The Real State of the Art in Waste-to-Energy Facilities: Design and Operations

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Today's "state-of-the art" facilities are those that began operating since the establishment of EPA's New Source Performance Standards and Emission Guidelines, proposed in 1989 and issued in 1991. Facilities built according to these tougher air quality standards, and coming on line in the past two years, define a new breed of WTE plants.

Because of the today's greater emphasis on a high level of environmental protection, contemporary facilities utilize air quality control equipment and meet emission levels that are unprecedented for solid fuel burning systems. However, these plants also show improvements in other areas over plants preceding them by only a few years. There is increased attention on the recovery of recyclable material and separation of hazardous and noncombustible material, better ash management and more exploration of ash reuse, and greater dependability in terms of on-line availability.

This paper characterizes the design and operating practices for modern waste-to-energy facilities. It illustrates that communities can rely upon such facilities to help them dispose of their solid waste--with confidence in the facilities' ability to manage the waste and to perform in an environmentally sound manner.

Selection Process

This paper is based on a survey of eight new operating WTE plants representing a cross-section of developers, waste-processing capacity, and ownership. The mix includes eight WTE developer companies and a split of three public and five private facility owners. [See Table 1 for a list of the facilities surveyed.] A key selection criteria was that the plants all began commercial operation within the last two years. The eight represent more than half of 15 facilities that came on line during 1991 and 1992.

One objective of the survey was to ensure a truly representative sample of the new breed. As such, our "state of the art" is defined by plants that are new enough to incorporate the latest equipment and technology, yet also have an operating history to enable evaluation of how well the plants are meeting their objectives. These facilities--not the "average" or "sum of experience" of the approximately 130 operating WTE facilities--are the most appropriate models for review by other communities that are considering WTE as a solid waste management option.

Table 1: Surveyed Facilities

Facility	*Capacity*	*Owner*	*Developer*	*Commercial Start Date*
Broward County, Fla.-South	2,250	Wheelabrator	Wheelabrator	April 1991
Camden County, NJ	1,050	Foster Wheeler	Foster Wheeler	July 1991
Huntington, NY	750	Ogden Martin	Ogden Martin	December 1991
Southeast CT (Preston)	600	Connecticut RR Authority	American Ref-Fuel	February 1992
Montgomery County, PA	1,200	Montenay Power	Dravo	February 1992
Adirondack, NY (Hudson Falls)	400	Hudson Falls	Foster Wheeler	February 1992
Peel, Ontario	450	Peel Resource Recovery	PRRI	April 1992
Mid-Maine Waste (Auburn)	200	Mid-Maine Action Corp.	American Energy	August 1992

Table 2: Air Emission Permit Limits at Surveyed Facilities (all corrected to 7% O_2)

Facility	*Particulate*	*Opacity*	*SO_2*	*HCl*	*CO*	*NOx*	*Hg*	*Cd*
Broward (South), Fla.	0.0152 gr/dscf	15% 20% max. (3 minutes)	65% 60 ppm (3 hours rolling)	----	88 ppm (4-day) 400 ppm (1 hour)	350 ppm (3 hours rolling)	1.2 mg/m³	----
Camden County, N.J.	----	20% (3 minutes in 30 minutes)	50 ppm (3 hours)	90% 50 ppm (1 hour)	100 ppm (4 day) 400 ppm (1 hour)	300 ppm (3 hours)	----	----
Huntington, N.Y.	.010 gr/dscf	10% (6 minutes)	70% 90 ppm	90% 50 ppm (8 hours)	100 ppm (8 hours)	190 ppm (3 hours)	0.28 mg/m³	0.045 mg/m³
Southeast, Conn.	----	10% (6 minutes) 40% max. (1 minute)	70% 50 ppm (3 hours) *and* 30 ppm (24 hours)	90% 50 ppm	240 ppm (1 hour)	357 ppm (24 hours)	----	----
Montgomery County, Penn.	----	10% (3 minutes per hour) 30% max.	70% 30 ppm (1 hour)	90% 30 ppm	100 ppm (24 hours) 400 ppm (1 hour)	300 ppm (24 hours)	----	----
Adirondack, N.Y.	0.0254 gr/dscf	20% (6 minutes)	70% 85 ppm (90-day average)	90% 85 ppm	378 ppm	283 ppm (NO_2)	1.7 mg/m³	----
Peel, Ontario	0.0126 gr/dscf	10% (6 minutes)	*	42 ppm (24 hours)	70 ppm (4 hours)	*	----	----
Mid-Maine	0.010 gr/dscf	----	80% 30 ppm (24 hours)	90% 25 ppm	100 ppm (4-hour block)	350 ppm (24 hours)	----	----

* Subject to Point of Impingement Standards, but not stack emission standards.

Refuse-derived fuel (RDF) plants were excluded from this survey. This was not to imply RDF plants do not make up a part of the "state of the art," of the industry, but to keep the comparisons within a similar combustion technology. Also, no RDF facilities came into operation in the past two years.

