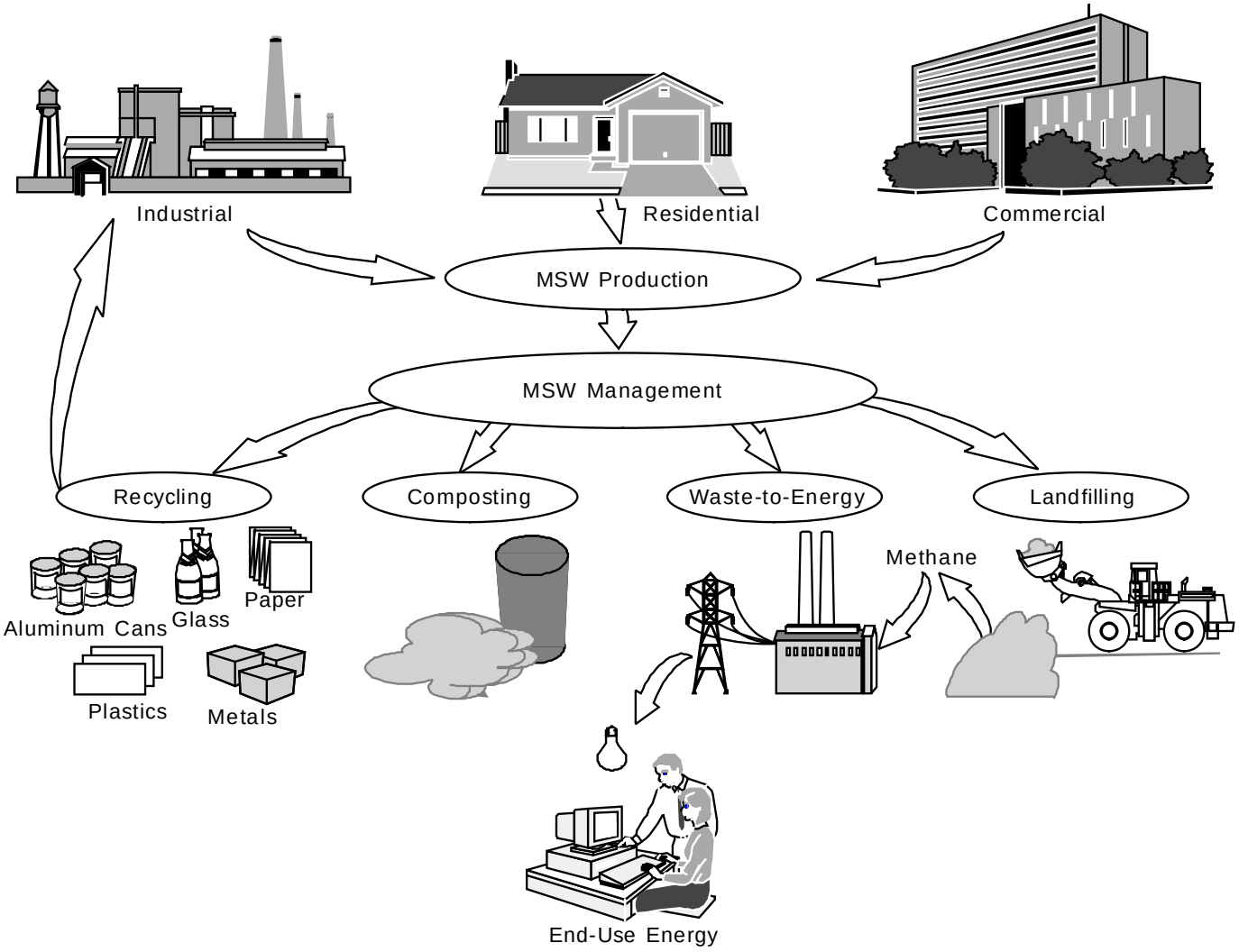
3. Municipal Solid Waste Profile

Introduction

The municipal solid waste (MSW) industry has four components: recycling, composting, landfilling, and combustion (Figure 7). The U.S. Environmental Protection Agency defines MSW to include durable goods, containers and packaging, food wastes, yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources.[54] It excludes industrial waste, agricultural waste, sewage sludge, and all categories of hazardous wastes, including batteries and medical wastes. More than 209 million tons of MSW was generated in 1994. Paper and paperboard accounted for 81.3 million tons (38.9 percent) of the total waste stream, yard wastes 30.6 million tons (14.6 percent), plastics 19.8 million tons (9.5 percent),

