.S. Solid Waste Management

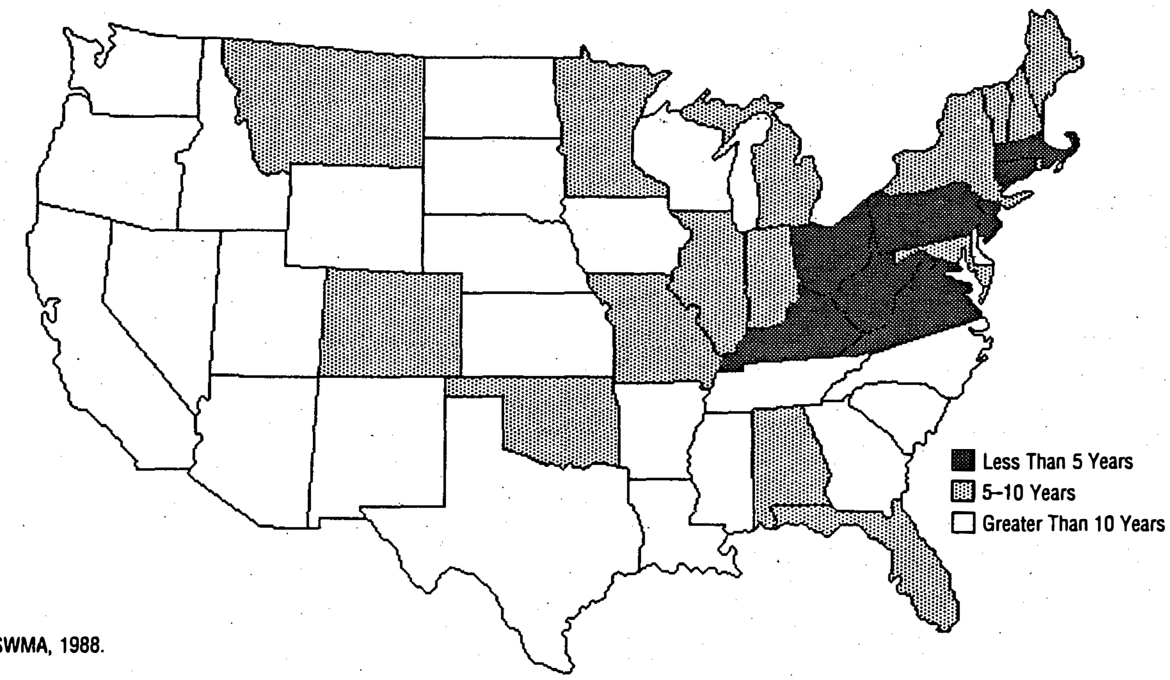
	1960 Volume*	%	1970 Volume	%	1988 Volume	%	2000 Volume	%
Landfills	81.7	93	112.1	93	119.8	76	96.3	50
Recycle	5.8	7	8.0	7	17.3	11	48.2	25
Waste-to-Energy	-	-	0.4	<1	20.5	13	48.2	25
Total	**87.5**	**100**	**120.5**	**100**	**157.6**	**100**	**192.7**	**100**

*in millions of tons per year

Many communities are able to recover 20% to 25% of their residential and commercial waste through recycling. Such wastes include glass bottles, cardboard and paper, aluminum cans, and other materials. If these programs are to succeed, viable and stable markets for these materials are required. Waste-to-energy plants reduce the remaining volume of waste by 90%. These plants use state-of-the-art pollution control equipment to protect the environment and recover the heating value of garbage as steam or electricity. Proper landfilling of remaining wastes and ash from waste-to-energy plants is still required.

Most solid waste landfills are owned by local jurisdictions and tend to be small sites located in rural or outlying areas. Private landfills represent 14% of the total, but include half the country's existing disposal space. But size and volume are not the only factors determining landfill capacity. Tougher environmental regulations are forcing older landfills to close regardless of how full they are. Five states -- California, Maine, New York, Texas, and Wisconsin -- now include about 40% of all MSW landfills in the United States. EPA estimates that landfill space throughout the United States will largely be exhausted within ten years; while most urban centers in the Northeast and Great Lakes region will run out by 1993. Without additional construction, remaining capacity will be mismatched with the places where most people live. These communities will have to ship their wastes to other landfills at high costs. The states included in WRBEP's region may be forced to accept these wastes in spite of the public "not in my backyard" syndrome.

Figure 4-1 shows landfill capacity by state and clearly indicates greater availability in the western part of the United States than many other areas of the country. Current legislation has been introduced to restrict the amount of waste that can be shipped across state lines, but there has been no definitive resolution to this situation.



Source: NSWMA, 1988.

Figure 4-1. State landfill capacity

5.0 CURRENT UTILIZATION OF MSW

There are a number of energy recovery options for converting the organic components of the municipal waste stream into useful energy products. Figure 5-1 shows some traditional approaches as well as longer term alternatives still in the research and development (R&D) stage. Traditionally, waste has been deposited into landfills where microorganisms degrade the organic components to methane and carbon dioxide. Recent efforts to produce energy from MSW utilize mass burn technology to produce steam and/or electricity; other options are still being researched.

Currently, more than 100 waste-to-energy plants are operating in the United States. These plants burn refuse at high temperatures and reduce its volume by as much as 90%. These facilities receive about 13% of the U.S. waste stream and produce an ash residue, which must be buried in appropriate landfills. A major advantage of these facilities is that they produce steam or electricity to help offset the cost of construction.

Table 5-1 breaks the solid waste projects in the United States into three categories: the advanced planning to operational stage includes 202 facilities that are all in advanced stages of planning (under

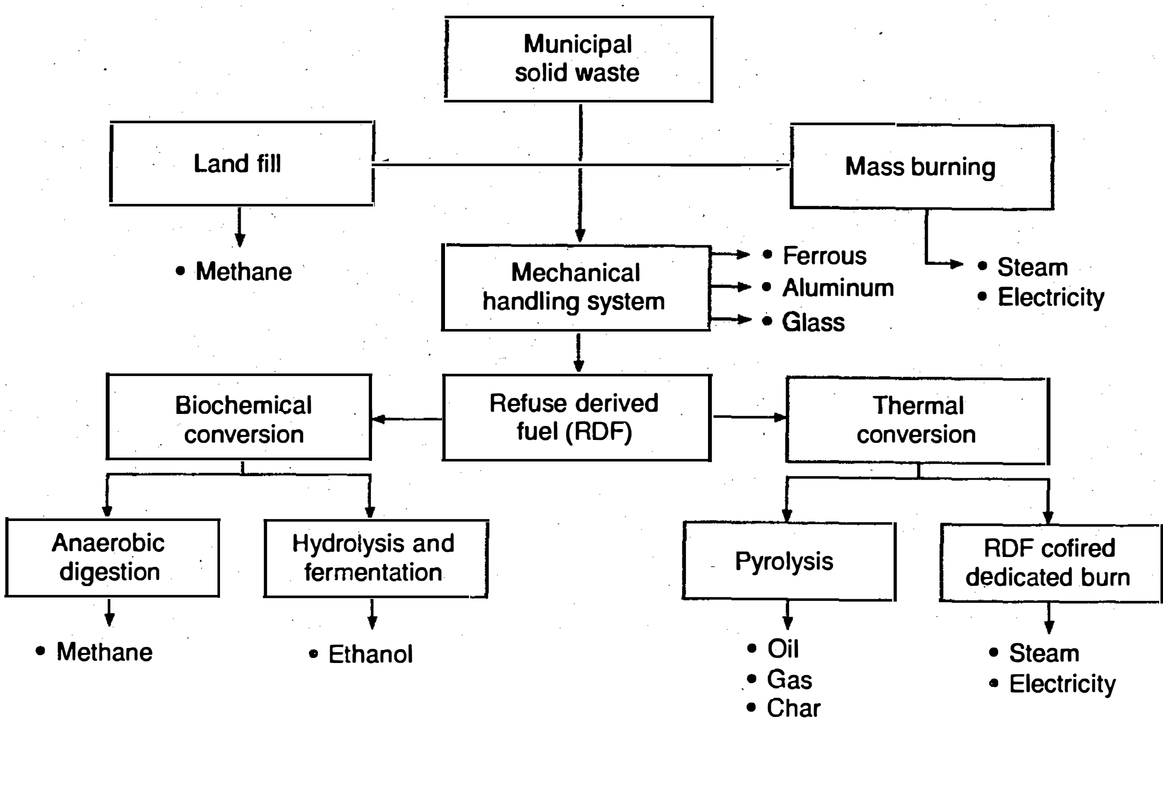


Figure 5-1. MSW energy recovery options

Table 5-1. Waste-to-Energy Projects in the United States

Advanced Planning to Operational Stage	202
Conceptual Stage	139
Permanently Shut Down	27
Total	**368**

construction, operational, and/or temporarily shut down for the purpose of retrofitting). These facilities have secured construction or full-service contracts and have developed construction schedules. The 139 projects in the conceptual stage have completed feasibility studies, requests for qualification (RFQ), or requests for proposals (RFP). The 27 facilities that are permanently shut down closed mainly because of equipment problems, followed by unfavorable economics and environmental problems.

Figure 5-2 shows the locations of existing waste-to-energy facilities. The greatest concentrations are in the Northeast and the Midwest. Population density and landfill availability appear to be the major reasons for the prevalence of facilities in these regions.

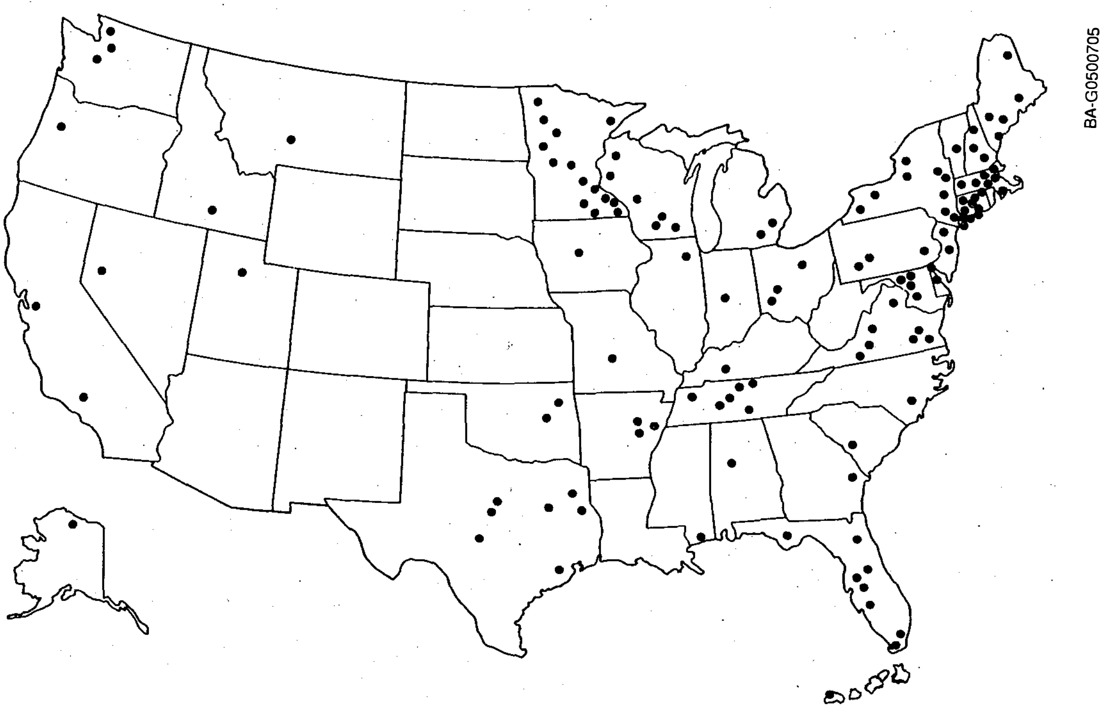


Figure 5-2. Location of existing waste-to-energy plants

The majority of these systems are mass burn units, as shown in Table 5-2.