Air Pollution Control

Because air pollution and ash management often raise concerns about WTE technology whenever a community plans a project, it is appropriate to examine the air emission limits, control systems, and air emissions performance records of these facilities.

All of the surveyed facilities include spray dryer (SD) absorber systems that use lime to neutralize acid gases in the flue gas exiting the furnace. These scrubbers are used in combination with either a fabric filter (FF) or an electrostatic precipitator (ESP). Both SD/FF and SD/ESP combinations have proven reliable in meeting air quality regulations and permit limits at these facilities.

Because of a growing emphasis on the reduction of acid rain and smog in many urban areas, more industrial sources of all kinds have limits for nitrogen oxides (NOx). All of the WTE facilities in our survey have NOx limits, even though none would be required to control NOx emissions under current federal regulations. (According to the current federal regulations, there is no NOx limit for facilities that began construction before December 20, 1989; or for new facilities with combustion capacity less than 1,100 tons per day.) These facilities typically emit less than 300 parts per million (by volume) of NOx using by a combination of combustion controls and spray dryer and particulate control devices.

In addition to spray dryer absorbers and fabric filters, the Huntington, New York, facility includes Thermal DeNox, for specific control of NOx, which has allowed controlling emissions of NOx to less than 150 ppm. The Thermal DeNox system, developed by Exxon, features injection of ammonia into the furnace to react with nitrogen oxide to form nitrogen and water. Only five facilities in North America currently employ systems dedicated to NOx control. Depending on the content of the waste streams to be handled by new facilities, and possible NOx requirements in emerging EPA regulations this year, more WTE facilities are likely to include dedicated NOx control systems.

Emission Limits

The permits at these facilities call for tight control over a wide array of parameters. These parameters include several pollutants requiring control (such as sulfur dioxide, hydrochloric acid, particulates), but also other parameters that are used as indicators of good combustion and pollution control practice (including furnace temperature and retention time, carbon monoxide levels, and combustion efficiency). [Table 2 lists many of the permit limits for these facilities.]

Even those facilities that began construction before the current regulations took effect have implemented systems to meet limits close to--and in some cases stricter than--these tough federal standards. Limits for NOx is one example, as noted earlier. Another example is specific limits for metals. Although the EPA has not yet issued specific limits for mercury, cadmium, and lead, many of the surveyed plants have limits for these metals--and several others as well.

Actual Air Quality Performance

No factor is more critical in building assurance about WTE plants than demonstrating a plant's ability to meet environmental mandates generally, and air quality standards, specifically. In this aspect, all the surveyed plants are behaving very well. [Figures 1 through 5 show that the facilities are achieving their permit limits by good margins. In many instances, the most recent tests or continuous emission monitoring (CEM) data show facility emissions below 50 percent of the permitted maximums.]

A caution about these performance records. These values may signal to some observers that facilities are achieving limits easily--and that, perhaps, plants could meet or should be required to meet even more stringent limits. Instead, these values are actually an indication of a doubly-stringent or overlapping air quality standard--not a standard that needs tightening. Today's facilities must meet not only stringent numerical limits, but also tight averaging time limits. In the past, where limits for certain pollutants were averages to be met in 24-hour periods (or longer), now many limits are for far shorter averaging periods--8-hour, 3-hour, and less. It is easier to keep average SO2 emissions below 30 ppm for 24 hours than to maintain the same average for each 3-hour period. The shorter time block allows operators less time to level out emissions due to high values or spikes that may occur within the time block. The effect of the double-tight standards is that plants must operate well below permit levels more than 90 percent of the time in order to ensure they can meet the numeric limits for the short averaging period. The result is often--but not always--actual performance data like you see in these figures--emissions at a fraction of the limits.

The advent of CEM equipment for a number of pollutants has made it possible to measure emissions on a constant basis. CEMs have improved operator control of the combustion process, by allowing quicker reaction to changes in fuel input and emissions. And CEMs have provided a beneficial means to gauge a facility's compliance with regulatory limits. However, CEMs have also been used by regulators as a tool to tighten regulations in the manner described above.

Performance in Other Areas

The most important basis in the evaluation of any plant, of course, is its ability to perform as designed and intended. Today's WTE plants are designed to meet several objectives--the main ones being disposing of MSW, generating useful energy, and maintaining the quality of the environment while accomplishing the former two.

The progress made by the still young WTE industry may be most evident in air quality, since air pollution control system development and design has received a lot of attention in recent years. But other, often overlooked, measures of progress are changes and improvements made in facility operations and processing strategies. Many of the changes have been spurred by the "integrated" approach to solid waste management and emphasis on the recovery of materials. Others have come about as facilities attempt to improve cost-efficiency of their operations. Some areas used to evaluate facility performance include: boiler availability, actual waste processed, energy production, and materials management.

