INDEN 5000
WASTE TO ENERGY

CREATIVE COMPONENT
SUBMITTED BY
R. THIAGARAJAN
SPRING 1992

SUBMITTED TO
DR. WAYNE C. TURNER
SCHOOL OF INDUSTRIAL ENGINEERING & MANAGEMENT
OKLAHOMA STATE UNIVERSITY

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ABSTRACT

Incineration of municipal and industrial solid waste for the purpose of reducing the waste volume is not a new technology, but has not been used extensively in the United States. Landfills are the most common method of solid waste disposal. Many of the existing nation's landfills are reaching their capacity and developing new landfills is becoming increasingly expensive. Municipalities and industries are now investigating the use of solid waste incinerators and some have constructed and started operation of these facilities. To help to stabilize or reduce the costs of these facilities, heat from the burning waste is used to generate steam and electricity.

INTRODUCTION

With current landfills reaching capacity and the decreasing availability for new landfills, the United States is facing a phenomenal waste disposal problem. In an effort to solve the problem many municipalities are building waste-to-energy plants for burning their garbage. Electricity and steam generated by the plants are sold to raise revenue, thus helping to stabilize or reduce the costs of refuse disposal. Most industrial analysts involved with the industry are projecting a market of $10 billion over next 10 years for construction of waste-to-energy plants using both the mass burning and refuse-derived fuel (RDF) technologies.

Each man, woman and child in the United States produces an average 1000 pounds of refuse per year. The service and trade industries generate an additional 2000 pounds per employee per year. According to some estimates this country will run out of landfill capacity by the year 2000 A.D. Some major metropolitan areas are already experiencing problems.

Events of the early 1970's showed how dependent the United States has become on overseas supplies of energy. This energy crisis and increasing costs for energy coupled with the difficulties experienced in disposing of garbage made thermal waste-to-energy systems more appealing to communities through the United States.

Burning of trash is not new in this country. Solid waste was incinerated in the United States as early as 1885. Primarily, incinerators are used for reducing the volume of waste prior to disposal in landfill. The type of incinerators and energy recovery equipment depends on the composition and quantity of the solid waste stream. Typically, municipal solid waste (MSW) contains over 50 percent by weight combustibles having a "higher heating value" of about 4500 Btu/lb of waste. However, there can also be large quantities of a particular waste component, such as scrap tires, at a given site. This waste component has a high fuel value and can have a significant bearing on available energy recovered at an existing landfill site. In addition to the normally expected type of solid waste there may be other waste classified as hazardous wastes, requiring treatment. In the past, disposal of industrial chemical wastes had taken many approaches, some of which have created a legacy of environmental problems for current and future generations because of insufficient long-term containment of hazardous chemical constituents - heavy metals, PCB's, and aromatic hydrocarbons among others.

This paper discusses the general methods for burning municipal solid wastes. It also discusses the mass-energy balances, costs of the facilities, payback period, advantages and disadvantages of each type, regulations which govern these facilities and how the rest of the world is dealing with this problem.

TECHNOLOGY DEVELOPMENT

During research on the evolution of solid waste incineration, Robert H. Brickner of Gershman, Brickner & Bratton in Washington, D.C., uncovered some very interesting facts. In a visit to one United States Patent and Trademark office he discovered that a patent had been awarded in January, 1879, to Henry R. Foote of Stamford, Connnecticut, for an invention called a "Furnace for Cremating Garbage." The patent claimed that Foote dispose off Garbage, ashes and street refuse without any special screening or mixing by partially drying and burning in a closed furnace. After burning, Foote claimed that the unconsumed and offensive gases would be transferred into a separate furnace for further burning. Thus his patent went some way in addressing the problem of eliminating obnoxious gases. Figure (1) outlines the history of municipal waste incinerators in the United States from 1885.

Figure (1). History of municipal solid waste incinerators in the United States [4].