Table 5-2. Current Waste-to-Energy Processes for the United States

Type of Process	%
Mass burn	47.0
Modular	34.2
Refuse-derived fuel	17.8
Other	1.0

The distribution of existing and planned facilities is shown in Table 5-3. The West is somewhat behind other regions of the nation, but the number of planned facilities is increasing. The time frame in which the planned facilities will become operational depends somewhat on the outcome of pending EPA regulations (see Appendix E).

Table 5-3. Distribution of Waste-to-Energy Projects

	% Existing	% Planned
Northeastern	36.6	49.5
Southern	33.2	20.9
North Central	19.8	17.6
West	10.4	12.0

The primary energy form for existing facilities is steam. However, as can be seen in Figure 5-3, the trend for planned facilities will be toward exclusive electricity generation. This trend can be explained by the fact that a number of past projects that sold steam to public or private customers encountered difficulties when the fuel buyers terminated or curtailed steam purchases. The sale of electricity involves less financial risk to project developers. Many developers, however, are still interested in selling steam because higher rates can generally be obtained from steam customers than electric utilities (especially in regions where "avoided-cost" of generating electricity is low).

The types of processes used in the western United States and their efficiencies are given in Table 5-4. The efficiency is defined as the actual capacity divided by the design capacity. Specific states where existing and planned facilities are located in the WRBEP area are given in Table 5-5. Table 5-6 gives details for each of these facilities including the start-up date, the size in tons per day, the type of system, the primary energy product, the cost received for sale of electricity (where applicable), and the capital cost.

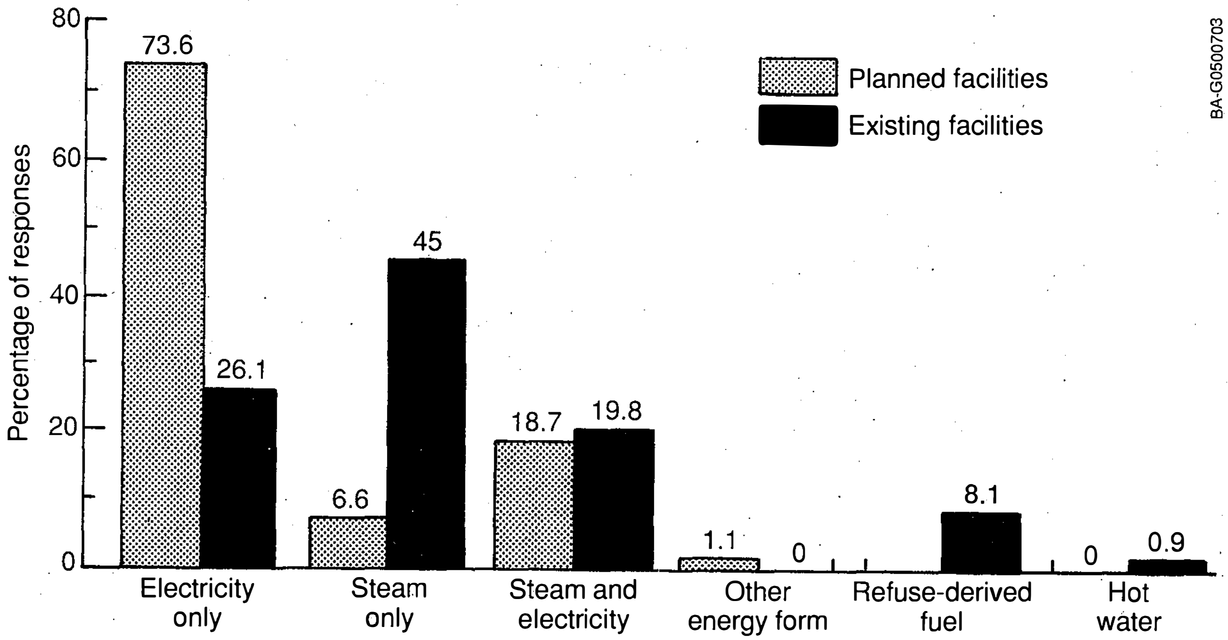


Figure 5-3. Primary energy form: planned and existing facilities

Table 5-4. Type of Process of Western Region

Type of Process	%	Efficiency
Mass Burn	47.6	0.847
Modular	28.6	0.817
Refuse-derived fuel	23.8	0.825
Other	0	

Table 5-5. Waste-to-Energy Facilities in Western Region

State	Existing	Planned
California	2	4
Nevada	0	1
Oklahoma	2	0
Texas	7	3
Utah	1	0
Total	**12**	**8**

Table 5-6. Existing/Planned Waste-to-Energy Facilities in the Western Region

Location	Date	Size (TPD)	Type	Primary Product	Cost of Electricity (¢/kWh)	Capital Cost ($ M)
Miami, OK	11/82	108	Mod.	Steam	N/A	3.56
Oklahoma City, OK	9/86	820	RDF	Elec.	4.20	32.00
Tulsa, OK	3/86	1125	MB	Steam	N/A	114.00
Austin, TX	9/90	800	MB	Elec.	N/A	70.00
Carthage, TX	1/86	40	Mod.	Steam	N/A	1.66
Center, TX	8/86	40	Mod.	Steam	N/A	1.87
Cleburne, TX	3/86	115	Mod.	Elec.	2.20	5.70
Gatesville, TX	2/80	13	Mod.	Steam	N/A	0.98
Lubbock, TX	1/90	425	Mod.	Elec.	3.92	21.10
Palestine, TX	2/80	25	Mod.	Steam	N/A	1.30
Texas City, TX	12/90	425	Mod.	Elec.	4.50	28.50
Waxahachie, TX	6/82	50	Mod.	Steam	N/A	2.64
Layton, UT	1/88	400	MB	Steam	N/A	40.00
Commerce, CA	5/87	400	MB	Elec.	8.70	35.48
Long Beach, CA	8/88	1380	MB	Elec.	8.10	102.00
Crows Landing, CA	11/88	800	MB	Elec.	8.00	85.18
San Bernadino, CA	4/90	1600	MB	Elec.	9.50	164.00
San Marcos, CA	9/90	2000	RDF	Elec.	6.20	217.00
Susanville, CA	11/84	100	Mod.	S & E	5.30	7.50
Reno, NV	12/90	1000	RDF	S & E	5.50	100.00

Legend

TPD = tons per day
MB = mass burn
Mod. = modular
RDF = refuse-derived fuel
Elec. = electricity
S&E = steam and electricity

6.0 ENVIRONMENTAL ISSUES

The EPA is currently developing air pollution emission rules for new and existing municipal waste combustion facilities pursuant to Section III of the Clean Air Act. These rules were proposed in November 1989, and promulgation is planned for December 1990. A paper providing information on EPA's technical activities related to this regulatory effort is included as Appendix E.

State-by-state current regulations are listed below.

Arizona. All incinerators must have two permits: an air quality permit and a solid waste permit. All incinerators must meet a particulate emissions standard of 0.1 gr/dscf (corrected to 12% CO_2) and a visual emissions standard of 20% opacity. For more information, call the Department of Environmental Quality, Air Quality Section in Phoenix at (602) 257-2277 and Solid Waste Section at (602) 257-6989.

California. Air quality is regulated by Air Quality Management Districts; regulations vary from district to district. All districts require permits to operate incinerators. Each district has particulate, visual, and air toxics emission standards. The air toxics emissions requirements depend greatly on the location of the facility and vary significantly from district to district. There are many other requirements. If the incinerator treats wastes generated offsite, it must have a permit from the State Health Services Department. For more information, call the California Department of Health Services, Hazardous Materials Management Section in Sacramento at (916) 324-9611.

Colorado. A permit is required for all incinerators. Particulate emissions may not exceed 0.1 gr/dscf (corrected to 12% CO_2). The visual emissions standard is 20% opacity. If offsite wastes are treated, a certificate of designation is required by the Solid Waste Management Department. Proposed regulations, which include air toxics emissions limits, will probably go into effect in late 1989 or early 1990. For more information, call the Department of Health, Air Pollution Control Division in Denver at (303) 331-8591.

Kansas. There are many solid waste processing requirements, including regulations on waste handling, storage, and ash disposal. Air quality regulations include particulate emissions standards that range from 0.10 to 0.30 gr/dscf (corrected to 12% CO_2) depending on the capacity of the incinerator. The visual emissions standard is 20% opacity. For more information, call the Department of Health and Environment, Solid Waste Management Section in Topeka at (913) 296-1590 and the Air Quality and Radiation Section at (916) 296-1572.

Nebraska. Incinerators with capacities less than 1 ton/h may not emit particulate matter at a rate greater than 0.2 gr/dscf (corrected to 12% CO_2). Larger incinerators may not emit more than 0.1 gr/dscf (corrected to 12% CO_2). Visual emissions may not exceed 20% opacity. Incinerators must meet best available control technology (BACT) if they emit more than 2.5 ton/yr of any of 309 specified contaminants. Other requirements, including secondary temperature and retention time, are written into permits. These requirements are determined on a case-by-case basis. For more information, call the Department of Environmental Control, Air Quality Division in Lincoln at (402) 471-2189.

Nevada. All incinerators must have a permit. The particulate emissions standard for incinerators with capacities less than 2000 lb/h is 3 lb/ton dry charge. The allowable particulate emissions rate for larger incinerators, e(lb/h), is determined by the formula

$$e = (40.7 \times 10^{-5})c,$$

where *c* is the charge rate in pounds per hour. The visual emissions standard is 20% opacity. The secondary chamber temperature must be at least 1400°F with a residence time of 0.3 s. There are also air toxics emissions limits. A county commission permit is required and is often difficult to obtain. For more information, call the Department of Conservation and Natural Resources, Division of Environmental Protection in Carson City at (702) 885-5065.

New Mexico. A permit is required for incinerators that emit any criteria pollutant at a rate greater than 10 lb/h for controlled emissions and greater than 100 lb/h for uncontrolled emissions. Visual emissions may not exceed 20% opacity. Registration of air toxics emitted above certain levels is required. Other requirements are determined on a case-by-case basis and specified in the permits. For more information, call the Health and Environment Department, Air Quality Bureau in Santa Fe at (505) 827-0070.

North Dakota. Incinerators must have a permit. The allowable particulate emission rate, *e*, is determined by the formula

$$e = 0.00515(R^{0.9}),$$

where *R* is the refuse burning rate in lb/h. Visual emissions may not exceed 20% opacity. The regulations state that the secondary chamber temperature must be at least 1500°F with a retention time of 0.3 s. However, more stringent requirements are usually written into permits. A minimum secondary chamber temperature of 1800°F and a retention time of 1 s are usually specified. There are no restrictions on air toxics emissions. For more information, call the Department of Health, Air Quality Management Branch in Bismarck at (701) 224-2348.

Oklahoma. Permits are required for all incinerators. Incinerators must be of multiple chamber design with a primary chamber temperature of at least 800°F. The particulate emissions standards vary depending on the charge rate. Visual emissions may not exceed 20% opacity for more than 5 min in 1 h and not more than 20 min in 24 h. For more information, call the Department of Air Quality Service in Oklahoma City at (405) 271-5220.