Plant Availability

In an industry where tube corrosion is often high, outages for repair or replacement are commonplace, and targets for boiler availability are typically 85 percent, the performance of the surveyed state-of-the-art plants is an eye-opener. These eight plants had boiler availabilities above 90 percent, some well above 90 percent. [Figure 6 shows availability figures for these facilities.] These percentages reported in Figure 6 are based on total available on-line hours compared to total hours in an operating period (24 hours a day, 365 days a year). The off-line hours include both scheduled and unscheduled downtime for maintenance or repair.

The reporting facilities achieved these levels of availability during their first year or so of operation, when facilities are typically working out the inevitable kinks and bugs. And, of course, some outages are due to causes outside the control of facility operators. The plant manager at Foster Wheeler's Adirondack (Hudson Falls, New York) facility told us that the 93 percent figure was "low"--and could have been closer to 97 percent had a lightning strike not knocked the facility out for 10 days.

The ability to operate more hours with fewer shutdowns allows the facilities to dispose of more trash, to produce more electricity for sale, and improve economics of the facility. The manager of the Camden County, New Jersey, facility said that facility is projected to burn 365,000 tons of waste in 1993 (compared to the facility guarantee of 305,000 tons). He notes that with this kind of operational availability, the facility has been able to divert additional tonnage from the local landfill.

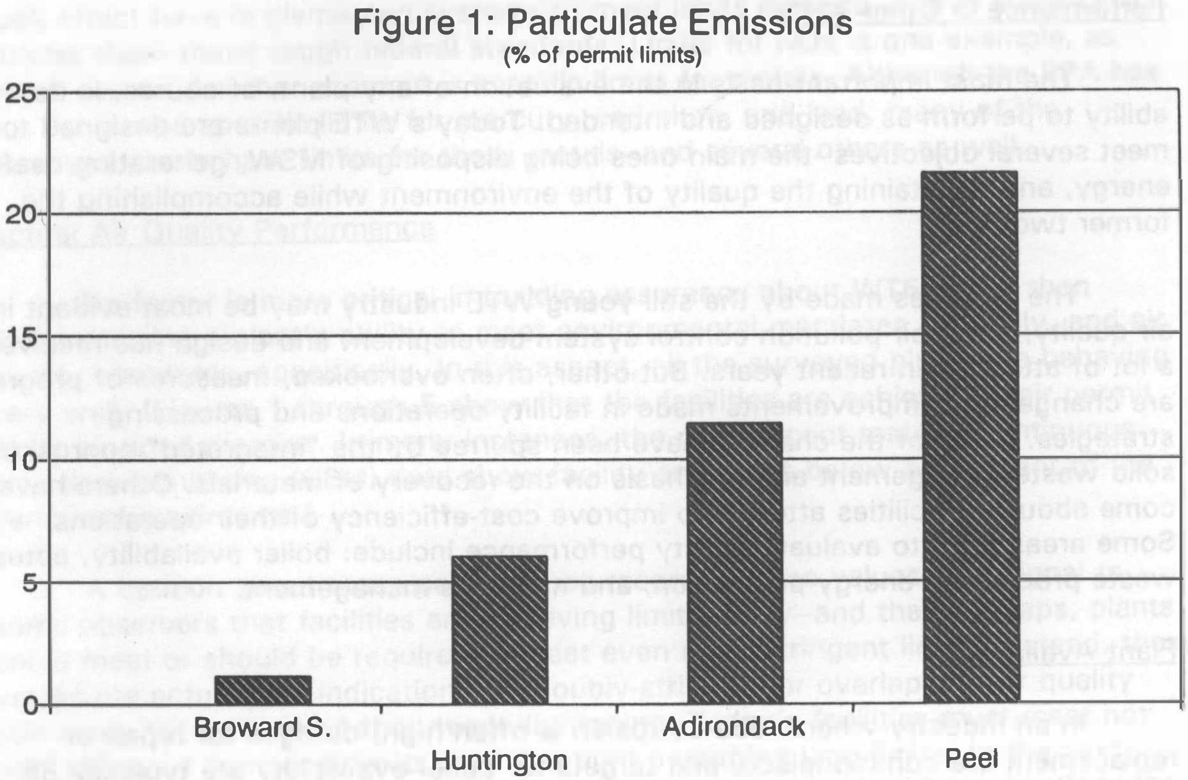


Figure 1: Particulate Emissions
(% of permit limits)
25
20
15
10
5
0
Broward S.
Huntington
Adirondack
Peel

