8 ❖ COMBUSTION

A decision many communities face is determining whether a waste-to-energy (WTE) system might be a feasible component of their integrated solid waste management program. The amount of waste combusted or expected to be handled by combustion systems through the year 2000 is shown in Table 8-1.

For some communities, developing a WTE project can be a lengthy and expensive process that requires making decisions which have long-term consequences. It is necessary, therefore, to follow a step-by-step process for evaluating the feasibility of constructing and operating a WTE facility. It is also crucial to acquire adequate information to understand the legal, technical, financial, and regulatory issues that must be addressed when considering a WTE system. This chapter describes the issues that communities should consider when evaluating the feasibility and appropriateness of including a WTE facility as part of their integrated solid waste management plan.

Table 8-1

Generation, Recovery, Combustion, and Disposal of Municipal Solid Waste, 1993 and 2000 (At a 30 Percent Recovery Scenario in 2000; In thousands of tons and percent of total generation)

	Thousands of tons		% of generation	
	1993	2000	1993	2000
Generation	206,940	217,750	100.0%	100.0%
Recovery for Recycling	38,490	54,245	18.6%	24.9%
Recovery for Composting*	6,500	11,175	3.1%	5.1%
Total Materials Recovery	44,990	65,420	21.7%	30.0%
Discards after Recovery	161,950	152,330	78.3%	70.0%
Combustion**	32,920	34,000	15.9%	15.6%
Landfill, Other Disposal	129,030	118,330	62.4%	54.3%

* Composting of yard trimmings and food wastes. Does not include backyard composting.
** 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.

Note: Percentages may not add to 100 due to rounding

Sources: USEPA. *Characterization of Municipal Solid Waste in the United States: 1994 Update*

From: Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995. Project Co-Directors: Philip R. O'Leary and Patrick W. Walsh, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison/Extension. This document was supported in part by the Office of Solid Waste (5306), Municipal and Industrial Solid Waste Division, U.S. Environmental Protection Agency under grant number CX-817119-01. The material in this document has been subject to Agency technical and policy review and approved for publication as an EPA report. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

8 ❖ HIGHLIGHTS

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Evaluate the project's usefulness and feasibility.

(p. 8-7)

Developing a WTE (Waste-to-Energy) project is often a lengthy and expensive process, lasting several years. It is crucial to carefully evaluate whether WTE is appropriate for your community.

Figure 8-1 diagrams a systematic evaluation and development procedure for communities to follow.

Establishing a project development team should be the first step.

(p. 8-8)

The technological, legal and other complexities involved in developing a WTE facility will require a range of professional expertise over an extended time. Creating a project development team in the initial stage is crucial. The team should include at least the following:

- project engineer
- financial advisor
- attorney
- operator
- regulatory officials.

Is WTE right for your community?

(p. 8-9)

To determine if an energy recovery facility is feasible and desirable for your community, the following questions must be answered. If the answer is "no" to even one, WTE will probably not be appropriate.

- Is the waste stream sufficient after waste reduction, composting, recycling, etc. are considered? Will this be true for the foreseeable future?
- Is there a buyer for the energy to be produced?
- Is there strong political support for a WTE facility?

What area will the facility serve?

(p. 8-12)

The governmental body planning the WTE system should determine the region it will serve. The amount of waste generated in an area will be a determining factor. The area may include one or more municipalities, a single county, or several counties. A study can determine which of several possibilities is most appropriate. Some examples include the following:

- building one large facility serving the entire region
- building several facilities located strategically to serve the entire region
- constructing one or more units to serve only the region's more populated areas.

WTE facilities must produce significant income.

(p. 8-12)

WTE facilities have high capital and operating costs. This means finding buyers willing and able to sign long-term contracts for purchasing energy or power.

Finding buyers requires marketing initiative.

(p. 8-16)

To successfully market WTE energy requires knowledge of buyers' needs and the ability to convince potential buyers that the facility will be able to meet their needs. Marketers must consider these three factors crucial to all buyers: price, service and schedule, and reliability of energy supply.

❖❖

Several WTE technology options are available.
(p. 8-17 — 8-27)

- *Modular incinerators (15-100 tons-per-day):* These are usually factory-assembled units consisting of a refractory-lined furnace and waste heat boiler, both of which can be preassembled and shipped to the construction site. Capacity is increased by adding units.
- *Mass-burning systems (200-750 tons-per-day per unit):* Mass-burn systems usually consist of a reciprocating grate combustion system, refractory-lining on the bottom four feet, and water-walled steam generator. These systems produce a higher quality of steam (pressure and temperature) than modular systems.
- *Refuse-derived fuel (RDF) systems:* Two types of RDF systems are currently used. Shred-and-burn systems require minimal processing and removal of noncombustibles; and simplified process systems, which remove a significant portion of the noncombustibles.

Controlling emissions is a crucial concern.
(p. 8-28 — 8-31)

WTE technology has recently seen tremendous improvements in emission controls. This chapter discusses controls for the following emissions:

- volatile organics
- NO_x
- acid gas
- particulates
- secondary volatile organics and mercury.

CEM equipment is required for all new facilities.
(p. 8-31)

CEM (Continuous Emission Monitoring) systems monitor stack emissions of NO_x, carbon monoxide, oxygen, particulate via opacity meters, and acid gases via monitoring sulfur dioxide. Gas temperatures are also monitored to control the scrubber process and to ensure baghouse safety.

Facilities must acquire the appropriate permits and licenses.
(p. 8-31 — 8-35)

Permitting and licensing are complex technical processes. Ensuring that the facility is successfully permitted requires enlisting an experienced and qualified consulting firm to prepare the necessary studies and documents.

Facilities must meet federal and state regulations.
(p. 8-31 — 8-34)

The project team must become familiar with both federal and state regulations. Keep in mind that state regulations may be more stringent than federal. The following federal requirements are discussed in this chapter.

- New Source Performance Standards (NSPS)
- National Ambient Air Quality Standards (NAAQS)
- Prevention of Significant Air Quality Deterioration (PSD) review process for attainment areas
- New Source Review (NSR) for non-attainment areas
- Operating Permit Review and periodic renewal.

8 ❖ HIGHLIGHTS (continued)

"SIPs" are required in every state. (p. 8-34)	SIPs (State Implementation Plans) are a set of state air pollution emission regulations and controls designed to achieve compliance with the NAAQS. SIPs must contain requirements addressing both attainment and nonattainment areas.
Disposal of residual materials is another crucial concern. (p. 8-35 — 8-36)	WTE facilities produce a variety of residues: bottom ash constitutes the largest quantity, fly ash is a lighter emission. Constituents in ash and scrubber product vary depending on the materials burned. The major constituents of concern are heavy metals (lead, cadmium, mercury). On May 2, 1994, the U.S. Supreme Court decided that ash which exhibits a hazardous waste characteristic is a hazardous waste and must be so managed. States may also have special requirements for MSW combustion ash, and readers are urged to check with state environmental programs, because such requirements may impact the feasibility of WTE for some communities.
WTE facility wastewater is another special concern. (p. 8-36)	Some facilities also generate wastewater. Those considering a WTE facility should anticipate and acquire all permits that are needed for wastewater treatment and disposal. WTE facility wastewater may affect both ground and surface waters.
Local permits are usually required. (p. 8-36)	The construction and operation of a WTE facility also requires several other permits, many of which satisfy local requirements, such as those for zoning or traffic.
Other environmental concerns must be addressed. (p. 8-37 — 8-38)	• Noise pollution: Truck traffic, plant operations and air handling fans associated with the combustion and emissions control equipment may produce troublesome noise. Most states have standards for noise levels from industrial facilities. Walls, fences, trees, and landscaped earthen barriers may reduce noise levels. • Aesthetic impacts: Negative aesthetic impacts can be prevented or minimized by proper site landscaping and design of facility buildings. • Land use compatibility: WTE plants should be located where they will be considered a compatible or nondisruptive land use. Construction in an industrially zoned area is an example of siting in a compatible land use area. Undeveloped land around the facility will mitigate undesirable impacts. • Environmentally sensitive areas: Impacts of WTE operations on environmentally sensitive areas should be thoroughly documented in environmental impact statements. Ambient air levels of metals and other substances should be established downwind and in the vicinity of the facility to use as a baseline for measuring future impacts on environmentally sensitive areas.

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Final site selection is based on a detailed environmental and technical evaluation.
(p. 8-38 — 8-40)

The final selection criteria should be based on facility design requirements, including

- adequate land area
- subsoil characteristics to structurally support the facility
- access to water supplies for the process and cooling
- access to required utilities
- access to the energy market.

Sites should also be evaluated for their social and environmental compatibility for the specific facility type:

- compatibility with other land use types in the neighborhood
- evaluation of the area's flora and fauna
- existence of any archaeological sites or protected species at the site.

Deciding how the facility will be managed and by whom is crucial.
(p. 8-40 — 8-41)

Facilities can be managed by public employees or a private contractor. There are several issues to consider when choosing among management options.

- WTE facility management requires a properly trained and well-managed team.
- Daily and annualized maintenance using specialized services and an administrative staff to procure and manage such services are required.
- To be financially successful, a WTE facility must be kept online. The cost to the service area when a facility is out of service can be great; quick action to re-establish service is essential.

The advantages and disadvantages of public vs. private operation must be evaluated.
(p. 8-41)

Public operation—advantages:

- The municipality fully controls the facility's day-to-day operation.
- The municipality gains all the facility's economic revenues from the operation.

Public operation—disadvantages:

- The municipality bears all of the facility's day-to-day problems, costs, and liabilities.

When deciding about public operation, consider these needs.
(p. 8-41)

The following needs should be considered when making a decision about public operation:

- attracting and adequately paying a trained and qualified operating staff
- procuring emergency outage repair services quickly
- maintaining sufficient budgetary reserves to make unexpected repairs
- accepting financial damages from the energy buyer if the facility is unable to provide power according to the energy sales agreement
- assuring bond holders that investments will be well maintained and the facility will operate for the term of the bonds
- finding qualified experts to meet the day-to-day operating demands.

8 ❖ HIGHLIGHTS (continued)

Private operation also has special considerations.
(p. 8-41)

Private operation offsets some of the major operating risks posed by WTE facilities, and there may be a long-term advantage to using the services of a private operating company to operate and maintain the facility.

In choosing a private operator, the municipality relinquishes some of the day-to-day operating control and decisions in plant operations. However, the municipality will gain financial security because the operator will be obliged to pay for the cost of failing to meet specific contract performance obligations between the municipality and the energy buyer.

Financing methods affect project execution.
(p. 8-41 — 8-42)

Project financing can be a very complex process requiring detailed legal and tax issues that need to be carefully reviewed and understood. After deciding to develop a facility, the team should add qualified financial advisors to their staff. Financing alternatives include the following:

- general obligation (G.O.) bonds
- municipal (project) revenue bonds
- leverage leasing
- private financing.

Project execution risks must be properly evaluated.
(p. 8-43)

Constructing and operating a WTE facility requires the participants to carefully consider project execution risks. Major risk issues include the following:

- availability of waste
- availability of markets and value of energy and recovered materials
- facility site conditions
- cost of money (i.e., bond interest rate)
- compliance with environmental standards (short- and long-term)
- waste residue and disposal site availability
- construction cost and schedule
- operating cost and performance
- strikes during construction and operation
- changes in laws (federal, state, and local)
- long-term environmental impact and health risks
- unforeseen circumstances (force majeure)
- long-term operating costs
- long-term performance.

8 COMBUSTION

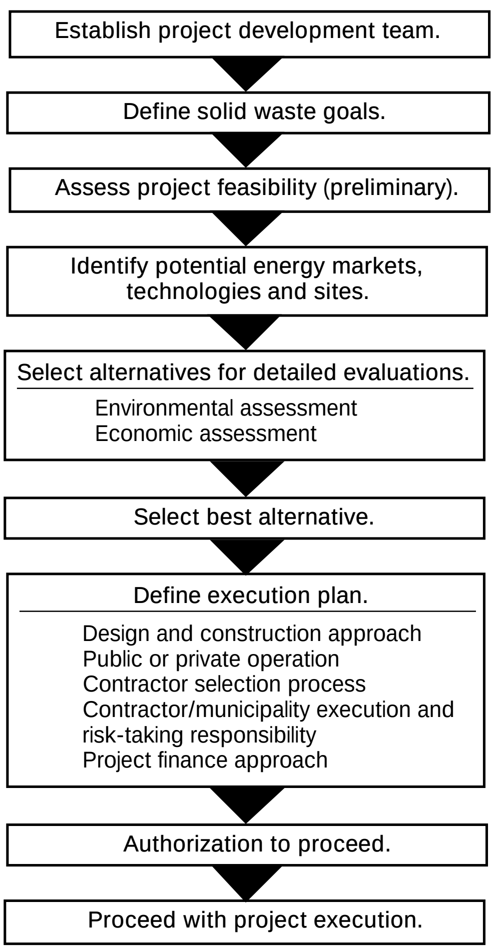
THE IMPLEMENTATION PROCESS

When contemplating a WTE system, following a systematic evaluation and development procedure is critical to success. Figure 8-1 diagrams such a process. Community leaders considering WTE incineration as part of their integrated waste management plan need to answer several questions: Is WTE a necessary part of their integrated waste management plan? Is energy recovery feasible for the community? If so, how can a project be implemented successfully?

These questions and many others need to be answered as program developers work through a step-by-step procedure that addresses each major issue involved in facility siting and implementation. Following such a plan will help ensure that important elements are not overlooked and will likely save time and money if issues are addressed at the optimum point in the process. It is important as well to recognize that a WTE project involves developing business-like relationships with several key players, including system vendors, waste producers, haulers, energy buyers, and citizens.

Also, remember that the project will take a number of years to implement, even if no stumbling blocks are encountered. The time frame may be as follows: one year for preliminary planning, including identification of waste sources, energy markets, most appropriate technology and best site; one year to identify the contractor / operator and the financing method; two to three years for development, including negotiating contracts, gaining regulatory agency approval and obtaining financing; and two to three years for facility construction and start up. A small facility may require less time, but many projects have taken even longer to complete than the six to eight years described here.

Figure 8-1
Project Definition and Development Plan



Source: G. L. Boley

Project Development Team

Developing and implementing a waste-to-energy project will probably be one of the largest and most complex projects that a municipality undertakes. Making decisions about complex technologies, facility operations, financing, and procurement methods requires assembling a project team whose members can provide many different skills over an extended time.

The project development team provides a broad spectrum of specialized skills over an extended period.