South Dakota. Permits are required for incinerators with capacities larger than 100 lb/h. The particulate standard for incinerators with capacity greater than or equal to 50 ton/day is 0.18 gr/dscm (corrected to 12% CO_2). There is no particulate emissions standard for smaller incinerators. Visual emissions may not exceed 20% opacity. For more information call the Department of Water and Natural Resources, Office of Air Quality and Solid Waste in Pierre at (605) 773-3153.

Texas. Incinerators must be of dual chamber design with a secondary chamber temperature of at least 1800°F and a retention time of 1 s. The visual emissions standard is 20% opacity. If hydrogen chloride emissions exceed 4 lb/h, the incinerator must be equipped with a scrubber. Other requirements, including air toxics emissions limits, are determined on a case-by-case basis and specified in the permits. For more information, call the Air Pollution Control Board, Combustion Section in Austin at (515) 451-5711.

Utah. All new air pollution sources must have a permit. All sources must meet BACT. Requirements, including air toxics emissions limits, secondary chamber temperature and retention time, and particulate standards, are determined on a case-by-case basis and specified in the permits. For more information, call the Department of Health, Bureau of Air Quality in Salt Lake City at (801) 538-6108.

Wyoming. A permit is required for all incinerators. Two-stage combustion is required. Incinerators must meet BACT. The particulate emissions standard is 0.2 lb/100.0 lb refuse charged. Visual emissions may not exceed 20% opacity. For more information, call the Department of Environmental Quality, Air Quality Division, in Cheyenne at (307) 777-7391.

Types of pollution control for planned and existing facilities are given in Table 6-1. The baghouse or fabric filter and dry scrubbers are typically used in combination. Indications are that future waste-to-energy facilities will employ more sophisticated air pollution control equipment than current facilities. The combination of scrubbers and baghouse filters can remove both acid gases (i.e., HCl) and particulates from stack gases; electrostatic precipitators generally remove only particulates. More stringent air pollution control standards will dictate that advanced technologies be employed in most regions of the country.

Ash disposal legislation from waste-to-energy facilities remains controversial. Table 6-2 shows the percent of ash residue generated based on the weight of incoming MSW for various systems. The average produced per facility is 166.12 tons per day, with the daily U.S. generation being 31,396 tons.

Table 6-1. Pollution Control Equipment

Type	%
Baghouse or fabric filter	28.3
Dry scrubbers	29.6
Electrostatic precipitators (ESP)	26.4
After-burn systems	8.0
Other	5.7
Nothing	1.9

Table 6-2. Ash Production

Process	% of Design Capacity
Modular	26.9
Mass Burn	23.7
Refuse-derived fuel	13.7
Average	23.5
	(166.12 TPD)

7.0 TRENDS

The increased development of waste-to-energy facilities is closely related to the solid waste disposal crisis. The public's perception of solid waste issues has changed in recent years, with the "garbage barge" as a tangible example of the mounting problem. Although environmental concerns are associated with solid waste disposal, many political leaders are recognizing the need for alternatives to landfills. Recycling efforts have increased in many communities, but these alone are not sufficient to alleviate the landfill shortages.

More than 100 waste-to-energy facilities are now operating and 18 more are scheduled to come on line during the next five years, indicating continued growth of the industry. Relatively few projects exist or are being planned in the western United States.

A shift in technologies from modular units to larger mass-burn systems is occurring; however, a decrease in the design capacity has been seen since 1986. The movement in energy production is toward electric power generation and away from steam. A total of 1252 MW of electric power (gross) is generated by existing waste-to-energy plants. An additional 3805 MW will be available if all planned projects are built in the United States.

Table 7-1 shows the time range required to complete various activities associated with waste-to-energy projects and emphasizes the need to plan systems prior to landfill closures.

Table 7-1. Timing of the Waste-To-Energy Project Development Process

Activity	Time Range Required to Complete Activity
Perceive landfill problem; perform feasibility study of alternative MSW disposal methods; assess resource recovery markets	1-4 years
Project design; issue bids; negotiate markets	1-4 years
Select and negotiate contracts with contractor(s); obtain permits begin construction	1-4 years
Project shakedown and acceptance begin operations	1-3 years
Total	**4-15 years**

Appendix A

Ad Hoc Committee Contacts

Arizona

Mr. Ray Williamson
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California

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California Energy Commission
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Colorado

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112 E. 14th Avenue
Denver, CO 80203
(303) 894-2144

Kansas

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Kansas State University
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Nebraska

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New Mexico

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North Dakota

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State Capitol, 14th Floor
Bismarck, ND 58505
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Oklahoma

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Director of Programs
Office of the Governor
212 State Capitol
Oklahoma City, OK 73105
(405) 521-2342

South Dakota

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South Dakota Energy Office
217½ West Missouri
Pierre, SD 57501
(605)773-3603

Texas

Ms. Judith Carroll
Office of Budget and Planning
Energy Management Center
201 East 14th
P. O. Box 12428
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Austin, TX 78711
(512) 463-1871

Utah

Mr. Tom Turner
Utah Energy Office
3 Triad Center, Suite 450
355 West North Temple
Salt Lake City, UT 84180-1240
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Wyoming

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Econ. Develop. and Stabilization Bd.
122 W. 25th Street
Herschler Building
Cheyenne, WY 82002
(307) 777-7284

Appendix B

Government Agencies

Involved With

Waste to Energy

FEDERAL GOVERNMENT

U.S. Department of Commerce

National Bureau of Standards
Chemistry Bldg. B348
Gaithersburg, MD 20899
Dr. Eugene S. Domalski
(301) 975-2588

U.S. Department of Energy

Office of Conservation and Renewable Energy
Biofuels and Municipal Waste Technology Division
Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585
Donald K. Walter
(202) 586-6750

U.S. Department of the Interior

Environmental Technology
Recycling Research
240 E Street, NW
Washington, DC 20241
Roger DeCesare
(202) 634-1237

U.S. Environmental Protection Agency

Office of Solid Waste
401 M Street, SW
Washington, DC 20460
Siva Garg, Environmental Engineer, Combustion Program
(202) 382-7937

U.S. House of Representatives

House Committee on Energy and Commerce
Subcommittee on Energy and Power
Rayburn House Office Building
Washington, DC 20510
Philip Sharp, Chairman
(202) 226-2500

U.S. House of Representatives

House Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development
Rayburn House Office Building
Washington, DC 20515
Marilyn Lloyd, Chairman
(202) 225-8056

STATE GOVERNMENT

Arizona

Arizona Department of Environmental Quality
Waste Program Planning Section
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Phoenix, AZ 85004
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Arizona Energy Office
Department of Commerce
State Capitol, 5th Floor
1700 W. Washington
Phoenix, AZ 85007
Mark Ginsberg
(602) 255-3632

California

California Energy Commission
Energy Facilities Siting and Environmental Division
1516 9th Street, MS 16
Sacramento, CA 95814
Lorraine Van Kekerix
(916) 324-3213

California Energy Commission
Energy Technology Development Division
1516 9th Street, MS 43
Sacramento, CA 95814
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(916) 324-3517
George Simons
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California Waste Management Board
1020 9th Street, Suite 300
Sacramento, CA 95814
Herb Iwahiro, Chief Deputy Executive Officer
(916) 322-6329

Colorado

Colorado Department of Agriculture
Resource Analysis Section
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Denver, CO 80203
Dr. David Carlson
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Colorado Department of Health
Waste Management Division
4210 East 11th Avenue
Denver, CO 80220
David C. Shelton
(303) 320-8333

Colorado Office of Energy Conservation
112 East 14th Avenue
Denver, CO 80203
Janet Hartsfield, Assistant Director
(303) 894-2144

Kansas

Kansas Department of Health and Environment
Solid Waste Management Section
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Topeka, KS 66620
Charles H. Linn, Chief
(913) 862-9360

Nebraska

Nebraska Department of Environmental Control
Water and Waste Management Division
P. O. Box 904877
Lincoln, NE 68509
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(402) 471-4219

Nebraska, continued

Nebraska Energy Office
State Capitol
Lincoln, NE 68509
Larry Pearce
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Nevada

Nevada Department of Conservation and Natural Resources
Division of Environmental Protection
Waste Management Program
Capitol Complex
Carson City, NV 89710
Verne Rosse
(702) 885-5872

New Mexico

New Mexico Health and Environment Department
Solid Waste Section
Harold Runnels Building
P. O. Box 968-1190, St. Francis Drive
Santa Fe, NM 87504-0968
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North Dakota

North Dakota Department of Health
Division of Hazardous Waste Management
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Bismark, ND 58502
Martin R. Schock, Director
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North Dakota Office of Intergovernmental Assistance
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State Capitol Building
Bismark, ND 58508

Oklahoma

Oklahoma Department of Health
Waste Management Service
Solid Waste Division
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South Dakota

South Dakota Department of Water and Natural Resources
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Foss Building
Pierre, SD 57501
Joel C. Smith, Administrator
(605) 773-3329

South Dakota Office of Energy Policy
State Capitol
Pierre, SD 57501
Clint Roberts, Director
(605) 773-3603

Texas

Texas Department of Health
Division of Solid Waste Management
1100 West 49th Street
Austin, TX 78756
Hector H. Mentieta, P.E., Director
(512) 458-7271

Utah

Utah Department of Health
Bureau of Solid and Hazardous Waste
288 North 1460 West
Salt Lake City, UT 84116
Brent C. Bradford, Director
(801) 538-6170

Wyoming

Wyoming Department of Environmental Quality
Solid Waste Management Program
122 West 25th Street
Cheyenne, WY 82002
David A. Finley, Program Manager
(307) 777-7752

Appendix C

System Vendors/Operators and Equipment Manufacturers

Accutech Environmental Services, Inc.
100 Highway 35
Keyport, NJ 07735
Harry J. Moscatello, President
(201) 739-6444

American Baler Company
Hickory Street
Bellevue, OH 44811
J. B. Russell, Vice President,
General Sales Manager
(419) 483-5790

American Recycling Corporation
2501 Lynnwood Drive, #105
Arlington, TX 76013
Francis A. Swartz, President
(817) 265-4764

American Ref-Fuel Company
757 N. Eldridge (77079)
P. O. Box 3151
Houston, TX 77253
Ed Joran, Vice President
(713) 584-4504

American Resource Recovery
600 Larry Court
Waukesha, WI 53186
Dan Warren, Vice President
(414) 784-9200

Atlas Systems Corporation
East 6416 Main Avenue
P.O. Box 11496
Spokane, WA 99211
W. B. Hickman, P.E.,
Executive Vice President
(509) 535-7775

Babcock & Wilcox Company
Power Generation Group
1990 North California Blvd., Suite 400
Walnut Creek, CA 94596
J. C. Wilcox, Jr.
(415) 947-1100

Basic Environmental Engineering, Inc.
21 West 161 Hill Avenue
Glen Ellyn, IL 60137
John N. Basic, Sr., President
(312) 469-5340

Belco Pollution Control Corp.
8 Peach Tree Hill Rd.
Livingston, NJ 07039
Eugene Lempicki
(201) 535-2500

Bepex Corp.
333 NE Taft St.
Minneapolis, MN 55413
Ralph Weggel
(612) 331-4370

Black & Veatch, Inc.
P. O. Box K228
Richmond, VA 23288
Hunter Taylor
(804) 288-6767

Blount Energy Resource Corp.
P.O. Box 4577
4520 Executive Park Drive
Montgomery, AL 36195
Thomas M. James, Vice President
(205) 244-5484

Bogot Brothers, Inc.
13700 Red Arrow Hwy.
Harbert, MI 49115-0026
Donald L. Buckle, President
(616) 469-5500