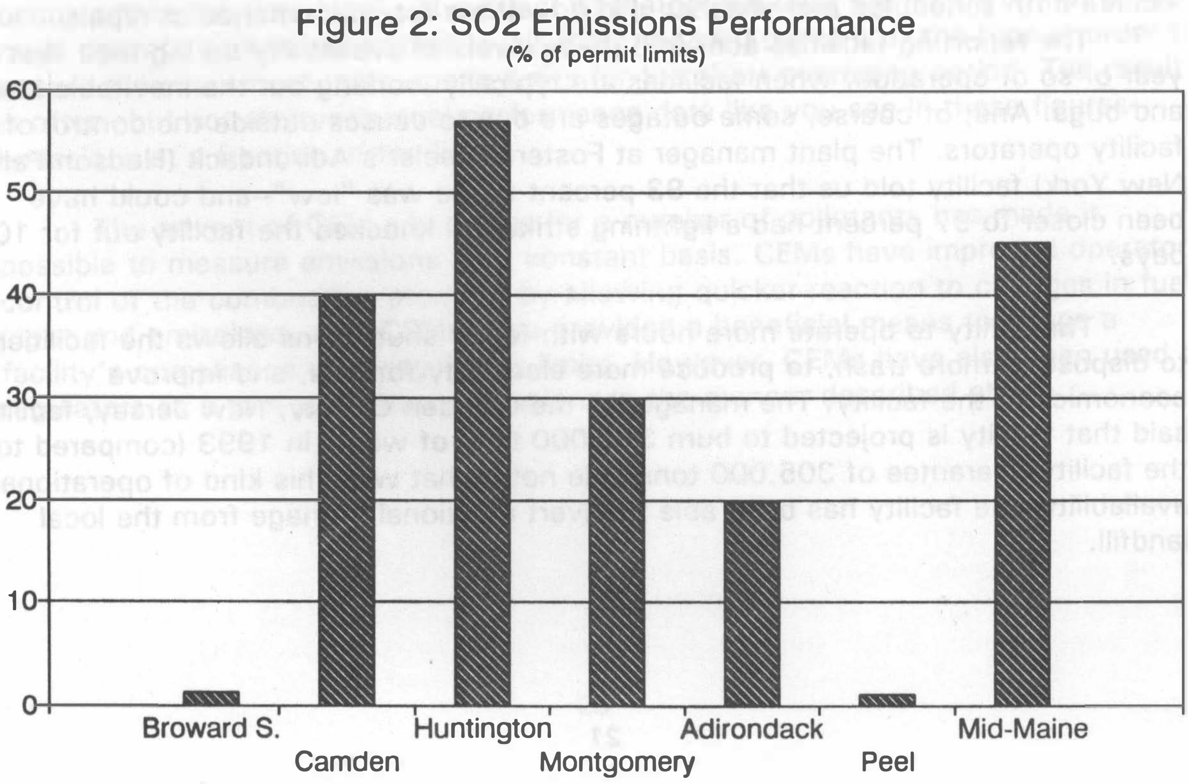


Figure 2: SO2 Emissions Performance
(% of permit limits)
60
50
40
30
20
10
0
Broward S.
Camden
Huntington
Montgomery
Adirondack
Peel
Mid-Maine

Figure 3: HCl Emissions Performance
(% of permit limits)

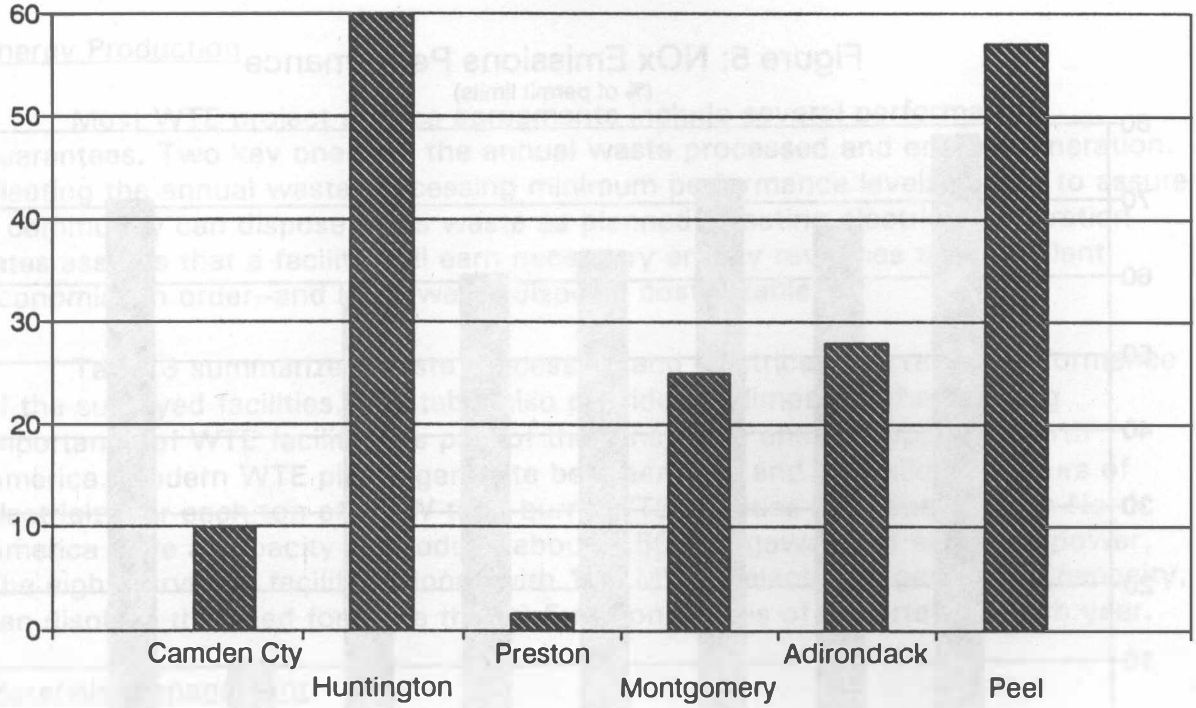


Figure 4: CO Emissions Performance
(% of permit limits)