Selecting the development team members is one of the most crucial decisions that program organizers will make. Decisions made at this point will impact the project throughout its development and even into the facility's operating future. Team members should represent all sectors of the community *and* provide the mix of necessary skills required by a complex and highly technical project. Team members may be municipal officials from government public works, finance, legal, and administrative departments, or they may be elected officials. The team can be augmented with experienced consultants who specialize in WTE technologies and project development. The following team members, however, are essential:

- **Project engineer:** Waste-to-energy projects involve many complex technical issues from the initial project evaluation through execution. The first project team member should therefore be a qualified engineer with adequate technical expertise, including facility operations.
- **Financial advisor:** Most WTE projects will require special funding. The financial analyst can assess the most appropriate approach for the community to take. He or she should be involved in the project at the early stages so that the technical work will be coordinated with the financing needs.
- **Attorney:** Contracts must be negotiated between the WTE generator and the participating vendors, waste producers and haulers, energy buyers, and the system operators. The attorney will prepare contracts and work with the engineer and financial analyst to ensure that the legal requirements for permits and bonding are satisfied.
- **Operator:** System design should allow for simple and efficient operation in conjunction with the community's other solid waste management activities. An experienced operations manager involved at the earliest stages of the project can help the team avoid expensive planning and implementation mistakes.
- **Regulatory officials:** While regulatory officials are not formally part of the project team, they should be kept informed of progress from the beginning. Regulatory permits will be required for air pollution, wastewater disposal, ash disposal, and zoning. Since regulatory requirements may drastically affect facility design and operation, regulatory officials should review design proposals and provide advice on a regular basis.

When putting the project team together, keep in mind that having qualified and experienced people will enhance the chances of a successful project. In addition, a well-conceived and well-designed project is essential for securing attractive financing rates. Putting together a good team is well worth the effort it takes.

PROJECT DEFINITION: IDENTIFYING GOALS

Before taking any action regarding a WTE facility, a community should take the time to answer the most important question: What are the goals? By answering this question at the start, managers can plan the project to meet those goals and avoid unnecessary complexities in the process. Deciding which goals are most important is crucial to defining the scope of the project. Determining early on why waste-to-energy is the technology of choice will give the project direction and can head off potential problems as the project unfolds.

ASSESSING PROJECT FEASIBILITY

To determine whether an energy recovery project is a feasible waste management alternative for the community, the following questions should be addressed:

Is a WTE facility appropriate for your community?

- When source reduction, reuse, recycling, composting, and waste-stream growth patterns are taken into account, is the remaining waste stream sufficient to support an energy recovery facility operating at or near capacity over the life of the project?
- Is there a buyer for the energy produced by the energy recovery facility?
- Is there strong political support for a WTE facility?

If the answer to any of these questions is "no," WTE incineration probably will not work, and other options should be considered.

Assess Political and Citizen Support

Political support is essential.

Developing a waste-to-energy system involves a great number of technical decisions. Political decisions, however, often dictate whether a project is successful. Political leaders and the public must understand the reasons for pursuing this approach to solid waste disposal. Frequently, the cost of a WTE system will exceed current landfilling costs. Explaining why this alternative was chosen is important in order to build a base of political support. Without this political base, energy markets will be more difficult to find, financing will be more expensive or unavailable, and the overall potential for success will diminish.

Political support is important for other reasons, too. First, siting a WTE facility is a long, complicated, and usually expensive undertaking. Unless the community is strongly behind the project from the beginning, its chances of failing are high. Second, a project may involve private partners as energy buyers. Industrial managers may be reluctant to become involved in a project that does not appear to have community support or is controversial. Finally, strong leadership is needed to bring together all of the diverse parties who are involved in a WTE project.

Evaluate Waste Sources

The fuel value of the waste must be determined.

The community's long-term solid waste generation rates will directly affect the project's viability and the willingness of local waste haulers to cooperate with the project. To determine if sufficient waste is available to support a resource recovery project, the long-term effects of waste management practices like source reduction, recycling, yard trimmings composting, and also changes in materials use (for example, from glass to plastic bottles) on waste volumes and composition should be considered.

Once the type and quantity of waste have been identified, the amount of recoverable energy can be estimated. This is a preliminary projection, since the particular waste-to-energy technology has not yet been determined. Later, a solid waste composition survey that includes tests for heating value to obtain a more accurate projection may be necessary. See Table 8-2 for heating values of typical solid waste components.

Waste Composition

Any form of solid waste management that alters the waste stream available to a WTE project (by reducing/increasing volumes, removing high- or low-Btu

Table 8-2
Heating Value of Typical Solid Waste Components

Material (BTU)	Composition (in %)	Energy Content (per pound)
Paper	50%	7,700
Food Wastes	10%	1,800
Yard Wastes	15%	4,200
Plastic	2%	17,000
Glass	8%	--
Metal	7%	--
Miscellaneous	8%	1,000
Total	100%	5,080

Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

materials, etc.) must be evaluated for its present and future effects on the project. WTE developers should be aware of any planned or anticipated statutory changes in the regional and local waste handling scheme. An evaluation of changes in the waste stream may include the following:

Changes in waste quantity and characteristics must be anticipated.

- annual range of waste quantities (minimum / maximum waste volumes in a year)
- moisture content
- waste analysis (i.e., heat value, chlorine and sulfur content, etc.)
- quantity of bulky items
- percent of noncombustible materials.

Coordination with Other Waste Management Practices

A significant advantage of waste reduction, regardless of the technique, is that a smaller WTE facility may result. A WTE facility is a long-term investment and the development of that facility should take into consideration other existing or future waste management practices in the service area.

Waste Reduction

"Source reduction" and "reuse" encompass a wide range of techniques for reducing the amount of solid waste that require recycling, incineration, or landfilling. The two basic types of source reduction techniques are those affecting the quantity of waste and those affecting the toxicity of the waste. Both types of source reduction ultimately affect WTE feedstocks.

Waste management practices can affect the volume of available waste — anticipate long-term trends before proceeding.

Source Separation of Nonrecyclable and Hazardous Materials

Some municipal WTE facilities have had problems when certain ash samples failed to pass the USEPA toxicity test (TCLP), which determines the material's likelihood for leaching potentially hazardous components. Ash samples have exceeded allowable concentrations of certain metals, like lead or mercury.

Bulky items are generally prevented from entering the combustion process by the crane operator of the WTE facility. The crane operator, however, cannot always remove every microwave, dryer, or freezer from the tipping floor. The problems and associated dangers that bulky items present are minimized in municipalities that collect these bulky items separately.

Recycling

Recycling benefits the incineration process by removing some noncombustibles (including ferrous, aluminum, and glass) and by allowing a reduction in planned facility size due to reduced waste quantity. Recycling can also increase the average heat value of the WTE feedstock. Nationally, recycling levels for all materials may increase over the next decade. This could impact the availability of feedstock for WTE operations. However, some of the effects of recycling may be offset if the annual increase in per capita solid waste generation continues.

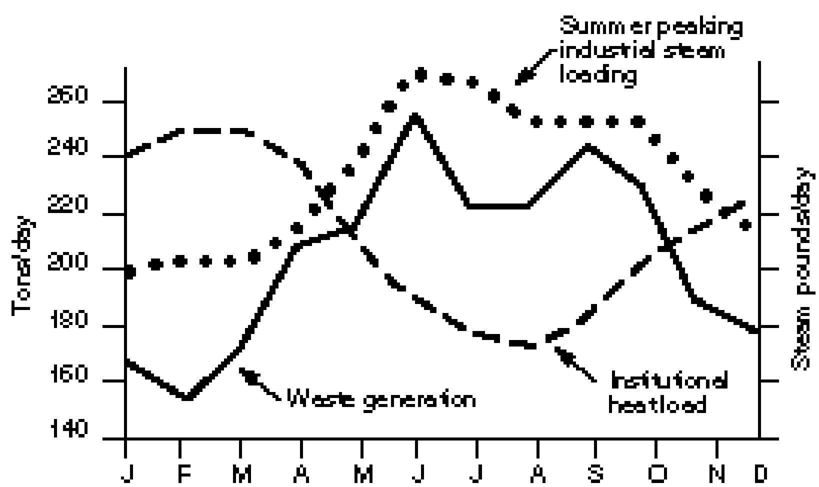
Coordinate recycling and composting planning with combustion system development.

Composting

Municipal yard and food waste composting programs can significantly benefit WTE projects. For example, increases in alternative yard trimmings management programs can reduce seasonal peaks in wet organic matter, which in turn may alter the moisture content and heat value of the feedstock. A decrease in moisture content increases fuel quality by reducing the amount of energy used to vaporize moisture. Thus, by separating or removing wet wastes, the likelihood of creating conditions for optimal boiler temperature and efficiency of energy recovery is increased.

Yard trimmings volumes fluctuate seasonally in temperate zones, with peak quantities occurring from spring to fall. By eliminating or leveling these peaks through other waste management practices, the boiler capacity can be smaller, thereby reducing capital and operation costs (see Figure 8-2).

Figure 8-2
Typical Monthly Waste Generation and Energy Demand Patterns



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Landfilling

Landfill availability must be determined.

The WTE facility siting plan should account for proximity to a landfill and current and projected capacity and tipping fees at that landfill. Hauling costs and tipping fees are essential factors in an accurate cost forecast of the WTE facility development process when comparing it to other options. Information on the life span of the landfill, as well as any planned future expansions, should be obtained. Municipal solid waste landfills are necessary for mass-burn as well as RDF processing plants. Incineration can achieve 80 to 90 percent volume reduction in MSW sanitary landfill needs.

What Area Will Be Served?

Establishing the service area is important.

The area served by the WTE system may be established by the governmental body planning the system. For example, a county considering an incinerator to extend landfill life most likely would see the whole county as the service area. The county might also allow limited use by hauling companies that may pick up household wastes just across county lines in normal route operations.

In less populated areas, waste generated within one county may be inadequate to build a facility of a workable size. In such cases, officials may consult with a regional-level authority to assess the feasibility of a facility serving a multi-county area.

In addition, there may be many unanswered questions regarding regional development. In this case, several counties may together fund a study identifying a preliminary plan for developing WTE systems in the region. The study's results could include proposals for the following:

- building one large facility serving the entire region
- building several facilities located strategically to serve the entire region
- building one or more units serving only the region's more populated areas.

A waste inventory for the region to be served is usually the first step. Questions regarding issues such as inter- and intrastate waste transport that may influence communities and waste transporters must then be settled. Then quantity and geographical distribution of wastes available to the facility can be estimated. Taken together, these efforts will provide information on logistics and related costs associated with transporting solid waste to potential facility sites.

ENERGY AND MATERIAL MARKETS

The facility's economic viability depends on significant energy sales.

Because WTE facilities have high capital and operating costs, most need to produce significant income from energy sales to be economically viable. A buyer must be willing and able to enter into a long-term contract to purchase energy at a competitive rate. Low revenues from energy sales must be offset by higher waste tipping fees. When several disposal options are available, the one with the lowest overall life cycle net cost per ton, including transportation and ultimate disposal, usually will be chosen.

Energy Market Options

A WTE facility may generate steam, electricity, super-heated water, or a combination of these. The form of energy produced depends on the energy buyer's needs. WTE facilities usually generate and sell the following marketable products:

- electricity only
- steam only

- co-generation of steam and electricity
- refuse-derived fuel (RDF).

Electricity Only

Electric utilities are attractive markets for power produced by WTE facilities.

Electricity is the most common form of energy produced and sold from WTE facilities constructed today. By directing the WTE system steam through a turbine generator, electricity can be produced and sold. A process flow diagram is shown in Figure 8-3. Since electric utilities can receive power 24 hours a day, seven days a week, and are usually very stable financially, public utilities are very attractive markets for power produced from WTE systems. Under the Public Utility Regulatory Policies Act of 1978, known as PURPA, public utilities must purchase electric power from small power producers and co-generators (those producing both steam and electricity). Section 210 of PURPA exempts small power producers from certain federal and state laws. It also mandates that electric utilities permit small power producers to interconnect and requires utilities to supply back-up power to such facilities at ordinary metered rates.

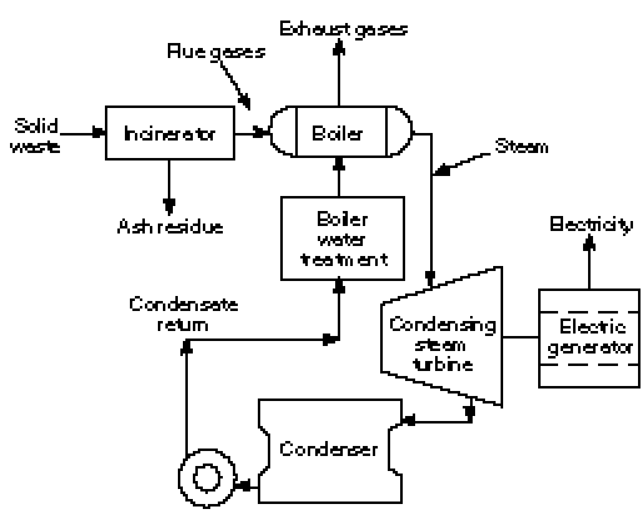
PURPA's most important requirement covers the price utilities must pay to small producers. The law stipulates that utilities must pay such producers at the rate (cents per kilowatt hour) that it would cost the utility to generate the same quantity of electricity, including the avoided cost of any added facilities or equipment. This payment rate, called "avoided cost," is the cost benefit to the utility for receiving electricity from the energy seller. Avoided cost consists of a capital investment component and an operating cost component. Due to local or regional electrical generation practices and electrical demand growth, the avoided cost can vary widely from region to region.

Steam

Steam is used widely in a variety of industrial applications. It can be used to drive machinery such as compressors, for space heating and generating electricity. Industrial plants, dairies, cheese plants, public utilities, paper mills,

Figure 8-3

Incinerator and Electrical Generation System



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Marketing steam requires matching available supplies with customers' needs.

tanneries, breweries, public buildings, and many other businesses use steam for heating and air conditioning. The challenge is to match the available supply with prospective customers' needs. Where industrial customers are not available, the use of steam at institutional complexes (a university, hospital, or large office complex) with year-round steam energy needs may be an option.

District heating systems, which provide heat to homes, apartment buildings, and commercial facilities, may also be prime steam customers. A principal disadvantage is that facilities may not be able to efficiently use the energy throughout the entire year since district heating / cooling systems usually have low periods in the spring and fall.

When assessing potential markets for steam, it is important to consider a market's proximity to the WTE facility and the quantity of steam produced. Proximity is important because steam cannot usually be economically transported more than one or two miles; the WTE facility, therefore, should be as close as possible to the potential market. The advantages of transmitting steam over a longer distance to an end user must be weighed against energy losses that will occur in transmission. Installation of a pipeline connecting the facility and the customer can also be prohibitively expensive in certain circumstances. High-temperature hot water may be an option for overcoming the transmission limitation for steam.

Anticipated steam quantity and quality are interrelated parameters, and must be carefully projected when assessing steam markets. The prospective user will most likely have an existing process requiring steam at a specific temperature and pressure. The quantity of steam produced from a given amount of waste will decline as the steam temperature and pressure increases, but the equipment using the steam will also operate more efficiently. To ensure the continuing availability of a high quantity and quality of steam, supplementary fuels, such as natural gas, may occasionally be used, and as a result operating costs may increase.