Brule, C.E. & E., Inc.
13920 South Western Avenue
P.O. Box 35
Blue Island, IL 60406
James Friedrich
(312) 388-7900

Buhler-Miag, Inc.
P. O. Box 9497
1100 Xenium Lane
Minneapolis, MN 55440-9497
Daniel J. Kenna, Sales Manager
(612) 545-1401

Burn-Zol
P. O. Box 266, Elm Road Station
Mountain Lakes, NJ 07046
Edward Abendschein
(201) 299-7622

C-E Environmental Systems
Combustion Engineering, Inc.
31 Inverness Center Parkway
Birmingham, AL 35243
Jim Wilmoth, Director,
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C-E Power Systems
Combustion Engineering, Inc.
1000 Prospect Hill Road
Windsor, CT 06095
Thomas Regan, Director, Marketing
(203) 285-5122

C-E Resource Recovery Systems
Combustion Engineering, Inc.
7 Waterside Crossing
Windsor, CT 06095-0500
Noel D. Hazzard, Director,
Marketing Services
(203) 285-9924

C-E Raymond
Combustion Engineering, Inc.
650 Warrenville Road
Lisle, IL 60532
Richard J. Grzelak, Vice President
Sales and Marketing
(312) 971-2500

CMI Energy Conversion System, Inc.
520 Colcord Drive
Oklahoma City, OK 73102
Robert T. Helm
(405) 235-2224

Cadence Chemical Resource, Inc.
Hazardous Waste to Energy
Recycling Dept.
One Marine Drive
Michigan City, IN 46360
Theodore J. Reese, President
(219) 879-0371

Cadoux, Inc.
2010 Exeter Road
Germantown, TN 38138
Gerard Holbach
(901) 754-0676

California Pellet Mill Company
101 Howard, Suite 2A
P.O. Box 6806
San Francisco, CA 94101
Robert D. MacDaniel
(415) 431-3800

Cambrian Energy Systems
2401 Colorado Avenue, Suite 270
Santa Monica, CA 91030
Tudor Williams
Bob Hatch
(213) 725-1139

Carthage Machine Company
571 West End Avenue
Carthage, NY 13619
Charles G. Astafan
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Clark-Kenith, Incorporated
7500 Old Georgetown Road, 15th Floor
Bethesda, MD 20814
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Executive Officer
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Clear Air, Inc.
c/o Ralph W. Taylor
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Naples, FL 33963
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Combustion Power Co.
1020 Marsh Rd., #100
Menlo Park, CA 94025
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Combustion Technologies, Inc.
1104 East Big Beaver Road
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Consumat Systems, Inc.
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M. H. Detrick Co.
19444 S. 97th Avenue
Mokena, IL 60448
Lloyd Bly, Vice President,
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(312) 479-5085

Detroit Stoker Company
1510 East First Street
Monroe, MI 48161
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Dynatech Scientific, Inc.
99 Erie Street
Cambridge, MA 02139
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Ecolaire Combustion Products, Inc.
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Jeannette, PA 15644
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Enercon Systems, Inc.
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Energy Answers Corporation
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Energy Development Industries
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(404) 792-3835

Foster Wheeler Power Systems, Inc.
Perryville Corporate Park
Clinton, NJ 08809
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GSF Energy, Inc.
O. Box 1900
Long Beach, CA 90801
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One River Road
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Harbert/Triga Resource Recovery
One Chase Corporate Center
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Birmingham, AL 35201
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Heil Engineered Systems
2000 West Montana
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Henley Burrowes Waste Management
9181 Interline Ave.
Baton Rouge, LA 70809
Herbert J. Boxill
(504) 923-3525

Herman Bogot and Company
3143 Nottingham Avenue
Chicago, IL 60634
Scott Bogot
(312) 637-6037

Industrial and Municipal Engineering
P. O. Box N
Galva, IL 61434
LaVerne Charlet, Sr. Vice President
(309) 932-2036
(800) 447-5684 (outside IL)
(800) 322-5661 (IL only)

Industronics, Inc.
489 Sullivan Avenue
South Windsor, CT 06074
Barbara C. Klenke, Reg. Sales Mgr.
(203) 289-1588

International Incinerators Incorporated
506 Coolidge Ave.
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Columbus, GA 31902
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John Zink Company
Comtro Division
4401 South Peoria Avenue
P. O. Box 702220
Tulsa, OK 74170
Roger Etter
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Joy Technologies, Inc.
Western Precipitation Division
404 East Huntington Drive
Monrovia, CA 91016-3633
Robert C. Hyde
(818) 301-1100

Katy-Seghers, Inc.
3844 Walsh Street
St. Louis, MO 63116
Art Beckman
(314) 752-2400

Keeler/Dorr-Oliver Boiler Co.
Manufacturers of Keeler Water Tube Boilers, Faber Combustion Systems
238 West Street
Williamsport, PA 17701
Max Wahler, Program Manager
(717) 326-3361

Laidlaw Gas Recovery Systems
39899 Balentine Drive, Suite 275
Newark, CA 94560
Kenneth Wuest, President
(415) 656-8327

Laurent Bouillet-Howard
2700 N. Central Ave.
Suite LL100
Phoenix, AZ 85004
James L. Grant, Manager of Business Development
(602) 222-5999

Lundell Manufacturing Co., Inc.
Hwy 3
Cherokee, IA 51012
Steve Paulsen, Vice President
(800) 831-4841

Pan Am Building, Suite 303 East
200 Park Ave.
New York, NY 10166
(212) 986-2515

Maxon Industries, Inc.
5750 South Eastern Avenue
City of Commerce, CA 90040
John Tidwell, Vice President, Finance
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McClain Industries, Inc.
P. O. Box M
Utica, MI 48087
James McManus
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Mechanical Technology, Inc.
968 Albany-Shaker Road
Latham, NY 12110
Frank S. Ralbovsky, Product Manager
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Methane Development Corp.
Telport 1, One Teleport Drive
Staten Island, NY 10311
Zain Mirza
(718) 983-2290

Montenay Power Corp.
300 Old County Rd.
Mineola, NY 11501
Steve Passage
(516) 742-6300

Morse-Boulger, Inc.
127-36 Northern Blvd.
Flushing, NY 11368
Matthew Gaskin, Vice President
(718) 672-2100

Nashville Thermal Transfer Corp.
110 First Avenue, South
Nashville, TN 37201
J. T. Hestle, P.E., General Manager
(615) 244-3150

National Ecology, Inc.
16 Greenmeadow Drive
Timonium, MD 21093
Charles A. Simms, President
(301) 252-5666

Natkin and Company
440 Patterson Park Rd.
Ashland, VA 23005
Charley Gilbert
(804) 798-4773

Newell Industries
P.O. Box 10629
San Antonio, TX 78210
Scott Newell, III
(512) 227-9090

Nicholson Manufacturing Company
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Appendix E

U.S. Regulatory, Research, and Legislative Activities Related to MWC Facilities

U. S. REGULATORY, RESEARCH, AND LEGISLATIVE ACTIVITIES RELATED TO MWC FACILITIES

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) is currently developing air pollution emission rules for new and existing municipal waste combustion (MWC) facilities pursuant to Section 111 of the Clean Air Act (CAA). These rules are planned for proposal in November 1989 and promulgation in December 1990. This paper provides information on EPA's technical activities related to this regulatory effort. These activities include assessments of combustion and flue gas cleaning technologies employed at MWC facilities; the collection and evaluation of MWC air pollution emission test data; the development of technical recommendations for good combustion practices at MWC facilities; the development of model plants representative of existing and projected MWC facilities; and an evaluation of the performance of employing alternative combustion and flue gas cleaning strategies for controlling air emissions at these model MWC facilities.

Proposed legislation is before the 101st Congress (S. 196) to control air pollutant emissions from municipal waste incineration and provide for safe disposal of ash. Key provisions of this proposed legislation are summarized.

This paper has been reviewed in accordance with the U. S. Environmental Protection Agency peer and administrative review policies and approved for presentation and publication.

INTRODUCTION

In 1960, the U.S. generated waste at a rate of 2.65 pounds* per person per day; by 1986, that figure had jumped to 3.58 pounds, and the rising trend is projected to continue into the Year 2000[1]. The generation of most types of municipal solid waste (MSW), including paper, plastics, glass, and metals, has increased (see Figure 1). A U.S. citizen generates approximately 1 pound per day more waste than his or her counterpart in West Germany, an equally industrialized nation.[2]

It is estimated that 80 percent of the nation's MSW is landfilled; only 10 percent is recycled, and 10 percent is incinerated or otherwise burned. At the same time that more wastes are being generated, the capacities for processing and disposal are diminishing. Since one-third of the nation's landfills will be full by 1991, the waste now disposed of in these facilities will have to be disposed of elsewhere.[3] Many existing facilities are closing either because they are filled or because they are not designed and operated in a manner which meets Federal or state standards for protection of human health and the environment.

Efforts to site new landfills, combustors, and recycling centers, however, are met with mounting public opposition. This opposition may stem from concerns about environmental or health risks from contaminated ground and surface waters and soil, from air pollution emissions from MWC, or from toxic residues produced by MWC facilities; from resistance to such nuisance factors as noise, odors, and truck traffic; or from anxiety over property values. Whatever the reasons, this opposition often results in the denial of requests to construct urgently needed new waste management facilities, especially MWC facilities.

There are two major public concerns in the U.S. related to pollution from MWC facilities. The first is the concern over air pollutant emissions, primarily dioxins and trace metals. The second is the concern over the leachability and toxicity of trace elements in MWC residues. EPA is currently developing new rules governing control of air pollution emission regulations from MWC facilities. The major part of this paper deals with the results of EPA activities in developing the air pollution emission control rules that are to be proposed later this year.

EPA is also developing a plan for the collection of information needed to promulgate guidelines for the management of MWC ash in an environmentally sound manner. The development of ash management standards will be contingent on new environmental laws the 101st Congress is expected to pass in the near future. A brief summary of S.196, a Senate bill dealing with the control of air pollution emissions and the disposal of residues from MWC facilities, is the second topic of this paper.

*English Engineering Units rather than metric units are used here because of their customary use in the U.S. See Appendix for unit conversions.

The paper also presents a brief summary of EPA organizations that are currently involved in the development of MWC regulations or that are engaged in research, development, or demonstration activities related to MWC

This paper presents the status of on-going work at EPA. In some cases draft reports or memoranda, which were distributed outside of the Agency for public comment, are provided for references. In some instances data in this paper represent up-dated versions of data from the draft references. The methodologies and data in the draft references are generally correct, but new information has resulted in the revision of the numerical results of studies.

BACKGROUND

The U.S. Environmental Protection Agency (EPA) regulates pollution from MWC facilities under authority of two major environmental laws: the Clean Air Act (CAA) and the Resource, Conservation, and Recovery Act (RCRA), an amendment of the Solid Waste Act (SWA). These Acts also authorize EPA to conduct research needed to identify environmental problems, and develop and demonstrate technology for pollution control.

CLEAN AIR ACT

The CAA and its amendments authorize EPA to carry out a national program of research, regulatory, and enforcement activities designed to reduce air pollution.[4,5] Prevention and control of air pollution at its source is the primary responsibility of States and local governments. EPA's role includes (1) conducting research and development programs, (2) establishing standards and regulations to meet environmental goals under the Act, (3) providing support to State and local governments, and (4) ensuring effective enforcement of the standards and regulations.