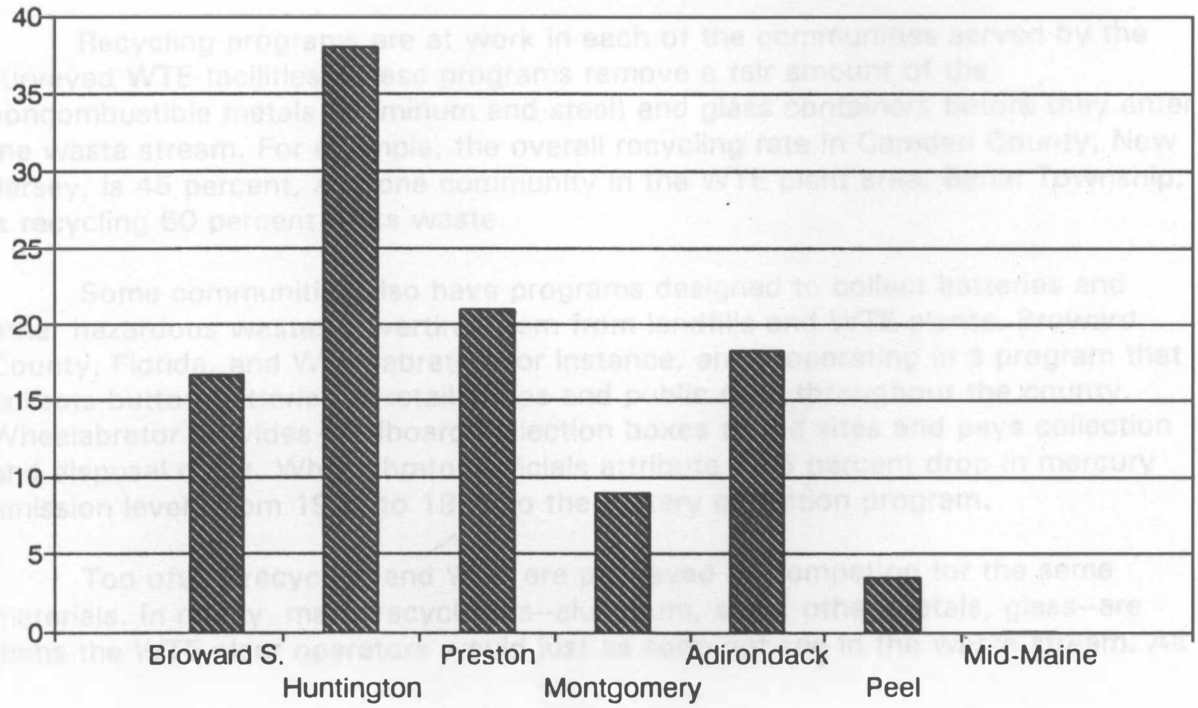
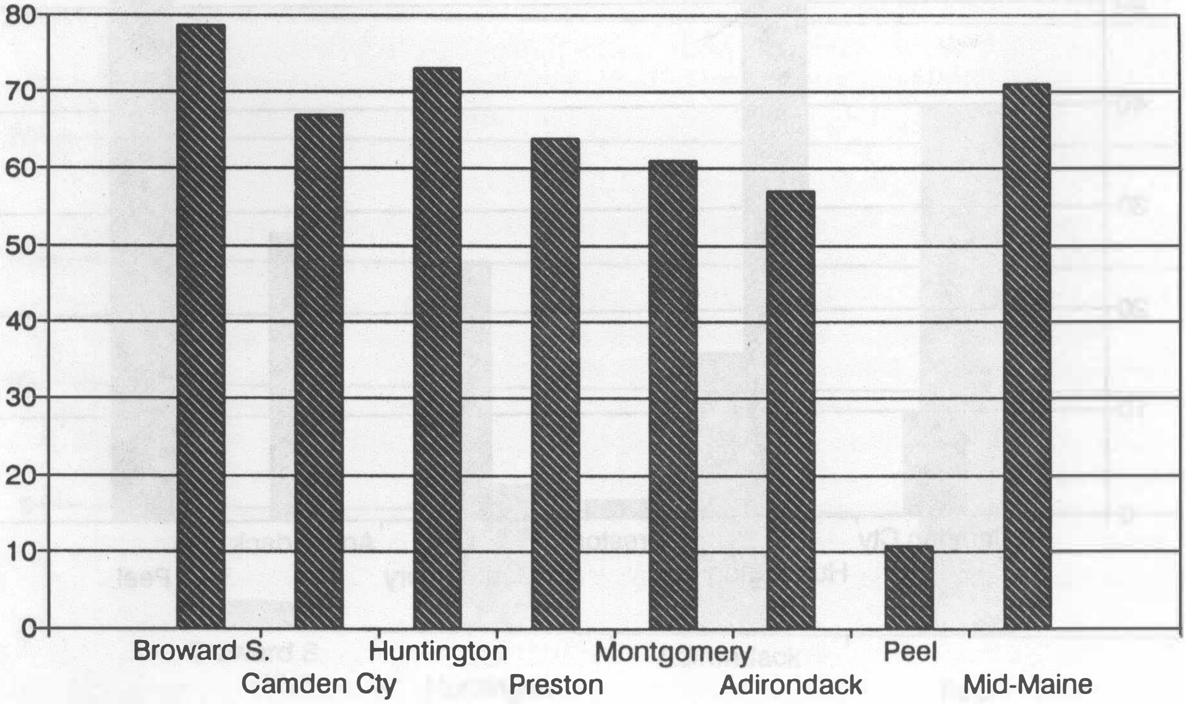