If the steam price is greater than the cost of energy (i.e., from gas, oil, coal, wood, etc.), and the steam demand is greater than the amount of energy that can be generated from the available waste stream, there may be an economic advantage to increasing the plant size to generate the steam needed by the energy customer.

Co-Generation

Co-generation provides greater energy efficiency, although overall output may be less.

In co-generation, high-pressure steam is used first to generate electricity; the steam leaving the turbine is then used to serve the steam users. Co-generation (See Figure 8-4) provides for greater overall energy efficiency, even though the output of the major energy product, whether electricity or steam, may be less than could be generated by producing one type of energy alone.

Co-generation allows flexibility, so that seasonal variations in steam demand can be offset by increases in electricity production. In addition, PURPA requires that public utilities purchase electricity from co-generators at the utility's avoided cost.

Constructing a multimillion dollar WTE facility to produce only steam for an industrial plant that goes out of business will result in serious financial problems for the WTE facility. Bonding and financing authorities will carefully evaluate the financial health of the energy buyer before agreeing to provide money for the project, and it is important that the energy customer's long-term financial health be assessed early in the energy market analysis. Co-generation can provide the project a financial base by selling electricity should the steam customer become unavailable.

Refuse-Derived Fuel (RDF)

Another form of energy that can be produced and sold is refuse-derived fuel (RDF). RDF is the product of processing the municipal solid waste to separate

RDF is produced from combustible waste and burned in specially designed boilers.

the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler. Owners of a WTE facility intending to sell RDF should consider the following:

- nature of the facility that will buy the fuel (i.e., boiler type, fuel fired, etc.)
- projected life and use of that facility by the owner
- facility modifications necessary to accommodate the fuel (including emission control)
- the value of the RDF as a supplemental fuel

RDF can be transported to other locations for use in boilers.

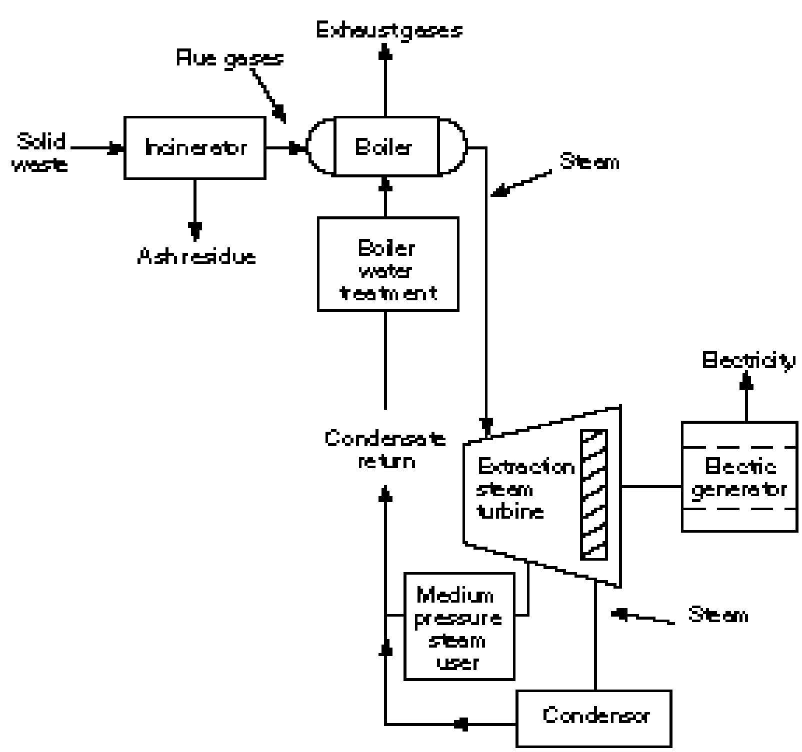
RDF can be produced at a facility some distance from the RDF buyer and transported by truck to the boiler facility. Depending upon the type of combustion facility (i.e., large utility, industrial boiler, etc.) the RDF can be produced in the form of fluff or as densified RDF (D-RDF).

RDF quality (how free the RDF product is of grit, glass, metals, and other noncombustibles) will directly affect a potential user’s desire to burn RDF. Where a high-quality RDF product has been developed, burning RDF fuel as a supplemental fuel in existing coal-fired boilers has not created major operational problems.

Coal-burning electric power plants, if appropriately designed or modified, can be a major market for fluff RDF. RDF burned as a replacement for up to 10 percent of the coal in existing utility boilers has been demonstrated to be successful in small projects; higher rates of replacement have been demonstrated in industrial stoker coal-fired steam generators.

Figure 8-4

Co-generation System for Producing Electricity and Steam



Source: P. O’Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Energy Contract Issues

Customers must be assured that using waste-produced energy is equal to or better than using energy from other sources.

In general, finding a market for energy requires initiative. Many opportunities are available for energy sales, but they must be sought out carefully and identified. The prospective customer must be convinced that using energy produced from solid waste is equal to or better than using energy from conventional sources, such as coal, oil, or gas.

Price

The price must be very competitive, usually at a discount compared to the customer's current energy costs. Unless there is some long-term price incentive, the customer may be unwilling to go to the trouble of participating in the project; this is especially true for steam or RDF buyers. The potential energy customer is likely to have a reliable energy source already. Also, the potential customer must somehow recover the administrative costs incurred while becoming involved in a WTE system. Such costs can become substantial when the project is complex or controversial.

Service and Schedule

Timing and reliability are important.

Energy must be available when the customer needs it. Steam and electricity contracts are normally negotiated to be either guaranteed (uninterruptible service) or "as needed or available" (interruptible service). The price received varies according to the type of service. The daily and seasonal demand fluctuations of the customer and the WTE facility must be estimated and taken into account in preparing an agreement. Figure 8-2 shows how waste generation and steam demands of potential users may vary seasonally. In the situation shown, the "Summer Peaking Industrial Steam Load" roughly correlates with the waste generation pattern. However, in the example, the "Institutional Heat Load" is highest when waste generation is the lowest. If waste quantities are insufficient to generate the required steam under an uninterruptible service plan, then the incinerator operator must generate steam with supplemental fuel or pay a penalty. Electrical contracts are usually negotiated on the basis of providing "on-peak" or "off-peak" power. "On-peak" power will be of greater value to the buyer.

Reliability

Anticipated system reliability is also important in developing energy markets. The customer must be assured that the facility can meet its commitments, especially for uninterrupted service. Contracts must state contingency plans for facility shutdown periods.

Material Markets

Sales of recovered materials can be an important revenue source.

In certain situations, more than one market may be available for the recovered products produced by the WTE plant. While these markets alone may not be sufficient to provide enough revenues to make a plant feasible, they can provide valuable additions to plant revenue. For example, sale of recyclable materials may be a source of additional revenue for a WTE project.

Where a vigorous recycling or source-separation program is employed, a plant should be downsized to avoid the additional capital cost of installing extra capacity. WTE facilities that separate paper also have the option of using some of the stored paper to make up for temporary waste volume shortfalls if a guaranteed energy demand must be satisfied, if the paper market is depressed, or if paper is unavailable for a period of time.

Ferrous materials are usually recovered in RDF facilities by magnetic separators as part of the RDF preparation process from mass-burn systems through magnetic separation from the ash. The economic benefit of metal recovery can be two fold: There is the revenue potential from the sale of the product and the avoided cost of hauling and disposing of that material.

THE COMBUSTION PROCESS AND TECHNOLOGIES

Combustion is a chemical reaction in which carbon, hydrogen, and other elements in the waste combine with oxygen in the combustion air, which generates heat.

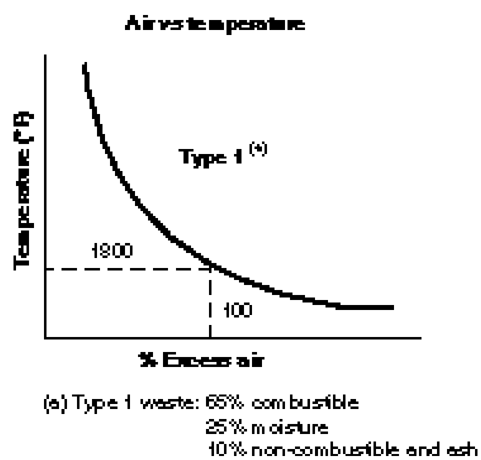
Usually, excess air is supplied to the incinerator in order to ensure complete mixing and combustion. The combustion principle gas products include carbon dioxide, carbon monoxide, water, oxygen, and oxides of nitrogen.

Excess air is also added to the incinerator to regulate operating temperature and control emissions. Excess air requirements will differ with waste moisture contents, heating values, and the type of combustion technology employed.

Many incinerators are designed to operate in the combustion zone at 1,800° F to 2,000° F. This temperature is selected to ensure good combustion, complete elimination of odors, and protection of the walls of the incinerator. A minimum of 1,500° F is required to eliminate odor. As more excess air is supplied to the incinerator, the operating temperature is lowered (see Figure 8-5).

Figure 8-5

Combustion Excess Air Versus Combustion Gas Temperature



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

WTE systems must be carefully designed to handle a wide range of waste input conditions.

Waste-to-energy systems are designed to maximize waste burn out and heat output while minimizing emissions by balancing the three "T"s:— time, temperature, and turbulence— plus oxygen (air). The heterogeneous nature of municipal solid waste requires that waste-to-energy systems be carefully designed to operate efficiently over a wide range of waste input conditions.

Technology Options

A number of demonstrated technology approaches are available for WTE projects today; the predominate ones are (1) modular incinerators, (2) mass-burning systems, and (3) refuse derived fuel (RDF) systems. Table 8-3 is a summary by state of the operating WTE facilities using mass-burn and RDF technologies.

The technology selection process begins with evaluating all plausible options, considering the quantity and quality of waste, the energy market options available, local environmental considerations, or other local factors that can affect selection decisions.

Modular Systems

Modular combustion systems are usually factory-assembled units consisting of a refractory-lined furnace and a waste heat boiler. Both units can be preas-

Table 8-3

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity*
Alabama		
Huntsville WTE Facility/Huntsville	MB	690
Alaska		
Fairbanks	RDF-P	50
Fairbanks (RDF Market)/ Area Markets (incl. U. of AK)	RDF-C	50
Juneau	INCIN	70
Shemya/Air Force Base	MOD	20
Sitka/Sheldon Jackson College	MOD	50
Arkansas		
Batesville WTE Facility/Batesville	MOD	100
Blytheville	INCIN	70
Osceola	MOD	50
Stuttgart	INCIN	60
California		
Commerce/Los Angeles Co.	MB	380
Long Beach (SERRF)/Long Beach	MB	1,380
Stanislaus/Modesto	MB	800
Southern California Edison/ San Bernardino Co.	RDF	150
Susanville	MB	20
Modesto Energy Project/Westley	TTE	170
Colorado		
Yuma Co./ N/D	N/D	N/D
Conecticut		
Bridgeport	MB	2,250
Bristol Resource Recovery Facility/ Bristol	MB	650
MID-Connecticut RRF/Hartford	RDF	2,000
New Cannan	INCIN	125
Southeastern/Preston	MB	600
Stamford	INCIN	360
Wallingford	MOD	420
Lisbon	MB	600
Exeter/Sterling	TTE	300

State/Plant Name/ Location	Technology Type	Design Capacity
Delaware		
Delaware Reclamation/Newcastle	RDF-P	620
Pigeon Point/Wilmington	MOD	600
Florida		
Bay Co./Panama City	MB	510
Broward Co. North/Pompano Beach	MB	2,250
Broward Co. South/Ft. Lauderdale	MB	2,250
Dade Co./Miami	RDF	3,000
Hillsborough Co. Resource Recovery Facility/Tampa	MB	1,200
Key West/Monroe Co.	MB	150
Lake Co./Okahumpka	MB	528
Lakeland	RDF	300
Mayport Naval Station/Mayport	MOD	50
McKay Bay Refuse to Energy Facility/Tampa	MB	1,000
Miami International Airport/Miami	MOD	60
Pasco Co./Hudson	MB	1,050
Pinellas Co./St. Petersburg	MB	3,000
West Palm Beach Co./ West Palm Beach	RDF	2,000
Lee Co./Fort Meyers	MB	1,200
Dade Co. (Expansion)/Miami	RDF	1,500
Polk Co./Winter Haven	N/D	N/D
Polk Co. TTE Project/Polk Co.	TTE	100
Georgia		
Savannah	MB	500
Atlanta (Tire Market)/ Various Area Markets	TIRE-C	165
Atlanta Waste Recovery/Atlanta	TIRE-P	165
Hawaii		
Honolulu Resource Recovery Venture (H-Power)/Honolulu	RDF	2,160

– Table 8-3 continued on following pages –

*Tons per day

Technology Abbreviations

- INCIN = MWC with no energy recovery.
- MB = Mass burn (MWC typically with a single combustion chamber, constructed on-site, with energy recovery).
- MOD = MWC typically with two-stage combustion, shop fabrication, field erection, and with energy recovery.
- MWC = Municipal waste combustor; includes both WTE plants and incinerators.
- RDF = Facility with extensive front-end waste processing and dedicated boiler for combusting prepared fuel on site.
- RDF-P = Municipal waste processing facility generating a prepared fuel for off-site combustion.
- RDF-C = Combustion facility typically capable of burning more than one fuel (e.g., RDF and coal).
- TTE = Tires-to-energy. Tire waste combustor with energy recovery.
- TIRE-P = Tire waste processing facility generating a prepared fuel for off-site combustion.
- TIRE-C = Combustion operation typically capable of burning more than one type of fuel.
- WTE = Waste-to-energy. (Municipal waste combustor with energy recovery. In this table, WTE includes MB, MOD, RDF, and RDF Combustion systems.)