The air program regulates two basic groups of pollutants: criteria pollutants and hazardous air pollutants. The emission of criteria pollutants from old ("existing") sources is controlled through State permits which specify emission levels needed to meet EPA's National Ambient Air Quality Standards (NAAQS). The emission of "designated" air pollutants from existing sources may be regulated under authority of Section 111(d). Control of criteria pollutants from new sources is regulated by Federal New Source Performance Standards (NSPS) pursuant to Section 111(b). National Emission Standards for Hazardous Air Pollutants (NESHAPs) are established by EPA to control emission of hazardous air pollutants from particular sources or operations pursuant to Section 112.

RESOURCE CONSERVATION AND RECOVERY ACT

RCRA was developed by Congress to address the health and environmental hazards posed by the improper management and disposal of municipal and industrial wastes. The goals of RCRA are to: (1) protect human health and the environment, (2) reduce waste and conserve energy and natural resources, and (3) reduce or eliminate the generation of hazardous wastes as expeditiously as possible.

Congress decided that wastes can pose qualitatively different degrees of hazard and therefore established two very different programs to accomplish the RCRA goals. Subtitle C of RCRA was developed to regulate the management of wastes which require a high degree of control to prevent harm to human health or the environment. Under Subtitle C, wastes are controlled from generation to final disposal (i.e., "cradle to grave"). Subtitle C wastes are commonly called "hazardous wastes."

Subtitle D of RCRA was developed primarily to promote environmentally sound disposal methods for wastes which do not pose as great a hazard.[6] Another major objective of the Subtitle D program is to encourage recycling or resource recovery. The Subtitle D standards set out limited technical requirements on "solid" or non-hazardous waste facilities as compared to Subtitle C's comprehensive set of regulatory controls.

EPA ORGANIZATIONAL ACTIVITIES

Major organizations within EPA involved in activities related to MWC facilities include the Office of Air Quality Planning and Standards (OAQPS), the Office of Research and Development (ORD), and the Office of Solid Waste (OSW). A major function of the OAQPS is to develop air pollution emission control standards for stationary sources. The Emission Standards Division (ESD) is responsible for developing technical background information on which the MWC rules are to be based. They are also responsible for developing the specific provisions of the regulations and for writing and publishing the regulations. OAQPS is in Durham, NC.

ORD is providing funds and technical support in the development of the MWC rules. The Air and Energy Engineering Research Laboratory (AEERL) is responsible for developing recommendations for good combustion practices and for jointly supporting and managing field test projects which are used to collect the emission and pollution control technology performance data on which the MWC rules are to be based. The air pollution emission control activities discussed in the next section of this paper include the results of OAQPS and ORD activities. AEERL is in Research Triangle Park, NC.

OSW is responsible for the development of regulations and guidelines dealing with solid wastes. The Risk Reduction Engineering Laboratory (RREL), an ORD organization, supports OSW in conducting R&D activities needed in the assessment and development of solid waste management technologies. OSW is located in Washington, DC, and RREL is located in Cincinnati, OH.

Organizationally, AEERL and RREL report to the Office of Environmental Engineering and Technology Demonstration (OEETD), which has its headquarters in Washington, DC. OEETD directs the ORD research, development, and demonstration program related to MWC (the MWC program). AEERL is responsible for managing projects dealing with combustion and flue gas cleaning technology. RREL is responsible for managing projects dealing with MWC residues.

AIR POLLUTION EMISSION CONTROL ACTIVITIES

DECISION TO DEVELOP NEW RULES

On July 7, 1987, an advanced notice of proposed rule making (ANPRM) was published in the Federal Register (52 FR 25399).[7] This notice from the EPA announced its intentions of regula   air pollution emissions from municipal waste combustion facilities under CAA Section 111. This decision was based, in part, on a comprehensive study of MWC. This comprehensive study was embodied in nine volumes; the summary volume was the "Municipal Waste Combustion Study: Report to Congress."[8] This MWC study involved the evaluation of health and environmental risks associated with MWC and an assessment of technology for limiting emissions of criteria and hazardous air pollutants either by control of the combustion process or by the use of flue gas cleaning technology.[9,10,11]

Concurrently with this ANPRM, OAQPS issued operational guidance to EPA's Regional Offices concerning approval of applications for permits (under prevention of significant deterioration and non-attainment new source review) to construct new incinerators.[12] These guidelines specified that all new incinerators use good combustion practice and the appropriate flue gas cleaning technology to ensure adequate control of air pollution emissions. Appropriate flue gas cleaning technology was defined as the use of a dry scrubber in combination with a fabric filter (FF) baghouse or electrostatic precipitator (ESP). Although the criteria for achieving good combustion were not defined in the operational guidance, the Regional Offices were referred to recommendations for good combustion provided in the report entitled "Municipal Waste Combustion Study: Combustion Control of Organic Emissions."[10]

REGULATORY PROCEDURE

OAQPS is responsible for the development of air pollution emission standards for MWC facilities. The development of standards encompasses a number of formalized activities specified by the CAA, its amendments, and Agency procedures.[4,5] Standards pursuant to Sections 111(b) and 111(d) are technology based rather than risk based. The NSPS must reflect the best degree of control available taking cost, energy, and non-air related environmental impacts into account. Standards for existing facilities [Section 111(d)] must take the remaining life of the facility into consideration.

OAQPS' first procedure in setting air emission rules under Section 111 is to select the pollutants or classes of pollutants which are to be considered for control. After the pollutants are selected, then background information on the emission levels, costs, energy impacts, and non-air environmental impacts associated with a number of emission control strategies are developed. Each strategy is selected to provide a different level of emission control and hence cost. These control options and their associated environmental and economic consequences are presented to the Administrator who, in consultation with other EPA officials, selects one of the options or a combination of options. The selected option is expressed in terms of a proposed set of rules which are published to obtain public comment. After a period of public comment, the proposed rules are modified as deemed necessary by EPA before they are promulgated. If the rules are proposed under Section 111(b), they are promulgated as Federal Standards or Regulations. If they are proposed under Section 111(d), they are promulgated as Guidelines and state governments are required to develop and enforce state regulations in accordance with the Guidelines.

CONTROLLED POLLUTANTS

MWC facilities emit a mixture of air pollutants of environmental concern. Table 1 lists the pollutants EPA evaluated for potential control in the studies which led to the decision to develop further air pollution emission rules for MWC facilities.[7,9] These pollutants can be grouped into three main categories: acid gases, trace organics, and trace metals.

While pollutants may be identified by classes of chemical compound or other criteria, they may also be grouped by the methods used to control them; i.e., by combustion and flue gas cleaning control mechanisms. The easiest method of limiting emissions of organics is by the use of good combustion practices (GCP). Pollutants emitted from the combustor can be controlled by mechanisms operational in flue gas cleaning (FGC) devices. The collection of pollutants in FGC devices depends on differences in the physical, chemical, and electrical properties of pollutants. Many metals condense at stack gas temperatures and are collected as particulate matter (PM). Other metals must be adsorbed onto the surfaces of particles, or the flue gas temperature must be lowered sufficiently to result in condensation. Acid gases are collected by reaction with a sorbent which converts them to a solid. They are then collected as PM. Condensed phase organics and semi-volatile organics are controlled in varying degrees by PM control devices. They are collected more effectively by methods used to control acid gases, condensation, adsorption, absorption, and particle collection. Volatile organics are difficult to control if they are not destroyed during combustion.

To reduce the technical and cost problems associated with studying and regulating a multiplicity of elements, compounds, and other groups of pollutants, the following pollutants are used to represent direct control or surrogate control of the major MWC pollutants of concern:

- PM for trace metals, inorganic particulate matter, and condensed organics.
- Hydrogen chloride (HCl) and sulfur dioxide (SO_2) for acid gases.
- Chlorinated dibenzo-p-dioxins (CDD) and chlorinated dibenzo-furans (CDF) for organics.

Although nitrogen oxides (NO_x) are also a MWC emission of concern, studies relating to NO_x control are not covered in this paper.

MWC MODEL PLANT STUDIES

The control options considered by EPA must take into account reductions in air pollution emissions, pollution control costs, economic impacts, energy impacts, and non-air environmental impacts. These factors vary with the size of MWC plants, the type of combustor, the pollution control technology, age of the plant, and numerous other factors. Rather than study each existing and projected plant, a model plant study approach was taken to provide information needed for development of MWC air pollution emission regulations.

Two sets of model plants were developed: a set representing those which will be subject to NSPS and a set representing those subject to Guidelines. The NSPS and Guideline model plants were defined as:

1. Information was collected on existing and planned plants in the U.S. which will be subject to MWC emission Guidelines. This information included plant name and location, type of combustor(s), number of combustors, heat recovery provisions, plant size (tpd), year of start-up, and air pollution control device employed.

2. Projections were made of plants to be constructed during the 5-year period after the NSPS become effective. The projections included estimates of the combustor type, number of combustors, heat recovery provision, plant capacity, and air pollution control devices employed.

3. Model plants were defined for each major type of combustor in the Guideline and NSPS model plant sets. A "retrofit study" was performed in which combustion and FGC retrofits were developed for each of several air emission control technologies for each Guideline model plant. The costs of implementing these plant modifications were estimated and the associated air emission performance

levels were defined. Similar design, cost, and performance studies were made for selected air pollution control techniques for each type of NSPS plant.

4. Estimates were made of the "baseline" air pollution emissions of concern. Baseline emissions are the estimated emissions which would result if EPA did not promulgate Guidelines or NSPS for MWC facilities. The "baseline" emission estimates for the model plants were based on the interpretation of all available field and pilot plant test data applicable to a given combustor type and FGC technology.

5. A number of air pollution emission control options were studied for the Guideline and NSPS model plants. These emission control options include the use of (1) GCP; (2) GCP and moderate PM control; (3) GCP and best PM control; (4) GCP, good acid gas control, and best PM control; and (5) GCP, best acid gas control, and best PM control. Emission control performance estimates for these control options were based on an interpretation of all available field and pilot plant test data applicable to each combustor type and FGC control option.

6. Environmental engineering studies were conducted in which the Guideline plant air pollution emission control options were applied to the set of model Guideline plants to provide estimates of emissions, costs, and non-air pollutant impacts. Similar studies were also conducted by applying the NSPS emission control options to the NSPS model plants.

Types of Combustors

EPA's municipal 1987 waste combustion study identified four classes of MWC facilities: mass burn incinerators, modular incinerators, refuse-derived fuel (RDF) combustors, and fluidized bed combustors.[8,10] In subsequent EPA work, these classes have been expanded to additional sub-classes or types of combustors. Types of combustion systems for which model plants were developed include:

- mass burn, refractory, traveling grate (MB/REF/TG)
- mass burn, refractory, reciprocating or rocking grate (MB/REF/RG)
- mass burn, refractory, rotary kiln (MB/REF/RK)
- mass burn, water wall, reciprocating or rocking or rolling grate (MB/WW/RG)
- mass burn, rotary combustor, water wall (MB/RC/WW)

- modular incinerator, starved air (MI/SA)
- modular incinerator, excess air (MI/EA)
- refuse-derived fuel, spreader stoker (RDF/SS)
- (bubbling) fluidized bed combustor (FBC)
- circulating fluidized bed (CFB)

The characteristics of the combustion systems used for the Guideline and NSPS model plant studies are described in the following sections.

Guideline Plants

Thirteen classes of plants were considered for model Guideline plants when EPA began its "Retrofit Study" of existing sources in 1987. A summary of these plants showing the type of combustor, number of plants, and air pollution control devices employed is presented in Table 2.[13] The majority of the mass burn and RDF plants employ electrostatic precipitators for PM control. Only 8 of 44 starved air modular combustors employ PM control devices. Only two operating plants employed high-efficiency acid gas scrubber and PM control devices (spray dryer and fabric filters) at the beginning of 1987. Six additional plants which incorporate spray dryers, dry sorbent injection in combination with fabric filter baghouses, or ESPs were to begin operation in 1987 or 1988. At least 39 of the 130 plants began operation before 1980. Few of these plants are believed to employ GCP.