Figure 5: NOx Emissions Performance
(% of permit limits)



Energy Production

Most WTE project service agreements include several performance guarantees. Two key ones are the annual waste processed and energy generation. Meeting the annual waste processing minimum performance levels is vital to assure a community can dispose of its waste as planned. Meeting electrical generation rates assures that a facility will earn necessary energy revenues to keep plant economics in order--and keep waste disposal costs stable.

Table 3 summarizes waste processing and electrical generation performance of the surveyed facilities. The table also provides a glimpse of the growing importance of WTE facilities as part of the renewable energy supply in North America. Modern WTE plants generate between 500 and 600 kilowatt-hours of electricity for each ton of MSW they burn. WTE facilities now operating in North America have a capacity to produce about 2,500 megawatts of electrical power. The eight surveyed facilities alone, with 180 MW of electricity generation capacity, can displace the need for more than 2.5 million barrels of imported oil each year.

Materials Management

Even though the plants we are profiling here are mass burn--designed to burn unprocessed MSW--the practice at these and other WTE facilities is to remove noncombustible and hazardous materials prior to incineration. Separation of recyclables and noncombustibles takes a coordinated effort on the part of the community, waste haulers, and WTE facility operators. A healthy percentage of separation can and should take place before the WTE plants receive the waste at the facility.

Recycling programs are at work in each of the communities served by the surveyed WTE facilities. These programs remove a fair amount of the noncombustible metals (aluminum and steel) and glass containers before they enter the waste stream. For example, the overall recycling rate in Camden County, New Jersey, is 45 percent, and one community in the WTE plant area, Berlin Township, is recycling 60 percent of its waste.

Some communities also have programs designed to collect batteries and other hazardous wastes--diverting them from landfills and WTE plants. Broward County, Florida, and Wheelabrator, for instance, are cooperating in a program that collects button batteries at retail shops and public sites throughout the county. Wheelabrator provides cardboard collection boxes to the sites and pays collection and disposal costs. Wheelabrator officials attribute a 75 percent drop in mercury emission levels from 1991 to 1992 to the battery collection program.

Too often, recycling and WTE are portrayed as competing for the same materials. In reality, many recyclables--aluminum, steel, other metals, glass--are items the WTE plant operators would just as soon not see in the waste stream. All

Figure 6: Plant Availability

(% on-line vs. total hours)