Source: IWSA (Integrated Waste Services Association), *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants*, 1993

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
Illinois		
Chicago NW/Chicago	MB	1,600
Crestwood (USA Waste RDF Market)/Crestwood	RDF-C	125
USA Waste of IL., Inc./Crestwood	RDF-P	125
Beardstown/Cass Co.	RDF	1,800
Havana WTE Facility/Havana	RDF	1,800
Rantoul	N/D	N/D
Robbins	RDF	1,600
West Suburban Recycling and Energy Center/Village of Summit	RDF	1,800
Ford Heights	TTE	200
Indiana		
Indianapolis	MB	2,362
Monroe Co./Bloomington	MB	300
Sullivan Co./Fairmount	RDF	3,000
Iowa		
AG Processing (Iowa Falls RDF Market)/Eagle Grove	RDF-C	75
Ames	RDF-P	200
Ames Municipal Electric Utility (RDF Market)/Ames	RDF-C	150
Iowa Falls	RDF-P	75
Kentucky		
Kentucky Energy Associates/Corbin	MB	500
Maine		
Harpswell/South Harpswell	INCIN	14
Maine Energy/Biddeford - Saco	RDF	750
Mid-ME Waste/Auburn	MB	200
Penobscot Energy Recovery Company/Orrington	RDF	1,000
Portland	MB	500
Easton	N/D	N/D
Maryland		
Hartford Co./Aberdeen Proving Grounds (Army)	MOD	360
Pulaski/Baltimore	INCIN	1,200
Southwest Resource Recovery Facility (BRESCO)/Baltimore	MB	2,250
Montgomery Co./Dickerson	RDF-P	1,200
Baltimore Co./Cockeysville	RDF-P	1,200
Carroll Co./Westminster	N/D	N/D
Fort Meade/Anne Arundel Co.	N/D	N/D
Hartford Co. (Expansion)/ Aberdeen Proving Grounds (Army)	MOD	125
Massachusetts		
Central Mass. Resource Recovery Project/Millbury	MB	1,500
Fall River	INCIN	600
Haverhill (MB)/Haverhill	MB	1,600
Haverhill (RDF)/Haverhill	RDF-P	900
Haverhill (RDF market)/Lawrence	RDF-C	710
Mass. Refusetech/North Andover	MB	1,500
Pittsfield Resource Recovery Facility/Pittsfield	MOD	240
Saugus RESCO/Saugus	MB	1,500
Massachusetts, cont'd		
SEMASS/Rochester	RDF	2,700
Springfield RRF/Agawan	MOD	360
Mass. Regional Recycling Facility/Shirley	MB	243
Michigan		
Central Wayne Co./Dearborn Heights	INCIN	500
Greater Detroit Resource Recovery/Detroit	RDF	3,300
Jackson Co. Resource Recovery Facitliy/Jackson	MB	200
Kent Co./Grand Rapids	MB	625
Oakland Co./Auburn Hills	MB	2,000
Southeast Oakland Co./ Madison Heights	MB	600
Michigan TTE Project/Albion	TTE	N/A
Minnesota		
Eden Prairie/Hennepin Co.	RDF-P	560
Elk River Resource Recovery Facility/Anoka Co.	RDF	1,500
Fergus Falls RRF/Fergus Falls	MOD	94
Hennepin RRF/Minneapolis	MB	1,200
Olmstead Co. WTE Facility/ Rochester	MB	200
Perham Renewable Resource Facility/Perham	MOD	100
Polk Co. Solid Waste Recovery Facility/Fosston	MOD	80
Pope-Douglas Solid Waste/Alexandria	MOD	72
Ramsey-Washington/Newport	RDF-P	1,200
Ramsey-Washington (Newport RDF Market)/Red Wing	RDF-C	720
Red Wing Solid Waste Boiler Facility/Red Wing	MOD	72
Richard's Asphalt/Savage	MOD	80
Thief River Falls	RDF-P	100
Thief River Falls (TRF RDF Market)/ Northwest Medical Center	RDF-C	100
Western Lake Superior Sanitary District (WLSSD)/Duluth	RDF	400
Wilmarth Plant (Eden Prairie and Newport RDF Market)/Mankato	RDF-C	720
Mississippi		
Pascagoula ERF/Moss Point	MOD	150
Missouri		
St. Louis	RDF	1,200
Montana		
Livingston/Park Co.	INCIN	72
Nevada		
Moapa Energy Project/Moapa	TTE	N/D
New Hampshire		
Auburn	INCIN	5
Candia	INCIN	15
Claremont	MB	200

– Table 8-3 continued on following pages –

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
New Hampshire, cont'd		
Concord Regional Solid Waste Recovery Facility/Concord	MB	50
Durham/University of New Hampshire	MOD	108
Lincoln	INCIN	24
Litchfield	INCIN	22
Nottingham	INCIN	8
Pelham	INCIN	24
Plymouth	INICN	16
Wilton	INCIN	30
Wolfeboro	INCIN	16
New Jersey		
Camden Resource Recovery Facility/Camden	MB	1,050
Essex Co. Resource Recovery Facility/Newark	MB	2,505
Fort Dix	MOD	80
Gloucester Co./Westville	MB	575
Warren RRF/Oxford Township	MB	400
Union Co./Rahway	MB	1,440
Mercer Co./Duck Island	MB	1,450
New York		
Albany Steam Plant (ANSWERS RDF Market)/Albany	RDF-C	600
ANSWERS Project/Albany	RDF-P	800
Babylon Resource Recovery Facility/Babylon	MB	750
Dutchess Co./Poughkeepsie	MB	506
Hempstead/Westbury	MB	2,505
Henry Street, Brooklyn/NY City	INCIN	1,000
Huntington RRF/E. Northport	MB	750
Islip (MacArthur Energy Recovery)/ Ronkonkoma	MB	518
Kodak/Rochester	RDF	150
Long Beach Recycling and Recovery Corp./Long Beach	MB	200
Niagara Falls	RDF	2,000
Oneida Co./Rome	MOD	200
Oswego Co./Fulton	MOD	200
Saltaire/Fire Island	INCIN	12
Washington Co./Hudson Falls	MB	450
Westchester Co./Peekskill	MB	2,250
Onondaga Co.	MB	990
Albany Port Ventures/Port of Albany	MB	1,300
Bay 41st St., Brooklyn SW/NY City	INCIN	1,050
Brooklyn Navy Yrd/NY City	MB	3,000
Capital District/Green Island	MB	1,500
Cattaraugus Co./Cuba	MOD	112
Glen Cove	MB	250
Islip (MER Expansion)/Ronkonkoma	MB	350
West Finger Lakes/Four Area Counties	N/A	550
North Carolina		
New Hanover Co./Wilmington	MB	450
University City RRF/Mecklenburg Co.	MB	235
BCH Energy Limited/Fayetteville	RDF	1,200
Arrowood/Mecklenburg Co.	MB	600
Carolina Energy/Chatam Co.	RDF	1,200
Ohio		
Akron	RDF	1,000
Columbus	RDF	2,000
Montgomery Co. North/Dayton	MB	300
Montgomery Co. South/Dayton	INCIN	900
Mad River Energy Recovery/ Springfield	MB	1,750
Stark Recycling Center/Canton	RDF-P	N/A
Oklahoma		
Miami	MOD	108
W.B. Hall Resource Recovery Facility/Tulsa	MB	1,125
Oregon		
Coos Bay/Coquille	INCIN	100
Marion Co./Brooks	MB	550
Portland	TIRE-P	100
Portland (Tire Market)/ Various Area Markets	TIRE-C	100
Pennsylvania		
Delaware Co./Chester	MB	2,688
Harrisburg	MB	720
Lancaster Co. RRF/Bainbridge	MB	1,200
Montgomery Co./Conshohocken	MB	1,200
Westmoreland Co./Greensburg	MOD	50
York Co./Manchester Township	MB	1,344
Falls Township-Wheelabrator/ Falls Township	MB	1,600
Falls Township-Technochem/ Morrisville	MOD	70
Glendon	MB	500
West Pottsgrove/Berks Co.	MB	1,500
Puerto Rico		
San Juan	MB	1,200
South Carolina		
Chambers Development/Hampton	MOD	270
Charleston/Charleston Co.	MB	600
Tennessee		
Nashville	MB	1,120
Robertson Co. Recycling Facility/ Springfield	RDF-P	50
Springfield (RDF Market)/ Various Area Markets	RDF-C	50
Sumner Co./Gallatin	MB	200
Texas		
Carthage Co.	MOD	40
Cass Co./Linden	RDF-P	-200
Cass Co. (Linden RDF Market)/ International Paper	RDF-C	-120
Center	MOD	40
Cleburne	MOD	115
Baytown	TIRE-P	165
Baytown (Tire Market)/ Various Area Markets	TIRE-C	165
Utah		
Davis Co./Layton	MB	400

– Table 8-3 continued on following page –

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
Vermont		
Readsboro	INICN	13
Stamford	INCIN	10
Rutland	MOD	240
Virginia		
Alexandria - Arlington/Alexandria	MB	975
Arlington/Pentagon	INCIN	50
Fairfax Co./Lorton	MB	3,000
Galax	MOD	56
Hampton	MB	200
Harrisonburg Resource Recovery Facility/Harrisonburg	MB	100
Salem	MOD	100
Southeastern Public Service Authority of Virginia/Portsmouth	RDF	2,000
Fort Eusits/Newport News		
Prince William Co./Prince William	MB	1,700
Washington		
Bellingham/Ferndale	MOD	100
Skagit Co. Resource Recovery Facility/Mt. Vernon	MB	178
Washington, cont'd		
Spokane Regional Solid Waste Disposal Facility/Spokane	MB	800
Tacoma (City Landfill)/Tacoma	RDF-P	500
Tacoma (RDF Market)/Tacoma	RDF-C	300
Fort Lewis	MB	120
Wisconsin		
Barron Co./Almena	MOD	80
LaCrosse Co./French Island	RDF	400
St. Croix WTE Facility/New Richmond	MOD	115
Madison	RDF-P	250
Madison (Power Plant - RDF Market)/ Madison Gas & Electric	RDF-C	400
Marathon Co./Ringle	RDF-P	200
Marathon Co. (Ringle RDF Market)/ Area Paper Mills	RDF-C	500
Muscoda	MOD	120
Waukesha	MB	175
Winnebago Co.	N/D	500–1,000

** End of Table 8-3 **

Source: IWSA (Integrated Waste Services Association), *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants*, 1993

Modular systems may be more cost-effective for smaller-sized facilities.

Pre-fabrication and assembly can lower construction costs.

sembled and shipped to the construction site, which minimizes field installation time and cost.

Modular systems are typically in the 15 to 100 ton-per-day capacity range. Facility capacity can be increased by adding modules, or units, installed in parallel to achieve the facility's desired capacity. For example, a 200 ton-per-day facility may consist of four, 50-ton-per-day units or two, 100 ton-per-day units. The number of units may depend on the fluctuation of waste generation for the service area and the anticipated maintenance cycle for the units.

Combustion is typically achieved in two stages. The first stage may be operated in "starved air" or in a condition in which there is less than the theoretical amount of air necessary for complete combustion. The controlled air condition creates volatile gases, which are fed into the secondary chamber, mixed with additional combustion air, and under controlled conditions, completely burned. Combustion temperatures in the secondary chamber is regulated by controlling the air supply, and when necessary, through the use of an auxiliary fuel. The hot combustion gases then pass through a waste heat boiler to produce steam for electrical generation or for process or heating purposes. The combustion gases and products of combustion are processed through air emission control equipment to meet the required federal and state emission standards.

In general, modular combustor systems are a suitable alternative and may, for smaller-sized facilities, be more cost-effective than other combustor alternatives. Because of the nature of these facilities, energy production per million Btu of heat input or plant efficiency will likely be lower than alternative combustion technologies. Because of their relative size, modular combustors and waste heat boilers can be factory-assembled or fabricated and delivered, minimizing field erection time and cost.

Mass-Burning Systems

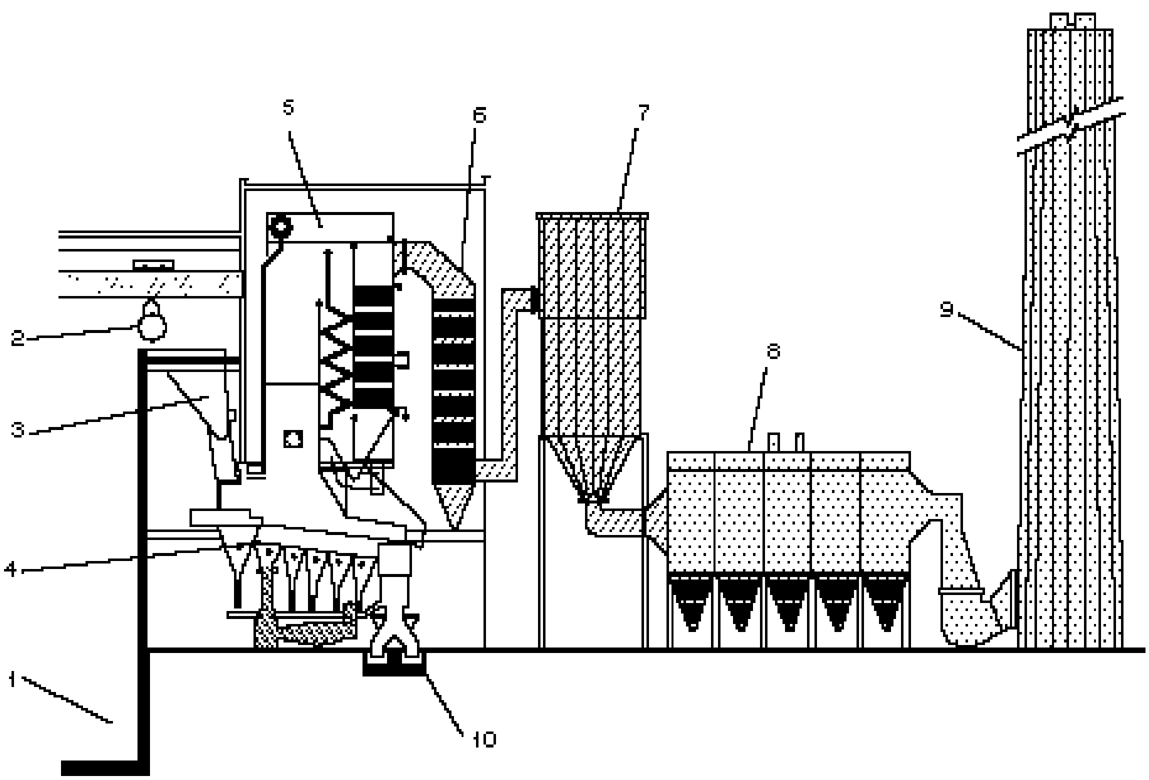
Mass-burning systems have larger capacities and higher thermal efficiencies.

A mass-burn WTE facility typically consists of a reciprocating grate combustion system and a refractory-lined, waterwalled, steam generator. Today a typical facility consists of two or more combustors with a size range of 200 to 750 tons-per-day each. Because of the larger facility size, the combustor is more specially designed to efficiently combust the waste to recover greater quantities of steam or electricity for export as a revenue source (see Figure 8-6).

To achieve this greater combustion and heat recovery efficiency, the larger field-erected combustors are usually in-line furnaces with a grate system. The steam generator generally consists of refractory-coated waterwall

Figure 8-6

Typical Mass-Burn Facility Schematic



1. Receiving Pit
2. Charging Crane
3. Feed Hopper
4. Grate System
5. Steam Generator
6. Heat Exchanger
7. Acid Gas Spray Dry Scrubber
8. Particulate Collection
9. Stack
10. Ash Quench/Removal

Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

systems with walls comprised of tubes through which water circulates to absorb the heat of combustion. In a waterwall system, the boiler is an integral part of the system wall, rather than a separate unit as is in a refractory system.