It is estimated that 330 individual combustors will be subject to the Section 111(d) emission guidelines. This includes combustors at both existing plants that are currently operating and "transitional plants" that were not operating as of March 1988, but will commence construction prior to November 1989, when the NSPS and emission guidelines will be proposed. The 330 combustors reflect an increase of about 30 percent in the number of existing combustors since publication of the June 1987 Report to Congress. It is estimated that, on a capacity basis, 68 percent of these 111(d) units will be mass burn facilities, 17 percent will be RDF, 5 percent will be modular, and 10 percent will be fluid bed combustors or unique designs not represented by model plants. In terms of number of combustors, 52 percent are mass burn, 8 percent are RDF, 30 percent are modular, and 10 percent are FGC or other unique designs.[14,15]

Seventeen model plants were developed to represent the existing and transitional MWC population. These include three mass burn/refractory models, four mass burn/waterwall models, four RDFs, four modular, and two rotary waterwall models, listed in Table 3. The also shows the number of

The existing and transitional models represent each common type of combustor design. Some of the existing designs include good combustion practices (GCP), while others do not. All models representing transitional MWCs are assumed to have GCP, since this is typical of newer units. The models were also selected to reflect the size ranges within each design type, the types of air pollution controls at existing and transitional facilities, heat recovery capabilities, and typical operating hours. While these models represent the great majority of existing and transitional combustors, it is estimated that four or more types of combustors are not now represented by model plants. Types of combustors which are not now represented include some batch-fed refractory wall combustors, a pulsating hearth combustor, a refractory wall rotary kiln combustor, and pulverized coal RDF combustors. There are also at least eight facilities with unknown combustor designs.

NSPS Plants

Municipal waste combustors that commence construction after proposal of the NSPS (late 1989) will be considered "new" facilities subject to the new NSPS (Subpart Ea). Using projections of the growth in combustion of MSW developed by Franklin Associates, it is estimated that up to 40,000 tpd of new MWC capacity could become subject to the NSPS in the 5-year period after proposal (1990-1994). It is expected that about 115 new combustors will commence construction within this time period.

To project the distribution of new MWCs to be constructed, information on facilities in advanced planning or early construction stages was used, because it is expected that typical combustor types and plant sizes for new MWCs would be similar to MWCs that have been recently built or are under construction. These distributions indicate that, of the projected total design capacity subject to the NSPS, 64 percent will be mass burn, 26 percent RDF, 3 percent modular, and 7 percent FBC facilities. In terms of the number of individual combustors, 58 percent will be mass burn, 18 percent RDF, 16 percent modular, and 8 percent FBC.[14,15]

Twelve different model plants were developed to represent new MWC facilities. New model plants were selected to represent each common type of combustor design and typical sizes were selected within each MWC design type. Where there was great size variation within a category (such as mass burn), model plants were developed for different combustor sizes (i.e., small, medium, and large). Other considerations in new model plant selection were annual operating hours and heat recovery ability. While most large new MWC plants are expected to operate continuously and produce steam and electricity for sale, some smaller modular and mass burn plants are expected to operate fewer hours or not to produce electricity.

The 12 model plants include 3 mass burn/waterwall, 1 mass burn/refractory, 1 mass burn/rotary combustor, 2 RDF, 1 modular excess air, 2 modular starved air, and 2 FBC facilities. These model plants are listed in Table 4. This table also shows the projected number of new facilities corresponding to each model plant.

Emission Control Technology and Performance

EPA is considering various aproaches to controlling emissions from MWCs. One approach is to alter the combustion process to reduce emissions of organics including CDD/CDF, sometimes called combustion control or good combustion practice (GCP). A second approach is to add FGC equipment to control emissions of PM, metals, and acid gases, and obtain additional CDD/CDF control. Another approach is to use a combination of GCP and FGC control. The following sections provide emission performance estimates defined during EPA's model plant studies.

Combustion Control

Good combustion practices include the proper design, construction, operation, and maintenance of an MWC. The use of GCP can minimize emissions of CDD/CDF and their precursors by promoting more thorough combustion to destroy these pollutants.

High emissions of CDD/CDF are generally associated with poor combustion conditions; low CDD/CDF emissions, with good combustion. The combination of combustion conditions which are defined by those MWC design and operating conditions which result in low emission of CDD/CDF are called GCP. A major indicator of good combustion is the CO concentration in stack gas. Other combustion conditions which are postulated to be necessary to achieve low CDD/CDF emissions are discussed in the paper entitled "Development of Good Combustion Practices to Minimize Air Emissions from Municipal Waste Combustors," which is included in the Proceedings of this conference.[16]

Following discharge from the combustor, additional CDD/CDF can form from precursors which have not been destroyed in the combustor in the presence of flyash at temperatures ranging from approximately 480 to 660°F (250 to 350°C).[17-20] Destruction of precursors and minimizing the amount and residence time of PM in this temperature zone help to limit this secondary formation. An interpretation of field test data indicates that the inlet temperature to PM control devices such as ESPs should be kept below 450°F to prevent significant secondary CDD/CDF formation in the control device.

The furnace formation of CDD/CDF is related to the design and operating conditions of MWCs. Table 5 summarizes estimates of current "baseline" and potentially achievable emissions of CCD/CDF and CO from different classes (types) of combustors now in operation in the U.S.[21] The baseline emissions represent an upper bound for average emissions of all incinerators in a given sub-class. Estimates of potential achievable emissions which can be attained through the use of GCP are provided for both existing and new combustors.[21,22] The emission estimates for existing combustors with GCP represent the performance levels which are believed attainable by combustion retrofits and by operating continuously with good combustion conditions. A range of <500-1000 ng/Nm^3 is estimated for some types of combustors. In these instances, there is currently insufficient information on the different combustors within each sub-class to make better estimates. Field test data available in the next 6 months should help provide more accurate estimates.

New combustors which have begun operation within the last several years generally employ GCP. Alternatively, builders and operators are working to improve combustion conditions with the intent of achieving GCP. The estimates for new units represent performance levels which are believed to be attainable over the next several years.

PM Control

The most frequently used high performance PM control devices in the U.S. are electrostatic precipitators (ESPs) and fabric filters (FFs). These devices control particulate and fine particulate which may include metals and organics in particulate form. Although other PM control technologies such as cyclones, electrified gravel beds, and venturi scrubbers are used at some MWC plants, they are infrequently applied and are not expected to be widely used at future MWC plants.

Existing plants have PM emissions ranging from 0.33 to less than 0.01 gr/dscf at 12% CO_2.[23-25] The 1971 NSPS for MSW incinerators specifies a PM emission limit of 0.08 gr/dscf.[26] Plants which must meet standards for new industrial boilers must achieve an emission limit of 0.05 gr/dscf.[27] This level of control (0.08-0.05) is defined as moderate PM control. Large, well-designed ESPs can achieve total PM emission levels of 0.01 gr/dscf or less. This PM performance level which is designated as best PM control can also be achieved by FFs.

Metals of concern emitted from MWC units include arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), and nickel (Ni). All of these metals, except Hg, are removed by ESPs or FFs with the fine particulates. Data indicate that well-designed ESPs or FFs operated at 450°F or less remove over 97 percent of As, Cd, and Pb and about 99 percent of Be, Cr, and Ni from MWC exhaust gases.[28] Because the metals content of MSW is variable, metals concentrations in the MWC exhaust gases vary from plant to plant. Because of great variability from plant to plant and the limited amount of metals test data for different plants, outlet metals concentration emission limits cannot be easily specified. However, it is believed that use of ESPs or FFs to comply with a sufficiently stringent PM emission limit and control of the flue gas temperature entering the PM control device will result in a high removal efficiency of the potentially toxic metals of concern, with the exception of Hg.

Hg has a high vapor pressure and remains as a vapor in flue gas at temperatures at which ESPs have traditionally been operated in the U.S. MWC industry. The evidence is that little Hg control is achieved by ESPs whether used alone or in conjunction with acid gas control Moderate to good Hg reduction can be achieved when FFs are used with acid gas control systems.

Semi-volatile organics such as CDD/CDF can be collected by PM control devices if they are adsorbed or condensed on the surface of particulate. Alternatively, results from a number of field tests lead to the conclusion that CDD/CDF can be formed in ESPs and granular bed filters if these control devices are operated at temperatures from 480 to 660°F.[25] Limited field data indicate that under certain conditions the inlet temperature of an ESP below 450°F reduces the CDD/CDF concentration across the ESP from 50 to 75 percent.[25] This and other data lead to the postulation that GCP and good PM control at an appropriate control device temperature can limit CDD/CDF emission levels to less than 500 ng/Nm^3 for existing combustors and 300 ng/Nm^3 for new combustors.* Tests to provide further evidence to corroborate these performance estimates were conducted in the Montgomery South Incinerator in Dayton, Ohio, earlier this year. The results of these tests are to be available within the next several months. While FFs will probably not be used without acid gas control, it is believed that GCP and PM control with a FF will provide comparable or better performance than GCP with an ESP.

Estimated emission performance levels which are believed achievable with GCP and various levels of PM and acid gas control are summarized in Table 6.

Good Acid Gas Control

Dry sorbent injection (DSI) is being considered primarily as retrofit technology for use in existing MWC systems which currently use an ESP. DSI technology has been developed primarily to control acid gas emissions. However, when DSI is combined with flue gas cooling and an ESP, control of CDD/CDF, PM, and metal emissions are achieved. Two primary subsets of DSI technology exist. One approach, referred to as duct sorbent injection, involves injecting dry alkali sorbents such as hydrated lime into flue gas downstream of the combustor outlet and upstream of the PM control device. The second approach, referred to as furnace sorbent injection, injects sorbent directly into the combustor.

There are limited data on the performance of DSI systems. Existing facilities that have been retrofitted with GCP and then apply DSI/ESP systems are believed capable of CDD/CDF emissions of less than 125 ng/Nm^3. New plants with DSI/FF systems are believed to be capable of achieving CDD/CDF emissions of less than 75 ng/Nm^3.[25]

Dry sorbent injection systems can achieve a 40 percent reduction in SO_2 emissions or an outlet SO_2 concentration of 30 ppmv at 7 percent O_2. An 80 percent reduction in HCl emissions or an outlet concentration of 25 ppmv is achievable.[25]

PM emissions of less than 0.01 gr/dscf are believed to be achievable for MWCs equipped with DSI followed by ESPs.

Dry sorbent injection/ESP systems achieve 97 percent or greater removal of arsenic, cadmium, and lead, and 99 percent removal of beryllium, chromium, and nickel.[29] Little mercury control is achieved by DSI/ESP systems, and no control is assumed for the control strategy studies.

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* PM emission values are corrected to 12% CO_2. CDD/CDF, HCl, and SO_2 emissions are corrected to 7% O_2.

The emission control levels for GCP and good acid gas control which are used in MWC emission control scenarios are summarized in Table 6.

Best Acid Gas Control

Lime spray drying systems followed by FFs were initially developed to control SO_2 and HCl emissions. However, the systems also control CDD/CDF, PM, and metal emissions including mercury. In the spray drying process, lime slurry is injected into the spray dryer and reacts with acid gases. The water in the slurry evaporates to cool the flue gas. The flyash and reaction products are removed by the FF. Spray dryer/fabric filter systems represent the best add-on control technology for MWCs currently used in the U.S.