Figure 7. Chief Components of Municipal Solid Waste Management

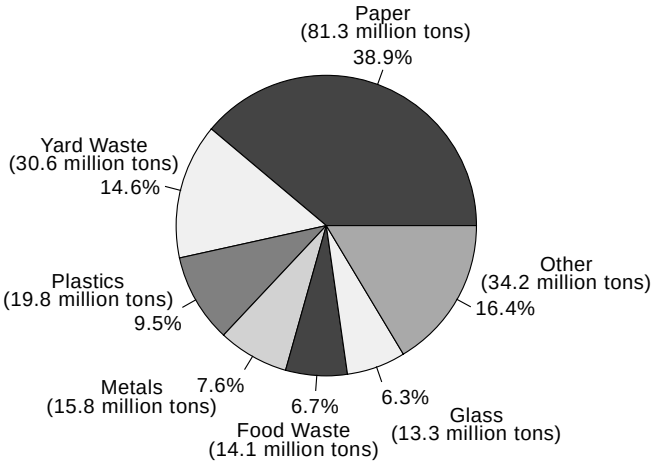


Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels (1996).

[54]U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1995 Update*, EPA/530-S-96-001 (Washington, DC, March 1996).

metals 15.8 million tons (7.6 percent), food 14.1 million tons (6.7 percent), glass 13.3 million tons (6.3 percent), and other 34.2 million tons (16.4 percent) (Figure 8).

Figure 8. Total U.S. Waste Generation Before Recycling, 1994



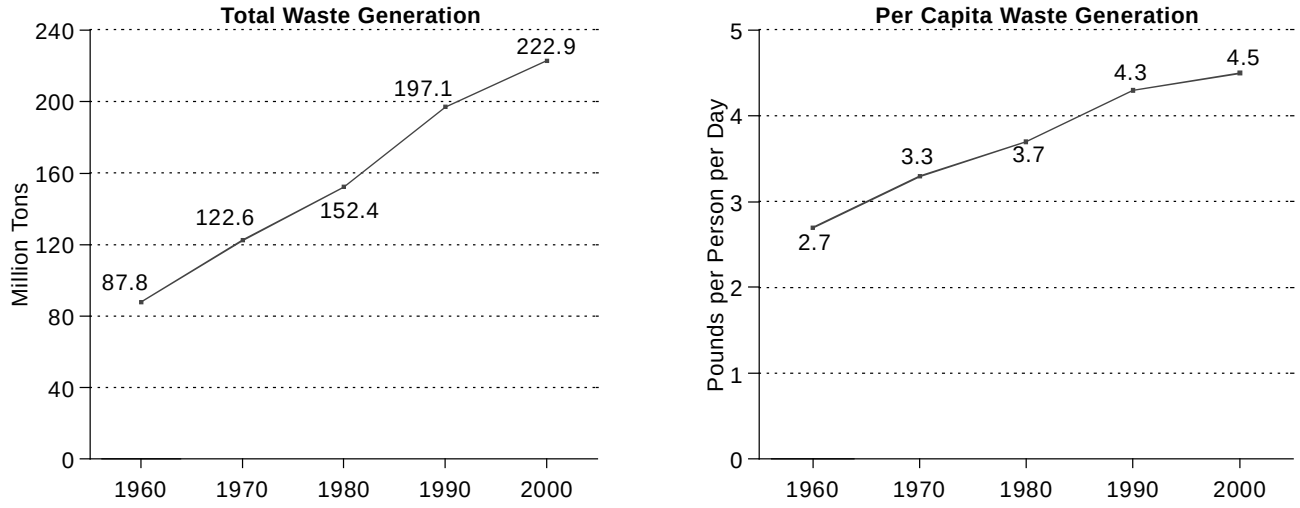
Source: U.S. Environmental Protection Agency, *Municipal Solid Waste Factbook*, database version 3.0 (Washington, DC, March 1996).

Trends in Municipal Solid Waste Generation

The generation of MSW has increased from 88 million tons in 1960 to 209.1 million tons in 1994. During that time, per capita generation of MSW increased from 2.7 pounds per person per day to 4.4 pounds per person per day (Figure 9). Per capita generation is expected to remain constant through 2000, when total MSW generation is expected to reach 223 million tons.