Mass burning of waste can also be achieved by the use of a rotary kiln. Rotary kilns use a turning cylinder, either refractor or waterwall design, to tumble the waste through the system. The kiln is declined, with waste entering at the high elevation end and ash and noncombustibles leaving at the lower end. Rotary combustors may be followed by a traveling or reciprocating grate to further complete combustion.

A typical facility consists of two or more combustors that are sized to properly fire or burn the area's municipal solid waste during its peak generation period. Typically, at least two combustor units are included to provide a level of redundancy and to allow waste processing at a reduced rate during periods of scheduled and unscheduled maintenance.

Mass-burn systems generate a higher-quality steam, allowing for higher revenues per ton of waste.

Mass-burn facilities today generate a higher quality steam, (i.e., pressure and temperature) compared to modular systems. This steam is then passed through a once-through turbine generator to produce electricity or through an extraction turbine to generate electricity and provide process steam for heating or other purposes. Higher steam quality allows the use of more efficient electrical generating equipment, which, in turn, can result in a greater revenue stream per ton of waste.

Refuse-Derived Fuel (RDF) Systems

RDF technology has benefitted from past experience and is now considered a "proven technology."

The early RDF projects, developed in the 1970s, were intended to produce a fuel to be used in existing utility or industrial steam generators with little or no modifications to the fuel combustor or its auxiliary equipment. Several projects were developed, but few of those projects are operating today (see Table 8-4).

The predominate RDF systems operating today have incorporated the lessons from the earlier projects and are now considered a proven technology. There are two primary types of systems in operation: the shred-and-burn systems with minimal processing and removal of noncombustibles, and simplified process systems that remove a significant portion of the noncombustibles. Each of these systems uses a dedicated combustor to fire the RDF to generate steam (see Table 8-5).

Table 8-4

RDF Production and Co-Firing Experience

Location	Design Capacity (tons/day)	Average RDF Production (tons/day)	Status
	Process Plan		
Ames	200	175	Operating
Baltimore	1200	58[a]	Operating[e]
Bridgeport	1800	N/A[d]	Closed[c]
Chicago	2000	300	Closed[c]
Lakeland	300	270	Operating
Madison	200	120[b]	Closed[f]
Milwaukee	1200	480-880	Closed[c]
Rochester	2000	400	Closed[ac]
St. Louis	200	185	Closed[c]

a = Process operated for short term. RDF was not fired.
b = RDF markets have not been able to utilize full production.
c = Closed after limited operation.
d = Consistent operation not achieved.
e = Burning discontinued in 1989.
f = Closed 12/31/92; RDF market for electrical generating demand significantly reduced.

Source: June, 1988 *EPRI Report*, Updated by ABB-RRS June, 1991

Table 8-5
Dedicated RDF Boiler Facilities

Shred-and-Burn Systems	Daily Capacity	Started Operation
Akron, OH*	1000	1979
ANSWERS (Albany, NY)	600	1981
Hooker Chemical (Niagara Falls, NY)*	2000	1981
SEMASS (Rochester, MA)	1800	1988

**Process modified to shred-and-burn technology*

Simplified Process Systems

	Coal Co-firing	Daily Capacity	Started Operation
Dade County, FL	No	3000	1982/1989**
Columbus, OH	Yes	2000	1982
Duluth, MN	No	400	1985***
MERC (Saco/Biddeford, ME)	No	600	1987
Ramsey/Washington City, MN	No	1000	1987
LaCrosse County, WI	No	400	1987****
Mid-Connecticut (Hartford, CT)	Yes	2000	1988
PERC (Orrington, ME)	No	1000	1988
Palm Beach County, FL	No	2000	1989
Anoka County, MN	No	1500	1989
H-POWER (Honolulu, HI)	No	2160	1990
Greater Detroit, MI	No	3300	1990
Tacoma, WA	No	300	1990***

** *Process system modified* *** *Used fluidized bed combustors*
**** *RDF and wood; fluidized bed combustor*

Source: G. L. Boley. "Refuse-Derived Fuel (RDF)—Quality Requirements for Firing in Utility, Industrial, or Dedicated Boilers," International Joint Power Generation Conference, San Diego, CA. October, 1991

Shred-and-Burn Systems

Shred-and-burn systems require minimal removal of noncombustible waste.

Shred and burn systems are the simplest form of RDF production. The process system typically consists of shredding the municipal solid waste to the desired particle size, magnetic removal of ferrous metal, with the remaining portion delivered to the combustor. There is no attempt to remove other noncombustible materials in the municipal solid waste before combustion. The municipal solid waste is shredded to a particle size that allows effective feeding to the combustor. Most systems operate the process system continuously, i.e., there is minimal RDF storage before being fed to the combustor.

Simplified Process Systems

With simplified process systems, a significant portion of noncombustibles is removed.

A simplified process system involves processing the municipal solid waste to produce an RDF with a significant portion of the noncombustibles removed before combustion. The municipal solid waste process removes more than 85 percent of the ferrous metals, a significant percentage of the remaining noncombustibles (i.e., glass, nonferrous metals, dirt, sand, etc.), and shreds the material to a nominal particle top size of 4 to 6 inches to allow effective firing in the combustion unit.

Early RDF process systems relied on air classification as the means to separate the combustible fraction from the noncombustibles. Recent systems rely on screening or trommeling to separate the noncombustibles from the fuel portion. Depending on the type of combustor to be used, a significant degree of separation can be achieved to produce a high-quality RDF (i.e., low ash), which typically results in the loss of a higher percentage of combustibles when compared to systems that can produce a low-quality fuel (i.e., slightly higher ash content) for firing in a specially designed combustor. These types of systems recover over 95 percent of the combustibles in the fuel fraction (see Figure 8-7).

RDF Combustors

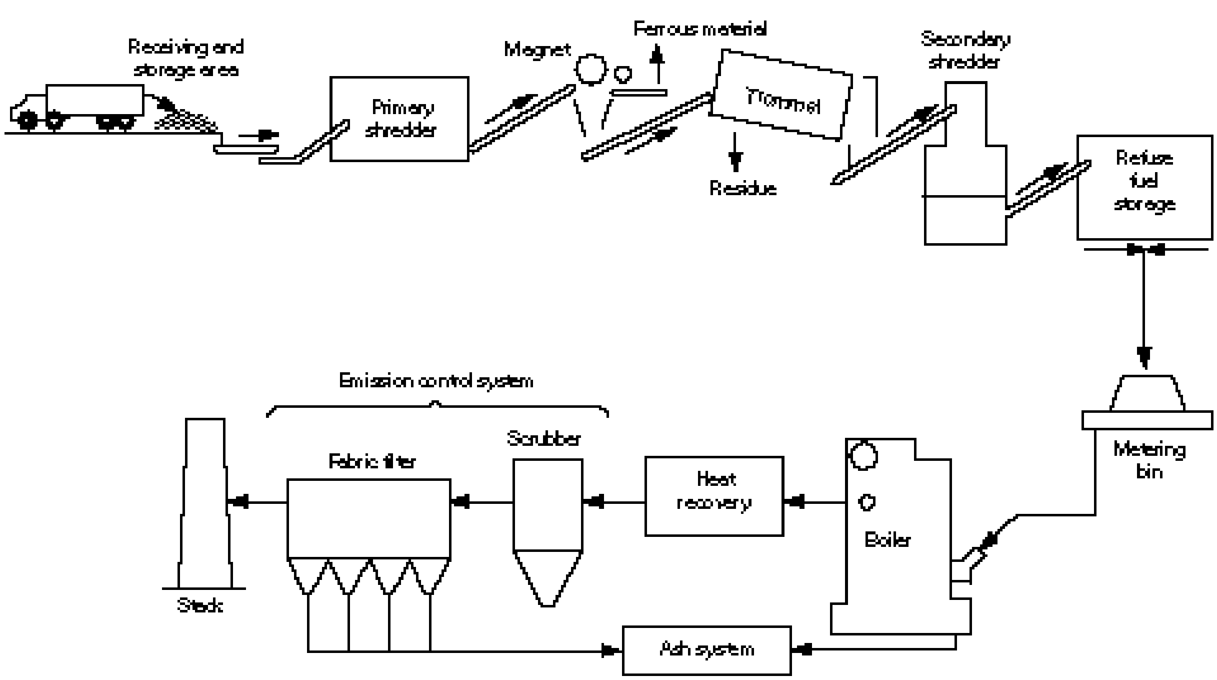
RDF fuel is conveyed, transported, and stored more readily than waste itself.

Because the municipal solid waste is transformed into a fuel that can be handled (conveyed, transported, temporarily stored, etc.) more readily than municipal solid waste itself, there are several possible combustor options, including the following.

- **Dedicated Combustor.** This is the most common type of combustor; it is in use at several facilities in the United States. A dedicated RDF combustor consists of a stoker-fed traveling grate and a waterwall steam generator. Unlike the mass-burn combustor, there is no refractory in the lower combustion zone of the combustor. The waterwall tubes are exposed to the combustion gases and radiant heat. The lower furnace is subject to corrosive attack, which can be controlled by using special corrosion resistant metal coatings. The RDF is fired through an air-swept spreader above the traveling grate and is partially burned in suspension with the larger and heavier particles burned on the grate. Combustors range in size from 500 tons-per-day of RDF to as large as 1500 tons-per-day. This

Figure 8-7

Typical Simplified RDF Facility Schematic



Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

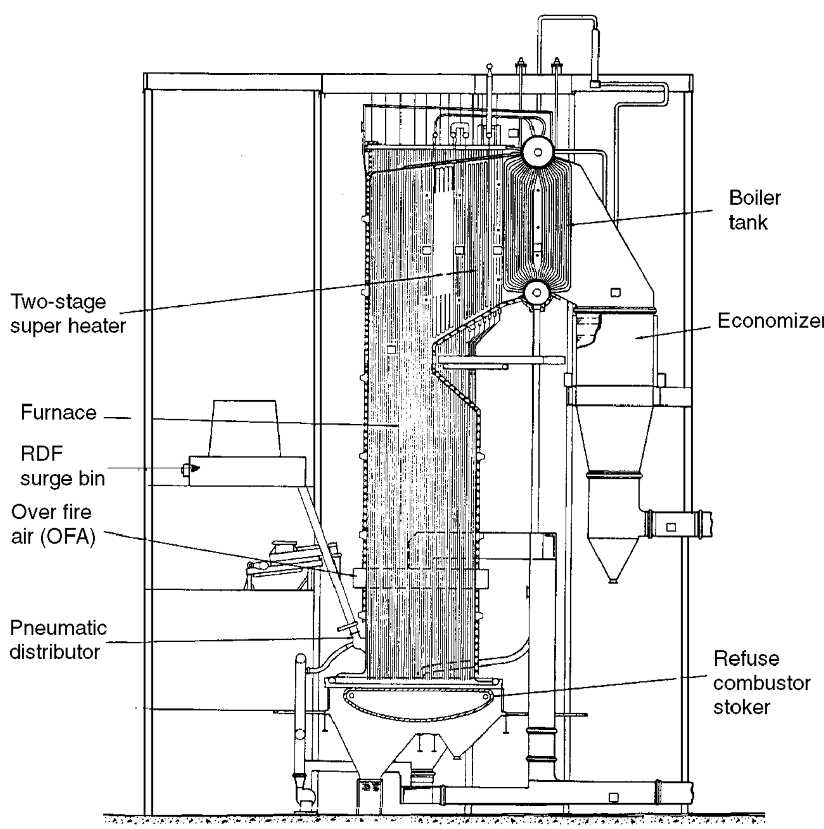
System options must be carefully considered.

technology is comparable to systems used to combust many biomass fuels such as wood, waste, bark, bagasse, and others (see Figure 8-8).

- **Fluidized Bed Combustion.** Fluidized bed combustors for RDF are a relatively new approach involving the firing of the RDF into a bed of fluidized inert noncombustible, high melting-point material (sand) that substitutes for a grate. The RDF is combusted in the suspended sand bed. This improves the combustion reaction by bringing the waste in direct contact with the bed of material. Above the fluidized bed is a waterwall boiler where the heat is transferred to produce steam. Fluidized bed combustion can be an attractive alternative because a wide variety of materials can be burned, including high-moisture content materials such as sludge. In addition, because the units should operate at lower excess air conditions, they can be relatively smaller in size when the emission control equipment is included. This type of combustor has been used less to burn RDF than the dedicated stoker-fired combustors.
- **Co-firing RDF with Coal or Other Biomass Fuels.** Dedicated RDF combustors can co-fire coal, wood waste, or other solid fuels. This may be an advantage if the waste generation rates vary widely by season or as a result of other waste management practices (recycling, waste reduction, pollution prevention, etc.). The facility can remain a stable source of steam or electricity if other fuels can be fired along with or independent of waste.

Figure 8-8

Typical RDF Stoker and Boiler



Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

- **Densified RDF (D-RDF).** D-RDF is a fuel produced by compressing already processed RDF into cubes or pellets. The increased cost of processing may be offset by allowing for more cost-effective transportation and temporarily storing the fuel product. This fuel type may also be more cost effectively fired into an existing industrial-type boiler firing stoker coal or other solid fuels.

Incinerator System Components

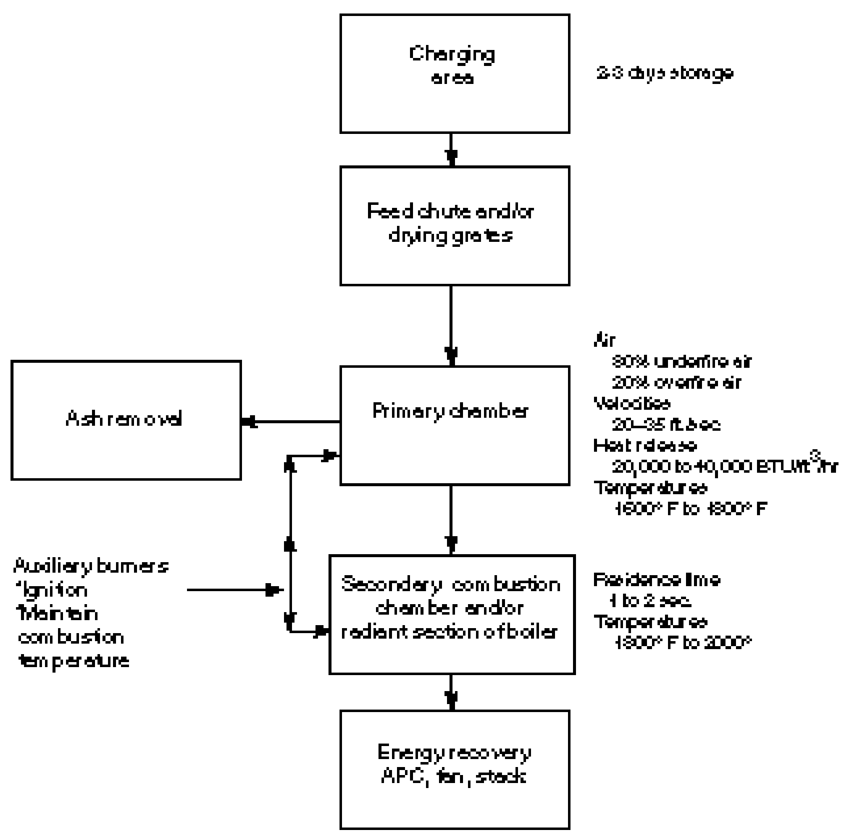
The components must be carefully integrated into a system.