Year	Event
1885	First U.S. incinerator; Army Post Governors Island, New York.
1898	First U.S. refuse to steam unit; New York.
1900's	Heenan and Fround (cell furnaces) and Sterling furnaces introduced to U.S. from England.
1901	First Decarie furnace; water-cooled system for drying garbage-produced steam for internal drives.
1930's	Plants in Atlanta, Chicago, Miami and Louisville generates steam for space heating and industrial processing.
1941	First continuous feed unit (Volund) in U.S.; Atlanta, GA.
1962	First year more continuous-feed incinerators constructed than batch-feed incinerators.
1963	First continuous rocking-grate furnace developed in the U.S. (Greenwich, CT-250 TPD unit.)
1967	First U.S. waterwall unit; Norfolk, VA Navy Yard.
1969	364 incinerator plants constructed or rebuild since 1922, 43 with energy recovery (mostly in-house purposes).
1970	Only 275 incineration plants reported to be operating.

FUEL PREPARATION

Essentially there are two ways of burning garbage, as prepared RDF and in mass burning. The basic distinction between the two is in garbage preparation. In mass burning systems the refuse is burned in an 'as received' condition. Generally in mass burning systems all of the garbage entering the facility is dumped into a large storage pit with bulky items like stoves, refrigerators and similar items being removed prior to entering the combustion chamber. Refuse-derived fuel, on the other hand, is processed so that all non-combustible materials are removed prior to burning. In many instances the garbage remaining after processing is shredded into confetti-like particles.

Refuse is difficult to handle but is easily burned using today's technology. However, it is also heterogeneous and difficult to handle because the amount of water and ash properties vary considerably. Furthermore, the makeup of municipal water estimates combustible components typically break down to paper 35.8 percent and leather, rubber, wood and textiles 5.6 percent. Noncombustible components according to the EPA consists of glass 8.4 percent, metal 8.2 percent and 5 to 6 percent of sand dirt, ash, rocks, bones and other miscellaneous inorganics. Using mere figures, garbage is 77.8 percent combustible and 22.2 percent noncombustible.

Table 1. Comparison of the properties of municipal solid waste (MSW) and refuse-derived fuels (RDF)[4]

Municipal Solid Waste	
Ultimate Analysis	
Carbon	28.0
Hydrogen	3.4
Oxygen	20.0
Nitrogen	0.4
Sulfur	0.2
Inerts	23.0
Moisture	25.0
Total	100.0
HHV	4600 Btu/lb
Refuse-Derived Fuel	
Ultimate Analysis	
Carbon	33.4
Hydrogen	4.0
Oxygen	25.0
Nitrogen	0.4
Sulfur	0.2
Inerts	14.0
Moisture	23.0
Total	100.0
HHV	5700 Btu/lb

The physical and chemical properties of municipal refuse used in mass burning and RDF systems are compared in Table 1.