In 1960, approximately 30 percent (27 million tons) of MSW generated was incinerated, most without energy recovery or air pollution controls (Table 8). During the next two decades, combustion declined steadily, to 13.7 millions tons by 1980, as old incinerators were closed. Less than 10 percent of the total MSW generated in 1980 was combusted. With the enactment of the Public Utility Regulatory Policies Act of 1978 (PURPA) and the emergence of a guaranteed energy market, combustion of MSW increased to 31.9 million tons or 16 percent of generation by 1990. All of the major new waste-to-energy (WTE) facilities are designed with air pollution controls and have energy recovery. During the 1990s, the absolute amount of MSW combusted and converted into energy remained fairly constant, although the share declined slightly. By the year 2000, the amount of MSW combusted is expected to reach 34 million tons.[55]

Figure 9. U.S. Waste Generation, 1960-2000



Source: U.S. Environmental Protection Agency, *Municipal Solid Waste Factbook*, database version 3.0 (Washington, DC, March 1996).

[55]U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1995 Update.*

Table 8. Historical and Projected U.S. Production of Municipal Solid Waste, Selected Years, 1960-2000
(Million Tons)

Disposition	1960	1970	1980	1990	1991	1992	1993	1994	2000
Combustion[a]	27.0	25.1	13.7	31.9	33.3	32.7	32.9	32.5	34.0
Recovery for Recycling and Composting	R5.6	8.6	R14.4	32.9	37.3	41.5	45.0	49.3	66.9
Discards to Landfill	R55.3	R89.5	R124.3	R132.3	126.2	128.8	129.0	127.3	122.0
Total Production	**87.8**	**R121.6**	**R152.4**	**R197.1**	**196.8**	**203.0**	**206.9**	**209.1**	**222.9**

[a]Includes combustion of MSW in mass burn or refuse-derived form, incineration without energy recovery, and combustion with energy recovery of source-separated materials in MSW.

R = Revised data.

Note: Totals may not equal sum of components due to independent rounding.

Sources: **1960, 1970, 1980, 1990, 1994, and 2000:** U.S. Environmental Protection Agency, *Municipal Solid Waste Factbook*, database version 3.0 (Washington, DC, March 1996). This source has revised some of the historical data. **1991, 1992, and 1993:** U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1995 Update*, EPA/530-S-96-001 (Washington, DC, March 1996).

Waste-to-Energy Facilities

As of the fall of 1996, there were 102 WTE facilities marketing energy in the United States.[56] The number of facilities has declined by more than 10 percent during the past few years. Most of the WTE facilities in the United States are located in the East, where landfill space is the most scarce. WTE capacity has declined by approximately 2 percent over the last year or so, from almost 101,000 tons per day to approximately 99,000 tons per day.

Type of Process and Capacity

Generally, WTE facilities can be divided into two process types: mass burn and refuse-derived fuel (RDF). Mass burn facilities process raw waste; it is not shredded, sized, or separated before combustion. Very large items such as refrigerators or stoves and batteries / hazardous waste materials are removed before combustion. Noncombustible materials such as metals can be removed before or after combustion, but they are usually separated from the ash with magnetic separators. The waste is usually deposited in a large pit and moved to furnaces with overhead cranes.

Combusting waste usually reduces its volume by approximately 90 percent. The remaining ash is buried in landfills. The ash is divided into two categories: bottom ash and fly ash. Bottom ash is deposited at the bottom of the grate or furnace. Fly ash is composed of small particles that rise during combustion and are removed from the flue gases with fabric filters and scrubbers. Fly ash is usually considered to be the more significant environmental problem.