Modular and mass-burn systems receive, store, and fire municipal solid waste without preprocessing or preseparation before firing into the combustor. RDF systems include a level of preprocessing and / or separation of noncombustibles before firing into the RDF combustor. Each of these options have many common components or design features to properly receive and process the municipal solid waste and the resulting products and residues.

Waste-burning facilities with energy recovery generally have the following components: waste storage and handling equipment, combustion system, steam / electrical generator, emission control system, and residual control system. Figure 8-9 shows an example design for a large-scale mass-burning WTE facility.

Figure 8-9

Typical Mass-Burn System Design Basis



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Storage and Handling Area

Tipping facilities for handling and storing waste must be sized correctly.

The solid waste storage and handling area consists of either a large tipping floor or tipping pit onto which waste is discharged directly from collection vehicles.

The tipping floor and tipping pit are usually enclosed in a building to control wind and odor problems, as well as to keep precipitation from increasing the moisture content of the waste. This area should be large enough to handle at least three to five days' waste generation volume. This additional space allows for waste storage during weekends, plant outages, and periods of heavy precipitation, when incinerator loadings may need to be reduced to allow for proper burning of wet waste.

A large waste-tipping floor or pit also facilitates the operator in mixing the waste (i.e., dry stored waste may be mixed with incoming wet waste after a rainfall). This results in a more uniform heat feed rate into the furnace. For facilities with a tipping floor, waste is normally pushed into the furnace using a small tractor. At a facility with a tipping pit, a crane lifts the waste from the pit and drops it into a hopper. When loading the furnace, plant operators normally remove large, bulky noncombustible items from the furnace feedstock.

Waste Combustion System

After being fed into the charging system or hopper, the waste is moved into the furnace either by gravity or with a mechanical feeder. Primary combustion occurs in this first chamber. Within the furnace, the waste is agitated and moved to the discharge end by grates, rams, or other equipment and is concurrently mixed with air to achieve maximum burn out.

During incineration, energy is released in the form of heat. Burned material and noncombustibles move downward through the furnace for removal by the ash handling system.

Energy Conversion and Use

Heat released during incineration is transferred to water that is circulated in the boiler tubes, where the energy is absorbed and steam produced. A variety of boilers, heat exchangers, and superheaters are available. The selection of specific units depends on the quality (temperature / pressure) and use of the steam. The steam temperature and pressure produced must satisfy the energy customer's needs and be able to efficiently produce its marketable products: steam and electricity.

Residue Control

Ash handling is an important design element.

The products of combustion include the combustor bottom ash and fly ash. The bottom ash includes the heavy noncombustible materials (i.e., ferrous and nonferrous metals, glass, ceramics, etc.), and ash residues from the combustible material. Bottom ash is normally cooled by quenching in water and then moved by a conveyor system to a temporary storage and truck load-out area. The lighter products of combustion and products collected in the emission control equipment are collected and transported in totally enclosed conveyors to a water-conditioning area to moisten the fly ash residue products and then discharged onto the bottom ash conveyor for truck load-out. Depending on the facility's size and other economic factors, the ferrous metals in the bottom ash can be removed for recycling by magnetic separation. Some new systems can recover nonferrous metals as well.

Emission Controls

In the last 10 years, significant advancements have been achieved in controlling emissions from WTE facilities, including improved combustion controls

Controls for particulates and acid gas are required — heavy metal controls may be required in the future.

and advanced acid gas and particulate emission controls. In the past, incinerator emission control was achieved with electrostatic precipitators to collect particulates. At the time, no other controls were anticipated. Today, however, WTE facilities incorporate not only particulate controls, but also acid gas, organics, and nitrous oxide (NO_x) controls. These new controls have resulted from a better understanding of the potential environmental impacts of waste combustor emissions; municipal solid waste composition; and the effects of uncontrolled emissions of acid gas constituents (i.e., sulfides and chlorides), organics and heavy metals.

Volatile Organic Controls

Volatile organics can be controlled with good combustion practices (i.e., controlling combustion air, municipal solid waste feed rate, and combustion temperature and residence time). The advancements in interactive control instrumentation have made it possible to more closely monitor the combustion process and adjust the municipal solid waste feed rate and combustion air to ensure volatile organic containment (VOC) destruction.

Nitrous Oxides (NOx) Controls

Air emission controls are an integral system element.

NO_x (gaseous oxides of nitrogen) can be controlled in the combustion process or by adding additional controls. Selective Noncatalytic Reduction (SNCR) is now the most common method for controlling NO_x from waste combustors. With SNCR, ammonia is injected into the combustor's boiler bank above the fire zone. The ammonia reacts with the nitrogen in the combustion gases to form nitrogen dioxide and water. Another method of controlling NO_x is with staged combustion, in which the combustion temperatures are controlled to minimize thermal NO_x generation. Either or both of these options may be appropriate depending on the combustion technology to be used.

Acid Gas Controls

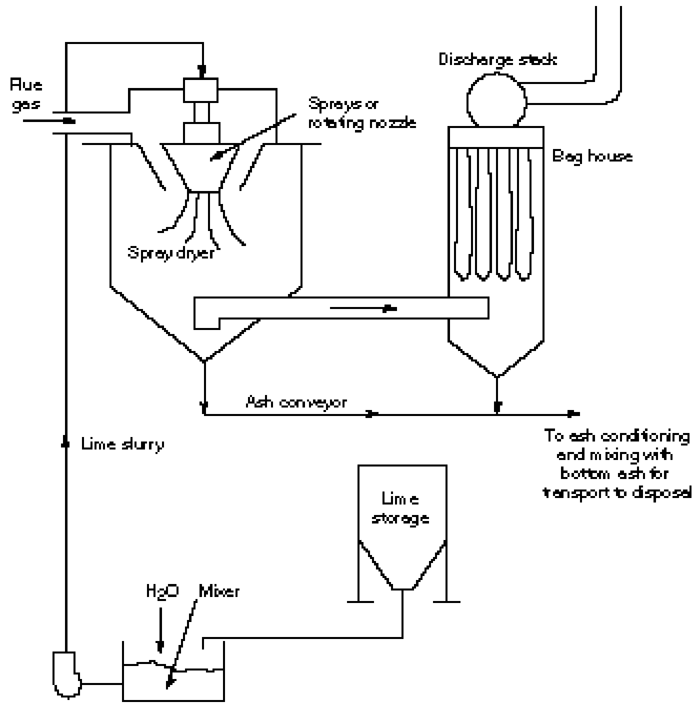
Acid gas emissions can be controlled by scrubbing acidic gases from the combustor exhaust gas. The products of scrubbing can be recovered either as a dry powder residue or as a liquid. The most common acid gas scrubber technology used in the U.S. is the spray-dry scrubber (Figure 8-10). The flue gas from the combustor is ducted into a reactor vessel, where the incoming flue gas is sprayed with a lime slurry. The lime particles react with the acid gases to form a calcium precipitate. The slurry water cools the incoming combustor exhaust and the water is vaporized; the lime is chemically combined with the chlorides and sulfates and condensed. Lower temperatures are used to promote the chemical reaction with the lime, to promote condensation of most heavy materials in the gas stream, and to control the flue gas temperature in the particulate control device.

Particulate Controls

Using fabric filters or baghouses has become the most common method of controlling particulates. Baghouses control particulate emissions by channeling flue gases through a series of tubular fabric filter bags. The bags are set together in an array through which particulates are directed then trapped. Due to the fineness of the fabric mesh and the resulting build up of fine particulates on the bag, the recovered particulates act as an additional medium to further filter out particulates (see Figure 8-11). The collected particulates with the precipitated end products from the scrubber are removed from the bag by various mechanical methods, including reversing the gas flow of cleaned flue gas through the bags by shaking or pulsing the bags.

Figure 8-10

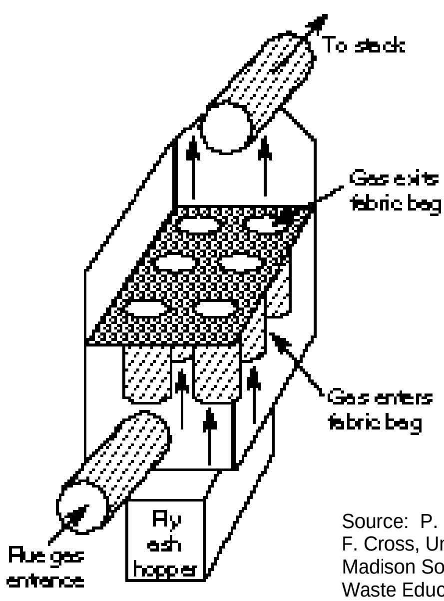
Spray-Dry Scrubber and Baghouse



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Figure 8-11

Baghouse Schematic



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

An inherent advantage of the baghouse systems is that the filtering process also acts as a secondary acid gas scrubber. The collected particles include the unreacted calcium from the scrubber, which also builds up on the bags and will react with any untreated acid gases.

Secondary Volatile Organic and Mercury Control

A developing control technology is the use of activated carbon as an additive to the scrubber process. The carbon is injected into the flue gas before it enters the baghouse to provide additional control of volatile organics and for controlling mercury. Another option is the addition of a carbon filter after the baghouse.

Emission Monitoring

To assist the operator in the proper operation of the combustion process and the emission control equipment, Continuous Emission Monitoring (CEM) equipment has become a requirement for any new or existing waste combustor. CEM systems typically monitor stack emissions of NO_x, carbon monoxide, oxygen, particulate via opacity meters, and acid gases via monitoring sulfur dioxide. Gas temperatures are also monitored to control the scrubber process and to ensure baghouse safety.

ENVIRONMENTAL PERMITTING

Air Permit Regulations

Developing and implementing a WTE facility involves an analysis of the region's air quality, use of the maximum achievable control technology, a detailed projection of the likely emissions from combustion of the waste, and an analysis of the potential impacts those emissions will have on regional air quality, human health and the environment.

Permitting is a complex technical and legal process requiring an experienced, qualified consultant.

Successful facility air permitting requires adhering to new federal and state source emission standards and using the best available control technologies for emission control. Permits are granted on a case-by-case basis through a licensing process, which, in part, involves demonstrating compliance with federal or state standards and showing that plant emissions will cause no significant deterioration of local air quality. It also includes conducting a site-specific health risk assessment. Because permitting and licensing are complex technical processes, it is important to select a qualified, experienced consulting firm to prepare the necessary studies and documents to ensure that the facility is successfully permitted.

Following is a summary of the federal standards and requirements for WTE facilities. The project team must also become familiar with applicable state and local requirements, which may be more stringent than the federal requirements. Federal regulations that will affect the construction and operation of new MSW combustors include the following:

- New Source Performance Standards (NSPS)
- National Ambient Air Quality Standards (NAAQS)
- Prevention of Significant Air Quality Deterioration (PSD) review process for attainment areas
- New Source Review (NSR) for nonattainment areas
- Operating Permit Review and periodic renewal.

New Source Performance Standards (NSPS)

NSPS standards apply to all new WTE units greater than 250 tons/day capacity.

The USEPA established "new source performance standards" for new solid waste combustors on February 11, 1991. These standards apply to all new WTE facilities with individual units greater than 250 tons per day (225 Mg/day) in waste combustion capacity. When establishing the facility's maximum capacity, the regulations assume the municipal solid waste has a higher heating value of 4,500 Btu's per pound. Should the service area's waste stream have a heating value greater than 4,500 Btu's per pound, these standards would apply to a facility that was intended to fire a lesser tonnage. NSPS emission standards for all types of waste combustors is provided in Table 8-6. The metals emission standard is measured as particulate and is equivalent to the particulate emission standard.

In addition, NSPS established carbon monoxide emission limits for each type of combustor. Because of differing operating characteristics, waste combustors will exhibit slightly varying carbon monoxide emissions. Table 8-7 shows minimum standards established for various combustion technologies.

Best Available Technology

The USEPA minimal emission standards are based on the use of SNCR (selective noncatalytic reduction) technology for NO_x control and spray-dry scrubber and a fabric filter for acid gas and particulate control. The NSPS also established "good combustion practices" (GCP) for controlling organic emissions. Although the emission standards are based on the emission control technologies described above, alternative technologies can be used to meet the emissions performance standards.

Operator Certification

Operator training and certification are required.

Another integral part of the NSPS is the American Society of Mechanical Engineers (ASME) Standardized Test Program for the "Qualification and Certification of Resource Recovery Operators." This is a standardized operator testing procedure administered by the ASME. The test verifies that the chief operator and the shift supervisors of WTE facilities are properly trained and, therefore, qualified to operate a municipal waste combustor. In addition, the facility owner or operator must ensure that on-site training is available and reviewed with all employees involved in the operation of the municipal waste combustor.

Co-Fired Facility

Facilities that fire RDF in combination with coal are subject to the NSPS regulations for waste combustors if that facility fires RDF at a rate greater than 30

Table 8-6

NSPS Emission Standards for All Types of Waste Combustors

Particulate	0.015 GR/DSCF @ 7% O_2
SO_2	30 ppmv @ 7 % O_2, or 80% reduction
HCl	25 ppmv @ 7% O_2, or 95 % reduction
NO_x	180 ppmv @ 7% O_2
Dioxin/Furan	30 ng/Nm^3 @ 7% O_2

Source: USEPA

Table 8-7

Minimum Carbon Monoxide Standards for Various Combustion Technologies

Combustion Technique	(CO @ 7% O_2)
Mass-burn (water-wall and refractory)	100 ppmv
Mass-burn (rotary)	100 ppmv
Modular (starved and excess air)	50 ppmv
RDF Stoker	150 ppmv
Fluidized bed	100 ppmv
RDF/coal co-fired	150 ppmv

Source: USEPA

percent on a weight basis. Facilities firing RDF at a rate less than 30 percent by weight are subject to the environmental emission standards for utility or industrial coal combustors.

"Prevention of Significant Deterioration" (PSD) Determination

PSD review and permitting requirements apply to facilities with emissions above those shown in Table 8-8.

Each new facility, depending on its size and the amount of pollutants that may be emitted on an annual basis, is subject to the requirements for the "prevention of significant air quality deterioration" (PSD) process and federal PSD permit requirements. In addition, depending on the status of the state's air quality program, the PSD permitting process may be delegated to the state permitting agency. Some states are not fully delegated to administer the PSD program, in which case the permitting process is administered jointly with the regional USEPA office. Obtaining a PSD permit can be a lengthy process. A variety of environmental and technical experts will be needed to make an accurate analysis of the existing air quality and the potential impacts the proposed facility will have on it and to properly prepare the necessary documentation.