Spray dryer/fabric filter systems can achieve outlet CDD/CDF concentrations of less than 10 ng/Nm^3.[7] They can also achieve an 85 percent reduction in SO_2 emissions or an outlet concentration of 30 ppmv at 7 percent O_2 and a 95 percent reduction in HCl emissions or an outlet concentration of 25 ppmv. PM emissions of less than 0.01 gr/dscf are believed to be achievable by MWCs equipped with SD/FF systems.[25]

Typically, SD/FF systems achieve 99 percent removal of all metals except mercury. Mercury removal of 70 percent or greater is believed achievable for those design and operating conditions which provide for adequate temperature control and emission control of SO_2, HCl and PM.

The emission control levels of GCP and best acid gas control which are used in the MWC emission control levels are summarized in Table 6.

EMISSION CONTROL SCENARIOS

Cost studies have been completed for each model plant with each pollution control option. Emission control scenarios are now being formulated to study the aggregated cost effectiveness (national reduction of pollutant emissions versus cost) of using plant emission control options, which depend on plant size and plant age (existing versus new). The results of these and other studies will be integrated with energy and non-air environmental impact studies to form regulatory options for presentation to EPA's Administrator. It is expected that proposed MWC air pollution emission control rules will be published in the Federal Register in November 1989.

LEGISLATIVE ACTIVITIES

Proposed legislation is before the 101st Congress (S.196) to control air pollutant emissions from municipal waste incineration and provide for safe disposal of ash.[30]

The proposed air pollution control provisions: specify pollutants to be controlled; require the use of best available control (BACT) technology on new sources; identify BACT deemed available for application to MWC facilities; require the development of emission standards for both new and existing sources; and define minimum standards for combustion temperature and emission of CO, PM, SO_2, and HCl. This last provision would require the use of GCP, acid gas control technology, and PM control technology on all new and existing units. EPA is to establish standards for new sources within 18 months of the effective date of the legislation. Existing sources are given 6 years from the effective date of the legislation to comply with the new air emission control requirements promulgated by EPA. There are provisions for extending the compliance date for some existing units.

The proposed ash disposal and management legislation defines general disposal, leachant collection, and monitoring requirements for bottom ash, flyash, or combined ash.

Key provisions of this proposed legislation are summarized in the following sections:

AIR POLLUTION

The EPA Administrator is to promulgate standards of performance for new and existing MWC sources no later than 18 months after enactment of the legislation. These regulations are to be authorized by amendment of the Clean Air Act.

No permits are to be issued for new incinerators until after an enforceable solid waste management plan has been submitted to an appropriate state official and until a plan for incinerator ash management has been submitted.

New Sources

New sources are to use best available control technology (BACT). Equipment deemed available for air emission control includes: "electrostatic precipitators, fabric filtration, spray dry scrubbers, negative air flow, and good combustion practices, including the availability of auxiliary fuel to maintain specific temperatures." "The Administrator may require new facilities to be constructed according to designs which allow for addition of selective catalytic reduction and other technologies as they become available."[30]

Promulgated standards are to "specify numerical emission limits for the following substances or mixtures: particulate matter (total and fine), opacity, sulfur dioxide, hydrogen chloride, oxides of nitrogen, carbon monoxide, lead, cadmium, mercury, halogenated organic compounds, dioxins, and dibenzo furans." Additionally, "the Administrator shall take into account the use of numerical standards or other methods to reduce the presence in air emissions or ash from a municipal waste incineration unit each of the additional substances: volatile organic compounds, beryllium, hydrogen fluoride, antimony, arsenic, barium, chromium, cobalt, copper, nickel, selenium, zinc, polychlorinated biphenyls, chlorobenzenes, chlorophenols, and polynuclear aromatic hydrocarbons."[30]

In no event are EPA's standards to allow:

- CO emissions greater than 50 ppm on a 4-hour average. The EPA Administrator may allow a 100 ppm CO emission limit for RDF units equipped with spray dryers and fabric filters. (All emission limits are corrected to 7% O_2.)
- PM emissions greater than 0.015 gr/dscf.
- SO_2 emissions greater than 40 ppm on an 8-hour average, or less than a 70 percent reduction in emissions.
- HCl emissions greater than 30 ppm on an 8-hour average or less than a 90 percent reduction in emissions.
- A minimum combustion temperature of less than 1800°F and a retention time of less than 1 second at fully mixed conditions. The Administrator may set different requirements for atmospheric fluidized bed combustors.

Existing Units

Emission and performance standards are to be promulgated for existing units. The methods of control and the pollutants regulated are to be the same as those specified for new sources. Existing sources are given 6 years to comply with the standards as measured from the effective date of the legislation. EPA shall in no event allow:

- CO emissions greater than 100 ppm on an 8-hour average. The Administrator may set emission limits of 200 ppm for units which employ acid gas scrubbers and fabric filters.
- PM emissions greater than 0.02 gr/dscf.
- SO_2 emissions greater than 60 ppm on an 8-hour average, or less than a 70 percent reduction in emissions.
- HCl emissions greater than 45 ppm on an 8-hour average, or less than a 90 percent reduction in emissions.
- A combustion temperature of less than 1800°F and a retention time of less than 1 second at fully mixed conditions.

ASH DISPOSAL AND MANAGEMENT

The proposed bill requires EPA to promulgate regulations for the management, handling, storage, treatment, transportation, reuse, and recycling of ash from municipal waste incineration units. These regulations are to be promulgated under authority of an amendment to RCRA, sub-title D. They are to be issued within 18 months after the enactment of legislation. The regulations can apply to flyash separately, bottom ash separately, or combined bottom and flyash.

If ash is to be disposed of in landfills, then EPA's regulations are to require:

1. The installation of two or more composite liners with a leachate collection system above and below the liners, and leachant treatment.

2. Ground water monitoring.

If combined ash or bottom ash is to be disposed of in a monofill (a landfill containing only ash from incinerators), then EPA regulations must require as a minimum:

1. The use of a single composite liner system, a leachant collection system, and leachant treatment.

2. Ground water monitoring.

If flyash is to be disposed of in a monofill which contains only flyash or substantially flyash, then the regulations may provide for two disposal options. If the flyash is treated prior to disposal by standards defined by EPA, then EPA disposal regulations must require as a minimum:

1. The use of a single composite liner system, a leachant collection system, and leachant treatment.

2. Ground water monitoring.

If flyash is not treated, then EPA disposal regulations must require as a minimum that the landfill be constructed with two liners, with a leachant detection system, leachant collection systems, and a leachant treatment system.

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APPENDIX

Unit Conversion Factors

English Engineering Unit	Multiplied By	Metric Unit
in.	2.540×10^{-2}	m
lb/hr	4.536×10^{-1}	kg/hr
gr/dscf	2.288×10^{3}	mg/dscm
tons/hr	2.268×10^{2}	tonne/h
°F-32	5.555×10^{-1}	°C

TABLE 1. POLLUTANTS OF CONCERN

ORGANIC COMPOUNDS	INORGANIC COMPOUNDS	
	METALS	ACID GASES
Benzene	Arsenic	Hydrogen Chloride
Benzo(a)pyrene (BaP)	Beryllium	Hydrogen Fluoride
Carbon Tetrachloride	Cadmium	Sulfur Dioxide
Chlorobenzenes	Chromium	
Chlorodibenzodioxins	Copper	
Chlorodibenzofurans	Lead	
Chloroform	Mercury	
Chlorophenols	Nickel	
Formaldehyde	Selenium	
Naphthalene		
Perchloroethylene		
Phenol		
Polychlorinated Biphenyls		

TABLE 2. EXISTING MWC FACILITIES IDENTIFIED FOR RETROFIT STUDY[a]

Combustor Type[b]	No. of Plants	Start-up Dates: Range	Start-up Dates: Ave.	Number of Plants Using Indicated FGC Devices[c]: NONE	WS	ESP	FF	DSI/FF	SD/FF (SD/ESP)	NI	OTHER
MB/REF/TG	6	1957-1980	1968	-	2	4	-	-	-	-	-
MB/REF/RG	10	1955-1982	1969	-	3	7	-	-	-	-	-
MB/REF/RK	5	1960-1985	1971	-	1	3	-	-	1	-	-
MB/WW/RG (LG)	7	1975-1988	1984	-	-	5	-	-	1 (1)*	-	-
MB/WW/RG (MD)	8	1973-1987	1982	-	-	6	-	-	2	-	-
MB/WW/RG (SM)	9	1967-1987	1983	-	-	7	-	1	1	-	-
MB/RK/WW	3	1981-1987	1985	-	-	2	1	-	-	-	-
RDF/SS (LG)	4	1981-1988	1985	-	-	3	-	-	1	-	-
RDF/SS (SM)	8	1979-1988	1984	-	-	6	-	-	2	-	-
MI/SA (LG)	14	1971-1987	1983	3	-	9	2	-	-	-	-
MI/SA (SM)	46	1970-1988	1977	37	1	4	1	-	-	1	CY(1) WS/FF(1)
MI/EA	10	1972-1987	1982	2	-	6	-	-	-	-	CY(1) EGB(1)
TOTALS	130			42	7	62	4	1	8 (1)*	1	4

* indicates one unit with SD/ESP

TABLE 2. FOOTNOTES

(a) An additional 32 plants with other types of combustors or unknown types of combustors were subsequently identified and included in the list of plants existing as of 1988.

(b)	MB/REF/TG	- mass burn, refractory, traveling grate
	MB/REF/RG	- mass burn, refractory, reciprocating or rocking grate
	MB/REF/RK	- mass burn, refractory, rotary kiln
	MB/WW/RG	- mass burn, waterwall, reciprocating or rocking or rolling grate
	MB/RK/WW	- mass burn, rotary kiln, waterwall
	RDF/SS	- RDF, spreader stoker
	MI/SA	- modular incinerator, starved air
	MI/EA	- modular incinerator, excess air
	LG	- large
	MD	- medium
	SM	small

(c)	WS	- wet scrubber
	ESP	- electrostatic precipitator
	FF	- fabric filter baghouse
	DSI/FF	- dry sorbent injection + FF
	SD/FF	- spray dryer + FF
	SD/ESP	- spray dryer + ESP
	CY	- cyclones
	WS/FF	- wet scrubber + FF
	EGB	- electrified gravel bed
	NI	- no information

TABLE 3. MODELS FOR EXISTING AND TRANSITIONAL MWC PLANTS FOR SECTION 111(d) EMISSION GUIDELINES

I.D. No. and Combustor Type[a]	Unit Size (tpd)[b]	Units Per Plant	Plant Capacity (tpd)[c]	Energy Recovery[d]	Baseline Controls[e]	Representation[f]	Distribution of Plants[g]	Total Capacity (tpd)
1. MB/REF/TC	375	2	750	N	ESP	E	3	2,250
2. MB/REF/RG	120	2	240	N	WS	E	5	1,200
3. MB/REF/RK	300	3	900	N	ESP	E	3	2,700
4. MB/WW/RG	750	3	2,250	S	GCP, ESP	E&T	11	24,750
5. MB/WW/RG	360	3	1,080	S	GCP, ESP	E&T	27	29,160
6. MB/WW/RG	100	2	200	S	ESP	E	5	1,000
7. RDF/SS	1,000	2	2,000	S	ESP	E	2	4,000
8. RDF/SS	300	2	600	S	ESP	E	4	2,400
9. MI/SA	50	3	100	S	GCP, ESP	E&T	11	1,100
10. MI/SA	25	2	50	N	GCP	E&T	24	1,200
11. MI/EA	100	2	200	S	ESP	E	5	1,000
12. MB/RC/WW	250	2	500	S	ESP	E	2	1,000
13. MI/EA	140	3	420	S	GCP, ESP	T	3	1,260
14. MB/WW	100	2	200	S	GCP, ESP	T	5	1,000
15. RDF/SS	1,000	2	2,000	S	GCP, ESP	T	4	8,000
16. RDF/SS	300	2	600	S	GCP, ESP	T	3	1,800
17. MB/RC/WW	250	2	500	S	GCP, ESP	T	4	2,000
Not represented by a model[g]						E&T	22	9,250
Total							143	95,070

Continued

TABLE 3 (CONCLUDED) FOOTNOTES

[a] MB/REF/TG = mass burn refractory, traveling grate
MB/REF/RG = mass burn, refractory, reciprocating grate, or rocking grate
MB/REF/RK = mass burn, refractory, rotary kiln
MB/WW/RG = mass burn, waterwall, reciprocating, or rocking, or rolling grate
RDF/SS = RDF, spreader stoker
MI/EA = modular incinerator, excess air
MI/SA = modular incinerator, starved air
MB/RC/WW = mass burn, rotary combustor, waterwall

[b] Tons per day of MSW or RDF combusted per combustor. All model combustors burn 100 percent MSW or RDF.