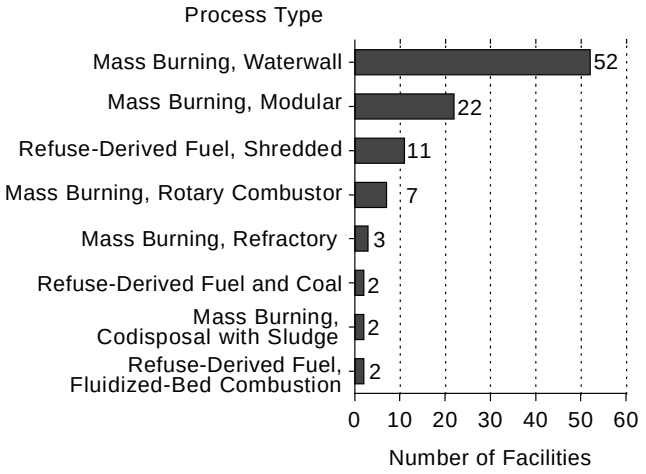
Waste is preprocessed at RDF facilities. Noncombustible materials are removed, increasing the energy value of the fuel. The extent to which noncombustible materials are removed varies. Most systems remove metals with magnetic separators; glass, grit, and sand may be removed through screening. Some systems utilize air classifiers, trommel screens, or rotary drums to further refine the waste.

Modular facilities are small mass burn facilities; they are usually prefabricated and shipped fully assembled or in modules to the construction site. Mass burn waterwall facilities are usually custom-designed and constructed at the site. Waterwall furnaces contain closely spaced steel tubes that circulate water through the sides of the combustion chamber. The energy from the burning waste heats the water and produces steam. Some waterwall facilities also use rotary combustors to rotate the waste, resulting in more complete combustion.

The overall majority of WTE facilities employ mass burn processes (Figure 10). Of the 101 facilities reporting the type of process employed in 1996, 86 were mass burn facilities and 15 were RDF facilities. Two of the mass burn facilities codisposed their waste with sludge. Although only 22 percent of the facilities were of the smaller modular type, 6 of the 13 facilities located in the North Central region were modular (Table 9). Over half of the facilities were of the mass burn, waterwall type. More than 40 percent of the facilities are located in the Northeast and another one-third in the South. Only 22 percent are located in the West and North Central regions, where landfill space is relatively less scarce.

[56]Data based on Governmental Advisory Associates, Inc., *Municipal Solid Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Figure 10. Number of Facilities Performing Waste-to-Energy Operations by Process Type, 1996



Note: One reporting facility did not list type of process.

Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

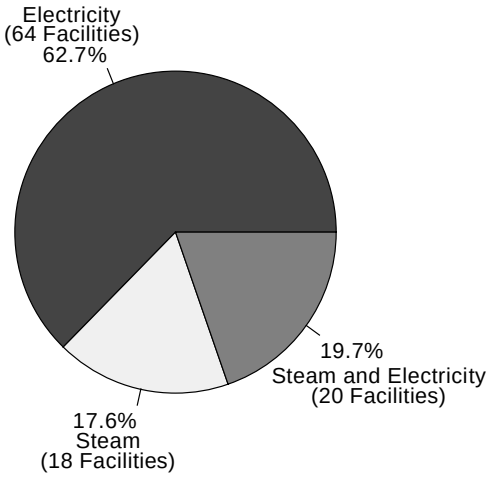
The average capacity of U.S. WTE facilities is almost 1,000 tons per day (Table 10). RDF facilities, on average, have more than twice the capacity of mass burn facilities (almost 1,900 tons per day versus 850 tons per day). The facilities in the Northeast and South regions have an average capacity greater than 1,000 tons per day. The average capacity of the facilities in the North Central and West regions is between 700 and 800 tons per day (Table 11). Modular facilities are by far the smallest, ranging from an average of 89 tons per day in the North Central region to 256 tons per day in the Northeast (Table 12).

Primary Energy Form

Over 80 percent of the 102 facilities produce electricity. Twenty of the 84 facilities that produce electricity co-generate steam and electricity (Figure 11). Only 18 of the facilities produce just steam; 12 of those facilities are modular. None of the RDF facilities produce steam only, compared with more than half of the modular facilities, most of which are older facilities.

In recent years most of the installations have generated electric power. The guaranteed market for electricity under PURPA minimizes the financial risk for facilities generating electricity. This condition could change if electricity prices drop as a result of restructuring in the electric utility market.

Figure 11. Energy Production from Waste-to-Energy Facilities by Type of Energy, 1996



Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Table 9. Waste-to-Energy Facilities by Type of Process and Region, 1996

Type of Process	Number of Facilities				
	Northeast	South	North Central	West	Total
Mass Burning, Modular	5	10	6	1	**22**
Mass Burning, Waterwall	27	16	4	5	**52**
Mass Burning, Refractory	1	1	0	1	**3**
Mass Burning, Rotary Combustor	5	2	0	0	**7**
All RDF Processes	5	5	3	2	**15**
Total	**43**	**34**	**13**	**9**	**99**

RDF = refuse-derived fuel.