If a facility's projected annual emission rate is greater than the amounts listed in Table 8-8 for any one of the potential pollutants, the facility will be subject to the requirements of a PSD review and permitting process. The PSD process includes the following requirements:

- **Existing Air Quality Analysis:** A detailed analysis of the existing ambient air quality of the area surrounding the facility is necessary. Depending on the availability of existing air quality data and the potential facility emissions and their impact, there may be a need to establish ambient air monitoring sites to collect data for a period of as long as a year prior to submission of the final PSD permit application.
- **Best Available Control Technology (BACT) Analysis:** The PSD application must include an analysis of alternative control technologies that might be used to control facility emissions through a process called "top-down" technology review. All relevant control technologies must be identified by the applicant and each option analyzed for its economic, energy, and environmental costs to determine which option will provide the best control at an acceptable cost. The control technology meeting the specified criteria will then be selected as the facility's BACT. Such a review can require emission limits based on control technologies beyond those for which the NSPS standards are based.
- **Emission Dispersion Modeling:** A detailed analysis of the impact that the facility's emissions are likely to have on the ambient air quality must be performed by modeling the expected emissions using local meteorological data over a five-year period to demonstrate that the proposed

Table 8-8
PSD Significant Emission Rates

Pollutant	Annual Emission (tons per year)
Particulate matter	100.0
Carbon dioxide	100.0
NO_x	100.0
Acid gases (SO_2 and HCl)	40.0
MWC metals (measured as PM)	15.0
MWC organics (measured as dioxins and furans)	3.5 *(10)-6

Source: USEPA

facility will not exceed the ambient air quality standards. Again, if sufficient data is not available, ambient monitoring may be required. The allowable increase (increments) in ambient air quality will vary with the existing air quality and the location of the facility. Allowable increments are given on a first-come, first-served basis, so it is incumbent for the project team to seek and secure those increments on a timely basis.

- **Facility Plans and Specifications:** The PSD permit application requires that the applicant provide general information about the facility to be constructed. Such information includes a facility description outlining the nature, location, design, and typical operating schedule, and including specifications and drawings showing the relevant design and plant layout; a detailed construction schedule; and a detailed description of the emission control technologies to be used and their effectiveness in controlling emissions. The latter are necessary for providing a detailed emissions estimate.
- **Public Comment and Hearings:** A critical part of the PSD process is providing the public with an adequate opportunity to participate in the decision-making process. Such participation can include public notification, public comment periods, and public hearings on the proposed facility and the facility's likely environmental impacts.

New Source Review (NSR) Permit

PSD requirements apply to facilities that are located in nonattainment areas and that have emissions equal to or greater than those listed for PSD review (see Table 8-8).

A "new source review permit" is required for any proposed facility that will be located in a nonattainment area and that will result in an emission increase equal to or greater than those listed for a PSD review. If the proposed facility is located in a nonattainment area for one or more of the regulated pollutants, the facility can be subject to further potential controls. The level of control will depend on the classification of nonattainment (i.e., the greater the level of nonattainment, the more stringent the level of control). The NSR requirements must be met for any pollutant that is not in compliance; for all other regulated pollutants, the PSD requirements would apply. In addition, an NSR applicant must comply with the following two requirements.

Lowest Achievable Emission Rate

To ensure that the facility will not result in a decrease in the region's air quality, the facility must be equipped with emission control technologies that will achieve emission rates that meet either the strictest emission rate achieved in practice by an existing facility or the strictest limitation in the State Implementation Plan.

Offsets

The facility emission rate of nonattainment pollutants needs to be offset by the reduction of that pollutant from an existing source times a factor that is dependent on the severity of the level of nonattainment of that pollutant.

State Implementation Plan (SIP)

The Federal Clean Air Act requires each state to adopt a state implementation plan (SIP) that provides for the implementation, maintenance, and enforcement of primary and secondary National Ambient Air Quality Standards (NAAQS) for each air quality control region of that state (see Table 8-9). State implementation plans are usually a set of state air pollution emission regulations and controls designed to achieve compliance with the NAAQS. SIPs must contain requirements addressing both attainment and nonattainment areas.

Federal Emission Standards

The current National Ambient Air Quality Standards, as written in the 1990 Clean Air Act Amendments, are provided in Table 8-9.

Table 8-9
NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Primary Standards	Averaging Time	Secondary Standard
Carbon Monoxide	9ppm (10Mg/m^3) 35ppm (40Mg/m^3)	8-hour[a]	None
Lead	1.5mg/m^3	Quarterly average	Same as primary
Nitrogen dioxide	0.053 ppm (100 mg/m^3)	Annual (arithmetic mean)	Same as primary
Particulate Matter (PM_{10})	50mg/m^3 150mg/m^3	Annual (arithmetic mean)[b] 24-hour[c]	Same as primary
Ozone	0.12 ppm (235 mg/m^3)1-hour[d]	Same as primary	
Sulfur oxides (SO_2)	0.03 ppm (80mg/m^3) 0.14 ppm (365mg/m^3) —-	Annual (arithmetic mean) 24-hour[a] 3-hour[a]	—- —- 0.5 ppm (1300mg/m^3)

[a] Not to be exceeded more than once per year
[b] The standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50mg/m^3, as determined in accordance with Appendix K.
[c] The standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 mg/m^3 is equal to or less than 1, as determined in accordance with Appendix K.
[d] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, as determined in accordance with Appendix H.
* Note EPA Regulations 40 CFR Part 50

Residual Disposal

A WTE facility and its emission control system produce a variety of residues. By far, the largest quantity is bottom ash, the unburned and nonburnable materials discharged from the combustor at the end of the burning cycle.

The process also produces a lighter emission known as fly ash. Fly ash consists of products in particulate form which are produced either as a result of the chemical decomposition of burnable materials or are unburned (or partially burned) materials drawn upward by thermal air currents in the incinerator and trapped in pollution control equipment. Fly ash includes what is technically referred to as air pollution control residues.

Constituents of bottom and fly ash vary, depending on the materials burned.

Fly ash normally comprises only a small proportion of the total volume of residue from a WTE facility; the quantity ranges from 10 to 20 percent of the total ash. Distribution of bottom and fly ash is largely influenced by the type of combustion unit. Excess air systems produce the most fly ash; controlled air units produce the smallest amounts.

Constituents in both ash and scrubber product vary, depending on the materials burned. In systems burning a homogeneous fuel such as coal, oil, or tires, levels of pollutants in residuals may be relatively constant. Systems burning a more heterogeneous mixture, such as municipal, industrial, or medical waste, may experience wide swings in the chemical composition of residuals.

The major constituents of concern in municipal waste combustion ash are heavy metals, particularly lead, cadmium, and mercury. These metals may impact human health and the environment if improperly handled, stored, transported, disposed of, or reused (for example, using stabilized ash in construction materials such as concrete blocks).

Solid waste is regulated by two major programs under the Resource Conservation and Recovery Act (RCRA). The RCRA Subtitle C program regu-

Hazardous waste standards may apply to ash disposal.

lates the disposal of solid waste that is hazardous, while the RCRA Subtitle D program regulates nonhazardous solid waste. WTE facilities must determine if their ash is a hazardous waste. This is usually done by testing. Ash classified as hazardous must be handled under RCRA Subtitle C regulations as a hazardous waste. Testing and possible hazardous waste treatment / disposal costs must be considered in economic evaluations of municipal waste combustion. Ash not classified as hazardous must be disposed of in accordance with Subtitle D and state regulations. Many states have their own special requirements for managing municipal waste combustion ash. Readers are urged to check with their state environmental program to determine the current regulatory status of municipal waste combustion ash.

Water Discharge

WTE facilities may also require water discharge permits.

While ash is usually the major residue problem at WTE facilities, some plants also generate wastewater. Those considering construction of a WTE facility should anticipate and acquire all permits necessary for wastewater treatment and disposal.

Surface Water Concerns

Wastewater at a WTE facility can be generated in various forms. These include tipping floor runoff system wash water, ash quench water, and water from pollution control systems. These systems also must deal with normal problems experienced by all large industrial facilities, including sanitary wastewater disposal and surface-water runoff. For most WTE facilities, wastewater can be recycled in a closed-loop system. In these systems, water from floor drains, ash dewatering, water softener recharge, and other process wastewaters are collected and stored in a surge tank. This water is then reused for ash quenching. Sanitary waste can be directed to municipal sewer systems.

For most facilities, the quantity of water used amounts to a few gallons per ton of refuse burned. Usually this effluent can be discharged to a local sewer system. In some cases, regulatory authorities may require that the waste stream be pretreated before discharge. State regulatory agencies and local sanitation officials should be consulted to determine the best method of handling wastewater.

Groundwater Concerns

Groundwater contamination at WTE facility sites has proven to be unlikely. Proper management and handling of surface waters and proper ash disposal will minimize potential contamination of groundwaters.

Local and Other Federal Program Requirements

The construction and operation of a WTE facility also requires several other permits, many of which satisfy local requirements, such as those for zoning or traffic. There are, however, two permits that are administered by federal agencies.

Public Utilities Regulatory and Policy Act (PURPA)

Be careful to review and comply with all pertinent regulations.

The Public Utilities Regulatory and Policy Act was established to encourage the development of co-generation facilities to support existing electrical generating capacity. PURPA requires utilities to purchase electricity from producers at the utilities' "avoided cost," that is, the cost of building that capacity or the cost of operating at a higher capacity. The application for certification of added capacity is administered by the Federal Energy Regulatory Commission.

Federal Aviation Administration (FAA)

The FAA controls the height of structures in the flight path of air traffic and the marking of structures that may be of excessive height. The purpose is to ensure that structures (for example, the stack) are not constructed in the direct flight path of any landing strip and that they are properly marked and lighted to warn air traffic of their existence. In some instances, stack height is restricted.

Other Environmental Issues

Land-Retained Pollutants

Land-retained pollutants originating as stack or fugitive emissions are of increasing concern. Bio-accumulation and subsequent ingestion from food is an indirect exposure route resulting from land-retained emissions. To provide better understanding of land-retained pollutants, it may be desirable to establish baseline contaminant levels before plant construction so changes in those levels throughout the plant's operating lifetime can be monitored.

Noise Pollution

Each potential environmental issue must be carefully evaluated.

Truck traffic is the greatest source of noise pollution resulting from WTE plant operations. Well-maintained and responsibly operated trucks will help minimize this problem. Local ordinances may restrict truck traffic to certain hours of the day and to specified truck corridors. Under these conditions, noise pollution should not be a significant factor.

Noise resulting from plant operations and air handling fans associated with the combustion and emissions control equipment is also a potential problem. Noise levels are likely to be highest in front of waste tipping floor doors, ash floor doors, and in the vicinity of the air emissions stacks. Most states have standards for noise levels from industrial facilities of this type. Walls, fences, trees, and landscaped earthen barriers can serve to reduce noise levels.

Aesthetic Impacts

Negative aesthetic impacts can be prevented or minimized by proper site landscaping and building design. Such impacts are much less problematic if the facility is sited in an industrial area and not adjacent to residential or commercial districts. Local zoning ordinances may ensure that aesthetic pollution does not occur. Environmental impact assessments should discuss potential aesthetic effects from a WTE project.

Keeping the process building at negative pressure can prevent undesirable odors from escaping outside of the building. Using air internal to the process building for combustion air in the plant processes will destroy most odors. Visible steam or vapor plumes can be emitted by some facilities. Smoke resulting from improper conditions in the combustion chamber can also be problematic. Air emissions stacks and cooling towers may also be unappealing anomalies in the skyline of some areas. If external lights on buildings prove objectionable to neighbors, perimeter lights on stands directed toward the plant may be preferable.

Land Use Compatibility

Ideally, a WTE plant will be located where it is considered a compatible or nondisruptive land use. Choosing an incompatible site can serve as a catalyst for any existing public opposition to siting a facility. Construction in an industrially zoned area may be considered an example of siting in a compatible land use area.

The availability of undeveloped land around the facility will mitigate any unexpected and undesirable impacts by the facility. Having additional land available is also desirable for future expansion and the installation of additional energy recovery or emission controls as conditions change over the life of the facility.

Environmentally Sensitive Areas

An environmental impact statement should thoroughly document the impacts of WTE operations on environmentally sensitive areas. Contaminant levels of metals and other substances should be established downwind and near the facility to use as a baseline for measuring future impacts on environmentally sensitive areas.

Health Risk Analysis

A health risk assessment may be necessary.

Humans can be exposed to air emissions from WTE incinerators through direct and indirect pathways. The most common direct pathway is inhalation of pollutants; indirect pathways can include ingestion of contaminated food or water. Both direct and indirect pathways through which pollutants enter humans and ecosystems should be documented and accounted for in WTE risk assessments. Land- and water-retained fallout is a growing concern for risk assessments.

Traditionally, risk assessment calculations have focused on air emissions. Potential problems associated with storage, handling, and disposal of ash should also be identified. Risk assessments should provide a full comparison of alternative waste management options and their associated risks.

Role of the Contractor in the Permitting Process

An environmental permit application must be consistent with the performance characteristics of the technology and operations procedures that will be employed. If the applications are not consistent with the performance characteristics, it may be necessary to reapply for some permits if there are technological changes requiring permits. Depending on the negotiated positions taken in the contracting process, either the contractor or the municipality will have a significant role in negotiating the permit language outcome.

Regulatory Approval Summary

Implementing an energy recovery project will require strict compliance with state and local regulations.

Implementing an energy recovery project will require strict compliance with state and local regulations. State permits must be acquired for air and water emissions and solid / hazardous waste disposal. Local governments may require special land-use approval or variances for land use impacts, including nonconforming zoning and overweight loads.

Obtaining permits for waste-to-energy facilities can be controversial, especially when community concerns are not appropriately addressed. Project progress depends upon anticipating these concerns throughout the siting process. Project development can be more effective when information is freely provided to the public during facility siting. The information in Chapter 2 on siting facilities should be carefully reviewed.

SITE SELECTION

As the project team identifies the geographic area to be served, the quality and quantity of solid waste available, and the viable energy markets, they can begin focusing on potential facility sites and identifying the technologies that will be required to meet the needs of specific markets.

The choice of site affects the technology needed.

For example, if one major steam buyer is available who can accept all the energy produced by a facility, a mass-burn facility or an RDF system with a dedicated boiler may be the best alternative. On the other hand, if a variety of industries are present in an area, but are miles apart, an RDF facility to provide these industries with supplemental fuel may be an alternative worth exploring.