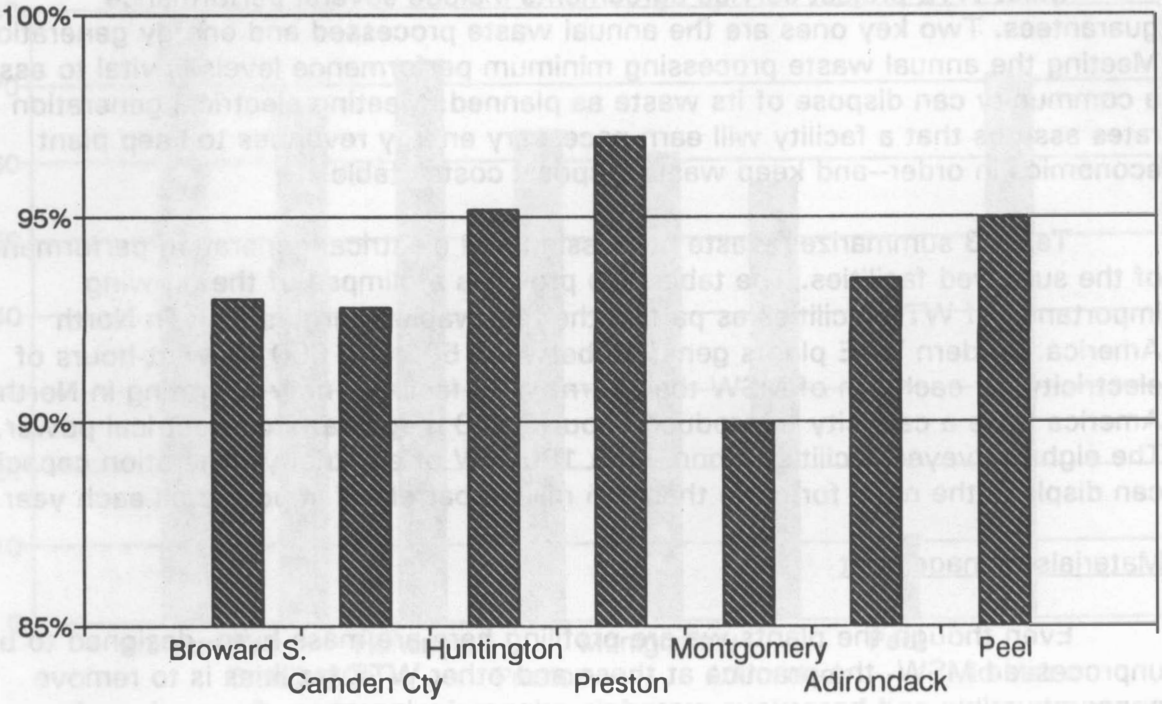


Table 3: Waste Processing and Electrical Generation Performance *

Facility	*Waste Processed (Tons)*	*Guarantee*	*% of Guarantee*	*Generating Capacity*	*Energy Produced (millions kWh)*
Broward County, Fla.-South	720,000	620,500	116 %	60.0 MW	NA
Camden County, NJ	351,000	306,000	114 %	24.0 MW	175,706
Huntington, NY	265,988	252,000	106 %	25.0 MW	156,877
Southeast CT (Preston)	128,000	NA	---	15.0 MW	62,000
Montgomery County, PA	343,413	304,932	113 %	31.0 MW	176,540
Adirondack, NY (Hudson Falls)	152,754	NA	---	11.0 MW	78,000
Peel, Ontario	165,000	110,000	150 %	9.0 MW	70,000

* All figures are for the full calendar year 1992 except Southeast Connecticut and Montgomery County, PA. Southeast figures are for 7 months, and Montgomery County figures are for 10.5 months. Some facilities were in commercial operation only part of the year, but were operating in start-up or acceptance testing modes. (NA = not available)

Table 4: Summary of Ash Management and Disposal Practices

Facility	*Ash*	*Testing Requirements*	*Disposal*	*Reuse*
Broward County	Combined	Quarterly for metals, leachate runoff	Monofill (double composite liner) adjacent to facility	
Camden County	Combined	---	MSW landfill	
Huntington	Combined	----	MSW landfill	Rolite process, used in landfill capping project
Southeast CT	Combined		MSW landfill	
Montgomery County	Combined	TCLP weekly for 40 weeks; then monthly	MSW landfill (double-lined); Hazardous waste facility if fails TCLP test	Testing mix with portland cement using as daily cover
Adirondack	Combined	Required of all permitted facilities	MSW landfill (single-lined)	Some as daily cover in single-lined landfill
Peel	Fly Ash		Hazardous waste landfill	
Peel	Bottom Ash	Tested at start-up and annually	MSW landfill	
Mid-Maine Waste	Combined		MSW landfill	

these materials have zero fuel value, and in fact, can create maintenance or handling problems in the WTE grate and ash handling systems. So, to meet operational requirements and to minimize air quality control problems from burning some wastes, each of the surveyed facilities have programs to inspect incoming refuse and to remove noncombustibles and hazardous materials on the tipping floor.

Efforts to pick out any questionable materials varies from facility to facility. Of the surveyed facilities, efforts ranged from random inspections of about 10 percent of the loads received to the establishment of full processing lines devoted to manual and automatic front-end sorting.

At Ogden Martin's Huntington facility, inspection involves three parties. Tipping floor personnel, crane operators, and host community personnel all examine MSW that enters the plant.

To reduce unacceptable waste received at the Montgomery County, Pennsylvania, facility, Montenay Power conducts random inspections of truckloads. Repeated discovery of unacceptable wastes can lead to a hauler being banned from the facility. In addition, Montenay trains its tipping floor personnel in hazardous waste identification to make sure they capture unacceptable wastes. Hazardous waste is dealt with immediately, including transport to appropriate disposal site, and completing a report to the Pennsylvania Department of Environmental Regulations. The list of items they remove is extensive--including construction and demolition materials, hazardous waste, auto batteries, and tires.

At the Camden County, New Jersey facility, tipping floor personnel and crane operators survey incoming waste and remove white goods, recyclable scrap, and oversize and questionable materials. In the last fiscal year, the facility received 358,000 tons of MSW, but fed only 351,000 to the combustors. Foster Wheeler personnel removed 7,000 tons (or 2 percent of received wastes) as "unacceptable."