Note: One facility did not list a process type. Two facilities that listed process as mass burning codisposal with sludge were not included in the totals. Information shown in this table includes only facilities that market energy.

Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Table 10. Design Capacities of Waste-to-Energy Facilities by Process Type, 1996
(Tons per Day)

Type of Process	Mean	Minimum	Maximum	Number of Facilities
Mass Burning	849.8	24	3,150	86
All RDF Processes	1,873.8	294	4,000	13
All Facilities	**965.4**	**24**	**4,000**	**99**

RDF = refuse-derived fuel.
Note: Two facilities did not list design capacities, and one facility did not list a process type.
Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Table 11. Design Capacities of Waste-to-Energy Facilities by Region, 1996
(Tons per Day)

Region	Mean	Minimum	Maximum	Number of Facilities
Northeast	1,021.2	50	2,688	42
South	1,012.1	40	3,150	34
North Central	780.4	72	4,000	14
West	734.4	24	2,160	10
All Facilities	**955.7**	**24**	**4,000**	**100**

Note: Two facilities did not list design capacities.
Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Table 12. Average Design Capacities of Waste-to-Energy Facilities by Type of Process and Region, 1996
(Tons per Day)

	Average Design Capacity				
Type of Process	Northeast	South	North Central	West	All Facilities
Mass Burning, Modular	255.6	149.7	88.7	100.0	**154.9**
Mass Burning, Waterwall	1,185.1	1,450.9	559.3	778.0	**1,179.6**
Mass Burning, Refractory	240.0	1,000.0	—	420.0	**553.3**
Mass Burning, Rotary Combustor	1,051.2	355.0	—	—	**852.3**
All RDF Processes	1,030.0	1,825.0	1,931.3	1,455.0	**1,873.8**

RDF = refuse-derived fuel.
Note: One facility did not list a process type. Two facilities that listed process as mass burning codisposal with sludge were not included in the totals. Three facilities did not list design capacity.
Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

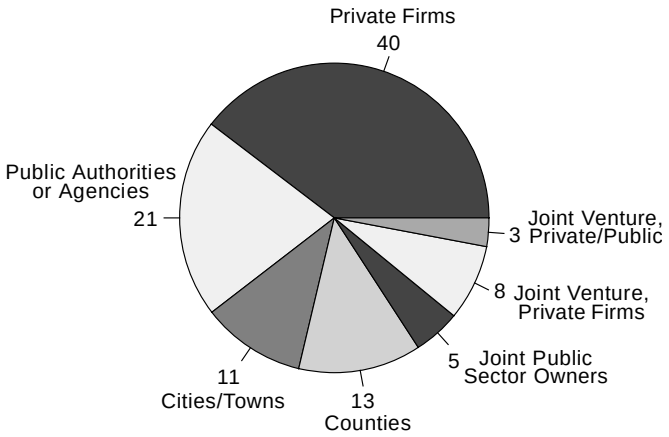
Air Pollution Control Equipment

Various types and designs of air pollution control equipment are used by most WTE facilities (Table 13). Dry scrubbers and baghouse filters used in combination are more efficient than most electrostatic precipitators in removing acid gases and particulates from stack gases. Nitrogen oxide and mercury emissions must also be controlled in most regions of the United States. Modular facilities that have exclusively used after-burn or two-chamber combustion systems can no longer rely on those systems for adequate pollution prevention in many parts of the United States. As a result, some have been retrofitted. Others have permanently closed down.

Owners and Operators

Almost half (48) of the WTE facilities in the United States are privately owned (Figure 12); 3 are joint public/private ventures; and the remainder are publicly owned. Twenty-five of the facilities owned by the public sector are operated by the private sector (Figure 13). Thus, 70 percent of all U.S. WTE facilities are operated by the private sector (Figure 14).