However, depending on the local public utility's payment rate for the electricity produced, either a mass-burn or an RDF unit with a dedicated boiler may prove to be the most feasible. The mix of markets that provides the best economic outlook for the developer will provide the basis for choosing the technology that will be used to burn the waste and produce the desired energy.

Map Overlay Technique For Potential Sites

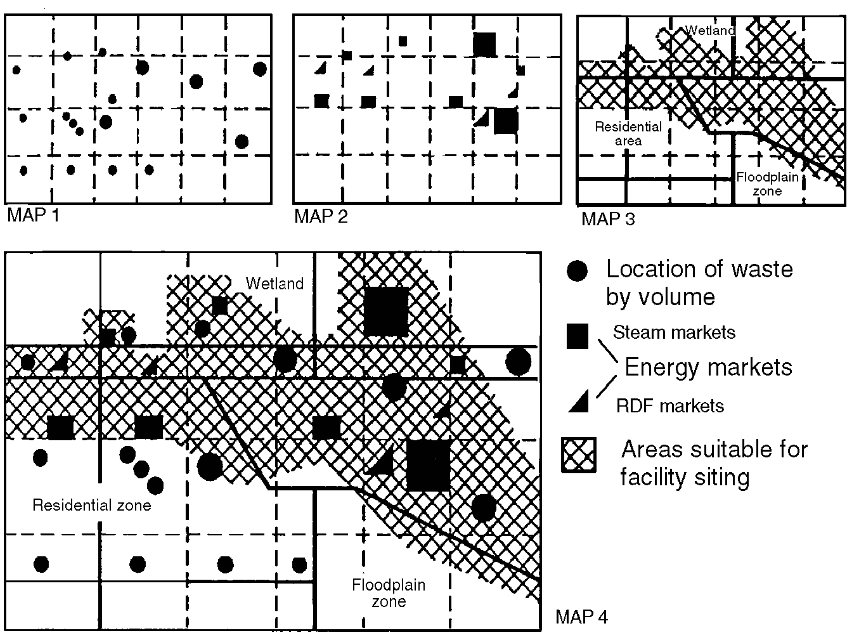
Waste supply, energy market, and land use information can be displayed in several different formats, including overlay maps, manually tabulated summaries, and computer-assembled tables. Mapping helps narrow down potential sites through a process of elimination based on predetermined criteria.

Overlay mapping helps eliminate sites based on predetermined criteria.

The preferred approach is to list all possible customers and the type of energy useful to them. For example, a hospital complex could heat and cool buildings with low-pressure steam; a manufacturing plant could use high-pressure steam; or an electric power plant could burn RDF. Note that selection in advance of a particular technology may limit potential energy customers to some degree.

As energy markets are being identified, an inventory should be conducted of land use in the service area. This will identify potential facility sites. The inventory should take into account highway system characteristics, sensitive environmental settings, land use compatibility, and zoning or regulatory constraints.

Figure 8-12
Waste-to-Energy Facility Siting Map Overlay Example



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

An example of map overlays is shown in Figure 8-12. Each area's available waste quantity is shown as a solid black circle (see Map #1, Figure 8-12); areas with relatively high waste generation rates have larger circles and the concentration of circles shows where the most waste is generated. In a similar fashion, potential energy customers are identified by squares and triangles representing where and how much steam and RDF may be used (see Map #2, Figure 8-12). The use of primary colors or patterns on transparencies are other options for overlays. Land use compatibility and general environmental conditions are also documented (see Map #3, Figure 8-12). Compatible areas indicated on the map are those that have not been deemed environmentally sensitive; those excluded from consideration in this example are wetlands, floodplains, and residential zones. Major roads are also shown on the map.

When the three maps are overlaid, locations with the service area that may be suitable for a steam or RDF WTE facility become evident (see Map #4, Figure 8-12). Areas where waste supply, energy demand, and suitable land use coincide are good candidates for the construction of either a steam-producing incinerator or an RDF plant and a dedicated or co-fired RDF boiler. The best option will be selected during the detailed evaluation of alternatives.

Detailed Site Evaluation

After the initial site screening process is completed, one or more viable sites may be available. The selection of the final site should be based on a more detailed and comprehensive environmental and technical evaluation. The selection criteria should be based on specific design requirements for the facility, including the following:

Final site selection is based on a comprehensive environmental and technical evaluation.

- adequate land area
- subsoil characteristics to structurally support the facility
- access to water supplies for the process and cooling
- access to required utilities
- access to the energy market.

In addition, each site should be evaluated in detail for its social and environmental compatibility for this type of facility, including the following:

- compatibility with oother land use types in the neighborhood
- evaluation of the area's flora and fauna
- determination of any archaeological sites or protected species existing on the site.

Detailed investigations are conducted at each site. Site access is usually arranged by negotiating an option to purchase with the land owner. If several sites will be considered in detail, this phase of the assessment is usually divided into two parts: First, the available information is used to shorten the list of candidate sites; second, the few remaining sites should be studied in detail.

RESPONSIBILITY FOR FACILITY OPERATION

How and by whom the facility will be managed are crucial questions for the development team.

How the facility should be managed and by whom the facility should be operated — by public employees or by a private contractor — are major decisions for the implementation team. There are several issues to consider. First, it is essential that the facility be effectively managed and operated, and that a properly trained and well-managed team be assembled to operate the facility. Important factors to consider include the availability of qualified personnel, the level of pay that can be offered under the existing municipal compensation structure, and whether the pay structure is competitive enough to attract qualified personnel.

In addition, a WTE facility is an industrial plant that requires both daily and annualized maintenance using specialized services and an administrative staff to procure and manage that service. The municipality's procurement methods and policies under both state and local laws and regulations should be evaluated to determine if those services and replacement components can be procured in a timely manner.

Keeping the facility online is critical to its financial success. In the event of an outage, the operating agency must have the ability and authority required to get the facility back online as quickly as possible. The cost to the service area when a facility is out of service can be great; quick action to re-establish service is essential.

Public Operation

When considering public operation of a WTE facility, a number of factors are important.

In the past, public facilities were operated by public employees. That is no longer the norm with complex facilities like WTE, which require unique skills or talents to effectively maintain and operate. However, there are still many publicly operated WTE facilities. The advantages of a public operation include the ability of the municipality to have full control of the day-to-day operation and to gain all the economic revenue benefits from the operation. The disadvantage is that all of the day-to-day problems, costs, and liabilities are also borne by the municipality.

To make an informed decision to operate a WTE facility, the decision-making body should consider the need for the following:

- attracting and adequately compensating trained and qualified staff members
- procuring emergency outage repair services quickly
- maintaining sufficient budgetary reserves to make unexpected repairs
- accepting financial damages from the energy buyer if the facility is unable to provide power according to the energy sales agreement
- assuring the bond holders that their investment will be well maintained and the facility will operate for the term of the bonds
- availability of qualified experts (i.e., combustion, instrumentation, environmental, etc.) to meet the day-to-day operating demands.

Private Operation

Private operation reduces the community's obligations and responsibilities but also means relinquishing control.

To offset some of the major operating risks of this type of facility, there may be a long-term advantage to using the services of a private operating company to operate and maintain the facility. In this case it is essential that the project team establish a process for selecting a well-qualified and financially secure operating company.

The operating company will probably assume several of the municipality's obligations in operating the plant. Among them will be the requirement to take the city's waste and process it into energy. By contracting with a private company, the municipality will be transferring some of the major operating risks to that company. In turn, the operator will expect to receive compensation in the form of a share of the energy revenues or additional operating fees. The contractor should also be required to pay for any increased costs for failure to provide that service.

The advantage of using a private operator will be offset by the municipality relinquishing some of the day-to-day operating control and decisions in plant operations. However, the municipality will gain financial security because the operator will be obliged to pay for the cost of failing to meet specific contract obligations between the municipality and the energy buyer.

METHOD OF FINANCING

The method of financing selected will affect the subsequent project execution options available and will involve potentially complex contractual and tax issues. Project financing can be a very complex process requiring detailed legal and tax issues that need to be carefully reviewed and understood. After deciding to develop the project, it is to everyone's advantage to seek qualified financial advisors and make them an active part of the project team as soon as

Financing methods affect subsequent project options.

possible. Potential project financing alternatives include the following:

- general obligation (G.O.) bonds
- municipal (project) revenue bonds
- leverage leasing
- private financing.

General Obligation (G.O.) Bonds

The least complex option is general obligation bonds, and, depending on the credit rating of the municipality, it may be the least costly option in interest rates. The bonds are backed by the full faith and credit of the municipality based on its ability to levy taxes as necessary to pay the principal and interest on the bonds. Financing the project by this method may affect the municipal debt capacity for future projects and its credit rating for those projects.

General obligation bonds also allow the municipality full flexibility to use traditional municipal project execution methods and allow public operation of the project. For securing funding, this method also requires the least direct technical or economical analysis of the project's details to be funded. Each of the other financing methods involves more complex project contracting and economic reviews to support the project feasibility and each has implications to the project and municipality that requires an expert analysis to clearly understand the implications under the relevant federal and state tax laws.

Municipal (Project) Revenue Bonds

Project revenue bonds are based on the credit worthiness of the project and the parties involved, the technological feasibility (i.e., is the technology to be used "proven"?), and the project's revenue forecast. The bond holder is not in a position to take project execution risks. Therefore, either the contractor or the municipality must take the financial risk for any deficiencies in the project technology, changes in the project's forecasted income, or other project-related risks.

Leverage Leasing

Leverage leasing is a method of project financing that allows private investment in the project in combination with public debt. Under this method, a private investor becomes the owner of the facility, and the tax benefits of owning the facility will thereby offset the taxes that may be due for profits from the owners of other enterprises. The private equity, typically around 20 percent of the project capital cost, is based on the value of those tax benefits and the rate of return the private investor expects to receive from the investment. The municipality gains the benefit for reducing the public debt necessary to finance the project and the reduced debt service payment from that debt.

With leverage leasing, the municipality does not own the facility and, therefore, "leases" the facility back for the term of the debt service payments. The facility is subject to local property taxes that would be paid to the host community. Once the debt has been fully paid, the facility is owned by the private investors.

Private Financing

Private financing has been used for WTE projects which are developed by a private development group. As in the case of leveraged leasing, the private developers attempt to use some form of tax exempt debt to make the project financially feasible. The municipality would likely be committing to a long-term contract to deliver waste to the facility at a specified tipping fee to financially support the project.

RISK-TAKING POLICY

Constructing and operating a WTE facility requires the participants to carefully consider project execution risks. Many risks can be covered by insurance but without a proper risk management program, the cost of insurance could be considerable or become unavailable as a result of a poor management history. Major risk issues that should be addressed include the following:

The appropriate approach for managing risk must be established.

- availability of waste
- availability of markets and value of energy and recovered materials
- facility site conditions
- cost of money (i.e., bond interest rate)
- compliance with environmental standards (short- and long-term)
- waste residue and disposal site availability
- construction cost and schedule
- operating cost and performance
- strikes during construction and operation
- changes in laws (federal, state, and local)
- long-term environmental impact and health risks
- unforeseen circumstances (force majeure)
- long-term operating costs
- long-term performance.

Clearly, the party with the least control is the bond holder. Therefore, the bond underwriter will accept little if any risk and will monitor the project negotiations and final documents to satisfy itself that the project is viable, both technically and financially. Their review will include the financial and technical viability of all contracting parties.

Private contractors are usually willing to take those risks that they control. Asking a contractor to take risks that are beyond their control, such as availability of waste, may be good short-term politics, but can jeopardize the long-term financial stability of the contractor and the project.

PROCUREMENT APPROACHES

Having made the decision about who will operate the facility, the method of financing and the risk-taking position of the municipality, the project team can select the method of implementation that reflects those decisions.

The Architect/Engineer Approach

The traditional architect / engineer (A / E) approach involves the municipality retaining a qualified firm to design and procure the WTE facility employing procurement methods used traditionally by municipalities for public facilities. Although this has been used for many WTE facilities, this method will involve the greatest risk to the municipality for facility performance and construction cost overruns. In addition, there will be a need to allow for adequate operator participation in the design phase. This approach could be used if the municipality will own and operate the plant. Also, financing would probably be limited to general obligation or revenue bonds backed by that municipality.

The Turnkey Approach

The turnkey approach involves selecting, through competitive bidding or other appropriate competition, a qualified team or company to design, build, and demonstrate the performance of the WTE facility according to predefined performance criteria. Turnkey contractors usually have more freedom in the detailed plant design and construction of the facility to meet the performance specifications.

The Full-Service Approach

Select the approach that best satisfies project objectives

The full-service approach involves selecting a company willing to accept a full service obligation with the municipality to take the municipality's waste and process it to produce energy at an agreed upon energy conversion rate. The full-service company will, for an agreed upon construction and operating price, design, construct, and operate the facility for the term of the project, typically for the term of the bonds.

This option enables the municipality to minimize its risk because the contractor will be accountable for the cost of construction or any schedule delays or cost overruns. It gives the municipality added security by providing the municipality with a known operating fee for the length of the contract. Risks associated with deficiencies in the technology over the length of the contract, labor costs, equipment replacement costs, etc., are all assumed by the contractor. However, because those risks are passed on to the contractor, the contractor will expect and should receive greater freedom to execute its obligations (i.e., the municipality will have less control of day-to-day facility activities that are not specified in the contract). The full-service approach, which is the most common implementation method used today, allows the municipality to finance the project through several instruments, including public and private funding.

CONSTRUCTION AND OPERATION PHASE

Be prepared to address complex issues during facility construction.

Having completed the financing and execution of the project contracts, the community can then begin project execution, which will involve two or more years of construction and twenty or more years of operation.

It is not uncommon to disband the project development team at this time and turn the project over to new individuals or organizations to implement. The method the community chose for executing the project (i.e., public, private, etc.) will dictate the type of organization that will be needed to manage the project. In many cases, the level of staff involvement is underestimated. Many complex issues needing expert input can still come up, including verifying the facility's performance with contract specifications and its compliance with environmental standards. The bond holder may be represented by an independent engineer to certify that the constructed facility conforms with those standards. There may be unanticipated situations requiring some form of dispute resolution.

How these issues are handled and resolved will greatly reflect the project developers' competence in selecting the contractor and negotiating the many contracts required to create the project.

REFERENCES

Boley, G. L. 1991. *Refuse-Derived Fuel (RDF)—Quality Requirements for Firing in Utility, Industrial, or Dedicated Boilers.* International Joint Power Generation Conference, San Diego, CA. October.

EPRI Report. June, 1988. Updated by ABB-RRS, June, 1991.

IWSA (Integrated Waste Services Association). 1993. *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants.*

P. O'Leary, P. Walsh and F. Cross. 1987. University of Wisconsin-Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles.

USEPA. 1994. *Characterization of Municipal Solid Waste in the United States: 1994 Update.* EPA530-R-94-042 (November).

USEPA. 1992. *Characterization of Municipal Solid Waste in the United States: 1992 Update.* EPA530-R-92-019 (July).