[c] Tons per day of MSW or RDF combusted for the total plant. All model plants burn 100 percent MSW or RDF.

[d] N = no energy recovery
S = steam generation

[e] GCP = good combustion practices
ESP = electrostatic precipitator
WS = wet scrubber

[f] E = existing MWCs (operating as of March 1988)
T = transitional MWCs (MWCs not operating as of March 1988, but under construction or expected to commence construction by November 1989, when Section 111(d) emission guidelines are proposed).

[g] This includes some older plants that are of unique designs as well as FBCs. The models represent the most common existing and transitional MWC designs; however, no models were developed to represent unusual designs of which there are only one or two MWCs.

TABLE 4. MODELS FOR NEW MWC PLANTS FOR SECTION 111(b) NSPS

I.D. No. and Combustor Type [a]	Model Unit Size (tpd) [b]	Units Per Plant	Model Plant Capacity (tpd)[c]	Fuel (Energy Recovery)[d]	Distribution of Plants[e]	Total[f] Capacity (tpd)
1. MB/WW/RG	100	2	200	100% MSW(S)	9	1,800
2. MB/WW/RG	400	2	800	100% MSW(E)	6	4,800
3. MB/WW/RG	750	3	2,250	100% MSW(E)	7	15,750
4. MB/REF/RK	250	2	500	100% MSW(E)	3	1,500
5. MB/RC/WW	350	3	1,050	100% MSW(E)	3	3,150
6. RDF/SS	500	4	2,000	100% RDF(E)	4	8,000
7. RDF/SS	500	4	2,000	50% RDF/50% wood (E)	1	2,000
8. MI/EA	120	2	240	100% MSW(E)	3	720
9. MI/SA	25	2	50	100% MSW(N)	1	50
10. MI/SA	50	2	100	100% MSW(E)	5	500
11. CFB	250	2	500	100% RDF(E)	2	1,000
12. CFB	250	2	500	50% RDF/50% wood (E)	3	1,500
TOTAL					47	40,770

[a] MB/WW/RG = mass burn waterwall, reciprocating, or rocking or rolling grate
MB/REF = mass burn refractory, rotary kiln
MB/RC/WW = mass burn rotary combustor/waterwall
RDF = RDF, spreader stoker
MI/EA = modular incinerator/excess air
MI/SA = modular incinerator/starved air
CFB = circulating fluidized-bed

[b] Tons per day of waste (or other fuel) combusted per combustor.

[c] Tons per day of waste (or other fuel) combusted for the total plant.

[d] S = steam generation, E = electricity generation, N = no energy recovery.

[e] Plants expected to commence construction in 5-year period after proposal of NSPS (1990-1994).

[f] 24 hr/day X 333 days/yr = 8,000 hr/yr for E plants
100 hr/wk X 50 wk/yr = 5,000 hr/yr for N and S plants

TABLE 5. ESTIMATES OF ACHIEVABLE EMISSION PERFORMANCE FOR CDD/CDF AND CO[a]

COMBUSTOR TYPE	EXISTING COMBUSTORS BASELINE EMISSION[b]		EXISTING COMBUSTORS WITH GCP		NEW COMBUSTORS WITH GCP[e]	
	CDD/CDF (ng/dscm)	CO (ppmv)	CDD/CDF (ng/dscm)	CO (ppmv)	CDD/CDF (ng/dscm)	CO (ppmv)
Mass Burn, Refractory, Traveling Grate	3500	500	-	-	NA	NA
Mass Burn, Refractory, R-Grate[c]	3500	500	<500-1000	150	NA	NA
Mass Burn, Refractory, R-Grate, Rotary Kiln	3500	500	<500-1000[d]	50	<500	50
Mass Burn, Waterwall, R-Grate - Large	500	50	<500	50	<200	50
Mass Burn, Waterwall R-Grate - Midsize	500	50	<200	50	<200	50
Mass Burn, Waterwall R-Grate - Small	2000	400	<200	50	<200	50
RDF, Spreader Stoker	2000	200	<500-1000[d]	100	<500	100
Modular Incinerator, Starved Air	500	100	<400	50	<300	50
Modular Incinerator, Excess Air	500	50	<200	50	<200	50
Mass Burn, Rotary Combustor, Waterwall	2000	100	<500-1000[d]	100	<500	100

(a) Estimate of achievable CO emission limits for all combustors in each sub-class (type).
(b) CDD/CDF baseline estimates are an upper bound for average emissions of all combustors of a given type.
(c) R-Grate = reciprocating, rocking or rolling grate.
(d) Field test data available within the next several months will provide for improved estimates.
(e) Values believed achievable by continued improvement of combustion control measures.

TABLE 6. ESTIMATED MWC CONTROL TECHNOLOGY LEVELS FOR GUIDELINE AND NSPS MODEL PLANTS

Control Levels[a]	Control Technologies[b]	ESTIMATED AVERAGE ACHIEVABLE EMISSION PERFORMANCE: PM, gr/dscf	HCl[c] ppm	HCl[c] %R	SO_2[c] ppm	SO_2[c] %R	CDD/CDF, ng/Nm^3 GL[d]	CDD/CDF, ng/Nm^3 NS[d]
GCP[e]	CMB	0.33-0.01	NA	NA	NA	NA	(See Table 5)	
GCP + MPM[f]	CMB, ESP	0.08,0.05[f]	NA	NA	NA	NA	500	300
GCP + BPM	CMB, ESP, FF	0.01	NA	NA	NA	NA	500	300
GCP + GAG + BPM	CMB, DSI, ESP, FF	0.01	25	80	30	40	125	75
GCP + BAG + BPM	CMB, SD, ESP, FF	0.01	<25	95	<30	85	10	10

(a) GCP = good combustion practice, MPM = moderate PM, BPM = best PM, GAG = good acid gas, BAG = best acid gas.

(b) CMB = combustion, ESP = electrostatic precipitator, FF = fabric filter baghouse.

(c) HCl and SO_2 performance levels depend on inlet values. PPM = achievable emission limit with normal inlet values, %R = maximum required removal efficiency with high inlet values.

(d) Model plant application: GL = Guideline plant, NS = NSPS plant

(e) GCP for existing plants only

(f) MPM = 0.08 gr/dscf for existing plant and 0.08 or 0.05 gr/dscf for NSPS plant depending on unit size

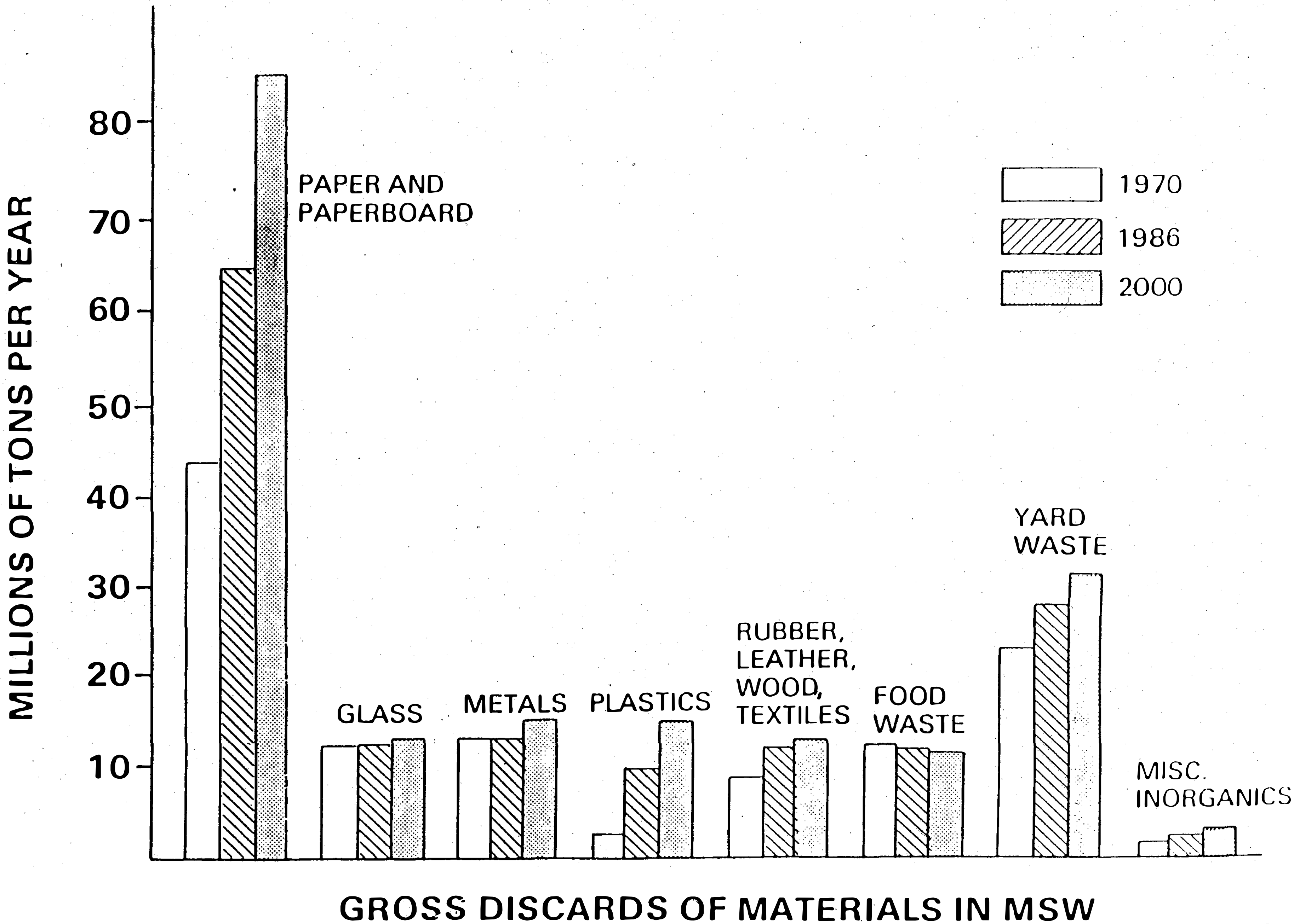

Figure 1. Trends in MSW Materials[2]

Appendix F

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Municipal solid waste (MSW) represents both a significant problem and an abundant resource for the production of energy. The residential, institutional, and industrial sectors of this country generate about 250 million tons of MSW each year.

In this report, the authors have compiled data on the status of MSW in the 13-state western region, including economic and environmental issues. The report is designed to assist the members of the Western Regional Biomass Energy Program Ad Hoc Resource Committee in determining the potential for using MSW to produce energy in the region.

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