Figure 12. Waste-to-Energy Facilities by Type of Ownership, 1996



Note: One reporting facility did not list type of ownership.
Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

The Landfill Gas Industry

Municipal solid waste contains significant portions of organic materials that produce a variety of gaseous products when dumped, compacted, and covered in landfills. Anaerobic bacteria thrive on the oxygen-free environment, resulting in the degradation of the organic materials and the production of primarily carbon dioxide and methane. Carbon dioxide is likely to leach out of the landfill because it is soluble in water. Methane, on the other hand, which is less soluble in water and lighter than air, is likely to migrate out of the landfill. In the United States, there are 133 facilities that convert landfill gas (LFG) into energy at landfill sites that are either operational or temporarily shut down.[57]

Location and Startup Date

The LFG-to-energy facilities appear to be evenly distributed throughout the regions of the country. The West region has the largest number, followed by the

Table 13. Air Pollution Control Equipment at Waste-to-Energy Facilities by Type of Process, 1996
(Percent)

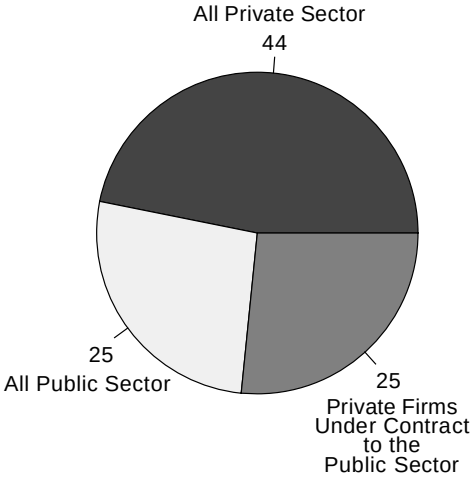
Type of Equipment	Process Type		
	Mass Burning	Modular Units	All RDF Processes
Dry Scrubbers	68.7	22.7	80.0
Baghouse/Fabric Filters	53.1	22.7	60.0
Electrostatic Precipitators	39.1	63.6	46.7
Wet Scrubbers	1.6	13.6	6.7
Ammonia DeNox System	21.9	4.5	20.0
Dry Sorbant Injection	25.0	0.0	6.7
After-Burn System	0.0	22.7	0.0
Mercury Control System	0.0	0.0	0.0
Other Technologies	3.1	13.6	20.0

RDF = refuse-derived fuel.
Note: One facility did not list process type.
Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

[57]E.B. Berenyi and R.N. Gould, *Methane Recovery from Landfill Yearbook* (New York, NY: Governmental Advisory Associates, 1995).

Northeast, North Central, and South (Figure 15). Almost one-third of all the facilities are located in California, and New York has the second largest number. These two States plus Pennsylvania, Michigan, Wisconsin, and Illinois have approximately two-thirds of all the facilities.

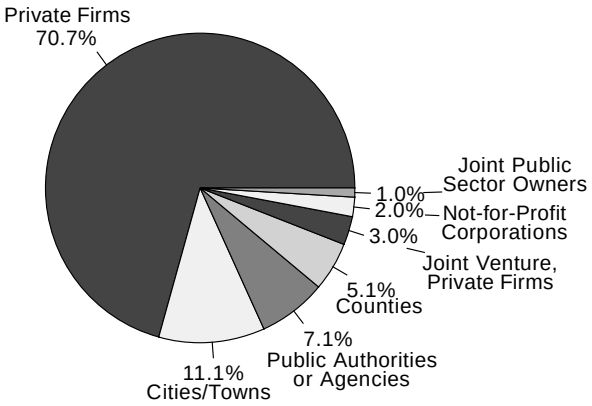
Figure 13. Waste-to-Energy Facilities by Relationship of Owner to Operator, 1996



Notes: Seven reporting facilities did not list relationship between owner and operator. One reporting utility did not list type of ownership.

Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

Figure 14. Waste-to-Energy Facilities by Type of Operator, 1996

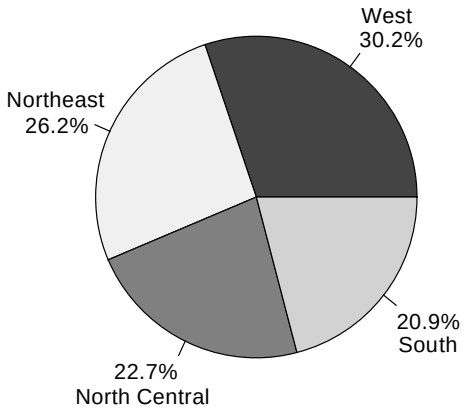


Note: Three reporting facilities did not list type of operator.