The Peel, Ontario plant uses a National Recycling Technology processing system to pre-sort the incoming MSW before feeding it to the incinerators. The MSW is deposited into hoppers by front end loaders, where inspectors remove materials unacceptable for combustion. These include oversize and bulky wastes that can jam the feed chutes, large pieces of steel that are recyclable, and other material that may present a hazard--such as propane tanks, and gasoline storage cans. Then the material passes through the NRT process--which removes ferrous, aluminum, glass, and grit. This process removes between 3 and 10 percent of the plant receipts.

Ash Management

Although EPA finally took a policy position last fall that ash from municipal waste combustors is not subject to RCRA hazardous waste regulations, the decision will have little effect until Congress directs EPA to develop a comprehensive ash management and disposal program. In the meantime, states will continue to develop ash regulations on their own, and WTE ash management will vary from facility to facility. Despite the variations, most states have arrived at a middle ground that likely anticipates the future direction of federal regulations. They manage ash as a special waste, developing specific regulations that require ash management plans, testing, and disposal in specified facilities.

Table 4 summarizes ash management and disposal practices at the surveyed facilities. Of the eight facilities surveyed, all but one--Peel, Ontario--manage their ash as a single product (combining bottom ash and fly ash), and most co-dispose of their ash with MSW in lined or double-lined landfills. In Ontario, regulations require separate handling of fly ash. The fly ash from Peel is collected and stored in closed containers, then shipped to a facility for treatment before disposal in a hazardous waste landfill. Bottom ash is transported without treatment to an MSW landfill.

Public concern about the nature of ash has prevented most of these facilities from undertaking ash reuse or recycling projects in the past. But, some pilot projects are now underway. Two facilities--Montgomery County, Pennsylvania, and Adirondack, New York--have begun using ash as daily cover in MSW landfills. The Montgomery County ash is mixed with portland cement to create an aggregate for the purpose. The Adirondack ash is used without special treatment. A third facility, in Huntington, New York, is providing some of its ash for use in capping a landfill in Islip. In the process, called Rolite, ash is mixed with portland cement in a trommel. It produces a fine aggregate material that allows methane gas to escape.

What's the Cost of State-of-the-Art WTE?

The capital costs of the surveyed plants average $115 million. The average cost per design ton of processing capacity is $133,000 (total capital costs divided by total tons). The range is very broad, from about $96,000 per design ton to $246,000. Although these costs per plant have increased since the 1980s, much of the rise is due to added sophistication of the facilities. Emissions control and monitoring systems can easily account for most of the increases. In fact, air pollution control systems are responsible for about 25 to 30 percent of the total cost of the modern WTE plant.

Table 5 summarizes capital costs and tipping fees for the surveyed WTE facilities. These capital cost figures include all component systems; legal, siting/permitting, and project management costs; construction; and any short-term construction financing. They exclude long-term financing and bond costs.

Of course, when financing and operations costs are added to the capital cost, they provide the basis for setting tipping fees at the plants. The rates charged at the surveyed facilities range from $63 to $86. Most of these are comparable, but higher than rates charged at other disposal facilities in their areas. However, these rates also are expected to be relatively stable for the next 20 to 25 years.

Conclusion

The phrase "state of the art" is often used to describe the latest technology. Too often, however, the phrase is applied to technology that hasn't been proven in application, to systems that are still on the horizon. The foregoing survey has attempted to define a more practical "state of the art," and simultaneously provide a more accurate portrait of WTE facilities than is commonly portrayed in the general press. Industrial facility success stories are rare in newspaper headlines--or even feature sections. The more typical articles on the "nasties" of incinerators during a typical siting process, though, don't relate the tale these state-of-the-art facilities have to tell. The survey defines a real state of the art by profiling actual WTE facilities that have used and demonstrated the latest design, equipment, and strategies to meet community needs for solid waste disposal. It shows facilities that also have met stringent demands for health and environmental protection.

Sometimes "state of the art" is used in confusing ways--such as to criticize past designs and performances--when its most appropriate use is to simply be a model for future facilities. This survey is meant to provide information that can be useful to communities considering WTE to play a role within their solid waste management programs. For communities exploring the technology, these eight facilities are excellent models of what WTE can achieve.

Table 5: Capital Costs and Tipping Fees

Capital Cost	*Cost per Capacity*	*Tipping (Millions $)*	*Design Ton*	*Fee*
Broward County, Fla.-South	2,250	225.0	$100,000	$63.40
Camden County, NJ	1,050	112.4	$107,048	$86.26
Huntington, NY	750	153.0	$204,000	NA
Southeast CT (Preston)	600	147.6	$246,000	$79.00
Montgomery County, PA	1,200	115.0	$ 95,833	$63.00
Adirondack, NY (Hudson Falls)	400	90.0	$225,000	$70.00
Peel, Ontario *	450	54.0	$120,000	$70.00
Mid-Maine Waste (Auburn)	200	26.0	$130,000	$80.00

Capital costs include design, purchase of components, construction and construction financing; siting, permitting, and hearings; project management; and land purchase. Costs exclude all long-term bond and finance costs and all normal operations and maintenance costs.

* Peel, Ontario costs are given in Canadian dollars.

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