Source: Derived from Governmental Advisory Associates, Inc., *Municipal Waste Combustion in the United States: 1996-97 Yearbook, Directory, and Guide* (Westport, CT, 1997).

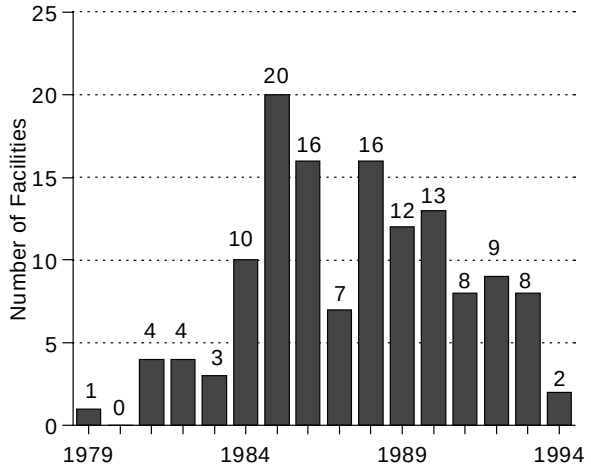
The first LFG-to-energy facility began operation in 1979 after the enactment of PURPA. Approximately 70 percent of the 133 facilities that are in existence today began operation during the 7-year period 1984 to 1990 (Figure 16).

Figure 15. Location of Existing Landfill Facilities by Region, 1994



Source: Derived from Governmental Advisory Associates, Inc., *Methane Recovery from Landfill Yearbook: 1994-95* (New York, NY, 1994).

Figure 16. Number of Landfill Gas Processing Facilities Entering Service by Year, 1979-1994



Source: Derived from Governmental Advisory Associates, Inc., *Methane Recovery from Landfill Yearbook: 1994-95* (New York, NY, 1994).

Energy Characteristics

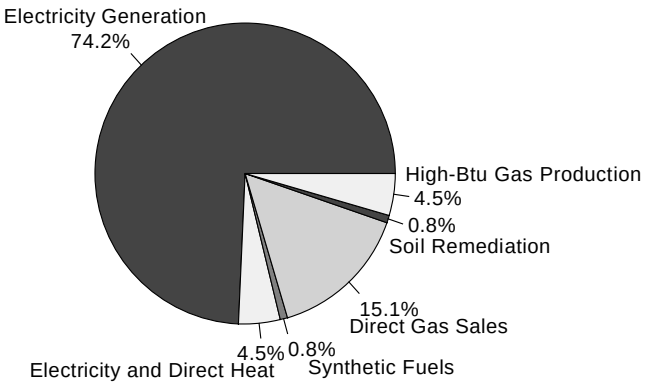
To collect LFG, wells are usually drilled 30 to 100 feet into a landfill. Key characteristics of a landfill that determine the amount of gas available include the type and compactness of the refuse buried, the length of time it has been buried, and the amount of rainfall in the area.

Historically, LFG has been collected and flared at sites because it was uneconomical to convert to energy. Energy applications include the use of low- to medium-Btu gas to generate electricity or as a boiler fuel. The LFG can also be upgraded for use in natural gas pipelines, and small amounts of LFG are used for soil remediation or synthetic fuels (Figure 17).

Most LFG-to-energy facilities create medium-Btu gas by filtering out particulate matter and removing water vapor. This gas has an energy value of approximately 500 Btu per cubic foot. Pipeline-quality gas (100 percent methane) can be created by further refinement to remove most of the carbon dioxide and other contaminants. However, in recent years the percentage of facilities producing pipeline-quality gas has declined as a result of low natural gas prices.

Approximately 75 percent of the LFG-to-energy facilities in the United States produce electricity (Figure 17). Prices for the sale of electricity from LFG plants in 1994 were reported for 82 facilities (existing and planned). The average prices (in cents per kilowatthour) were 6.81, 5.76, 4.98, and 4.39 in the West, Northeast, South, and North Central regions, respectively. Many of the facilities receive peak and off-peak rates. The rates presented above are average payments per kilowatthour, which may vary from year to year.

Figure 17. Landfill Gas Utilization by Existing Facilities, 1994



Note: One plant generates electricity, sells gas directly, and produces both pipeline-quality gas and synthetic fuels.

Source: Derived from Governmental Advisory Associates, Inc., *Methane Recovery from Landfill Yearbook: 1994-95* (New York, NY, 1994).