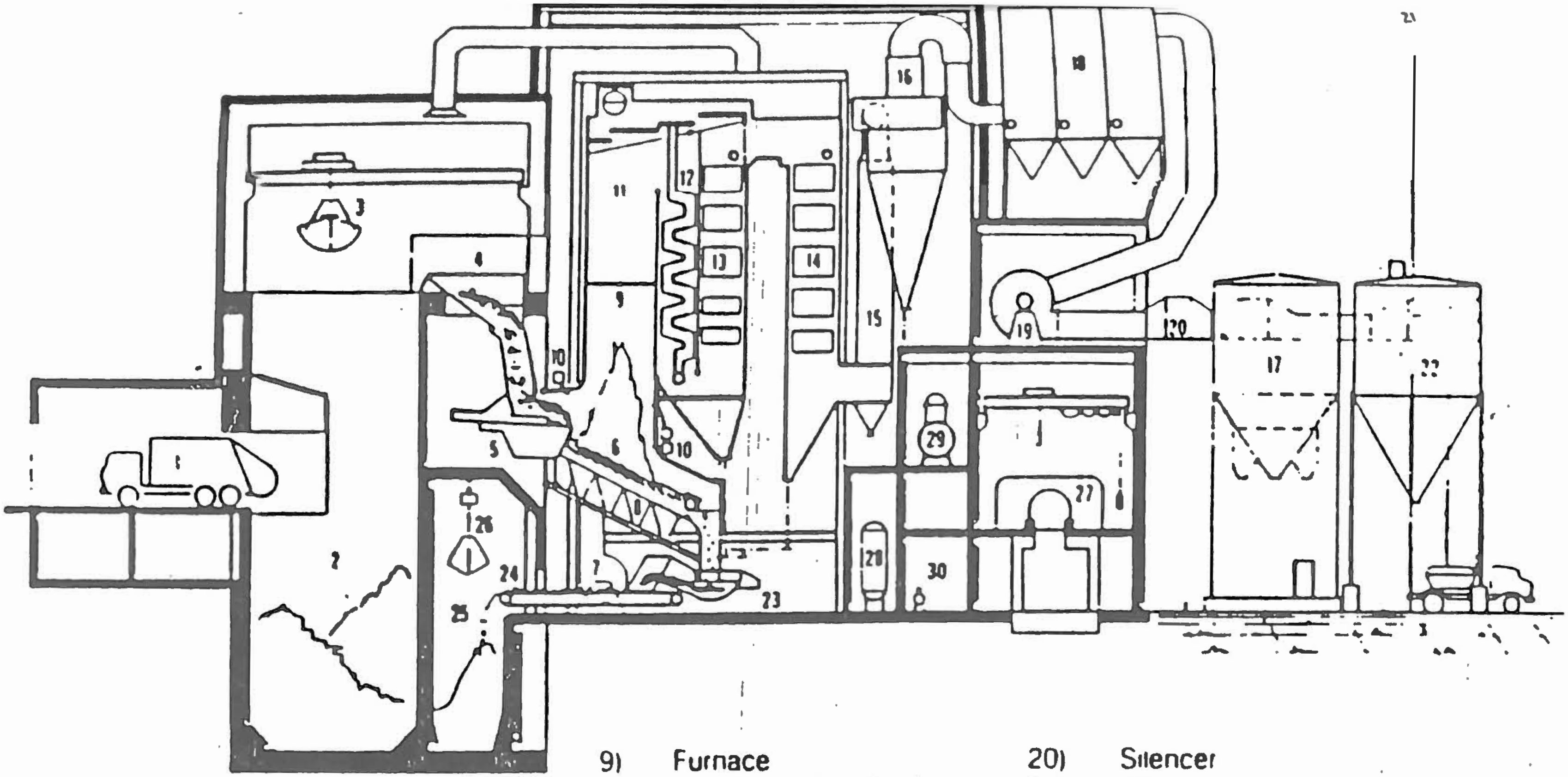
As previously mentioned the moisture content varies widely from little or none in commercial paper to 70 percent or more in food and yard waste. The major ash component in garbage fuels is from the clay added during the manufacture of paper.

MASS BURNING

A typical mass burning plant is shown schematically in Figure 2. Refuse is delivered to the plant by trucks (1), which enter an enclosed receiving area and dump their load into a storage pit (2). The storage pit is usually large enough to hold about three days worth of waste material. In this way, the plant can be run on weekends and holiday weekends when no waste is delivered. This size of pit also acts as a buffer during down times of equipment for maintenance. Both the receiving area and the storage pit are emissions of noise and odors from the plant. Also, air for combustion in the furnaces is drawn from these areas so that the odors are destroyed by the combustion process. By drawing air from these area, a slightly reduced pressure is maintained so that the odors do not escape from the plant.

An overhead crane (3) is used to separate large bulky items such as appliances and engine blocks. It is also used to mix the remaining waste in the pit and then to transfer the waste to feed hoppers (4). The material falls by gravity through the feed hoppers and then hydraulic ram feeder (5) charge the material onto the stoker grate (6). The ram feeders are controlled to charge the grate at the desired rate.

The waste material is then burned as it moves across the grate. The grate is usually inclined and consists of



1) Refuse Collection Vehicle
2) Refuse Storage Pit
3) Refuse Handling Crane
4) Feed Hopper
5) Feeder
6) MARTIN® Reverse-Acting Stoker Grate
7) Forced-Draft Fan
8) Undergrate Air Zones
9) Furnace
10) Secondary Air Nozzles
11) Boiler
12) Evaporator
13) Superheater
14) Economizer
15) Conditioner
16) Cyclone Reactor
17) Reagent Additive Silo
18) Fabric Filter Baghouse
19) Induced-Draft Fan
20) Silencer
21) Stack
22) Fly Ash Silo
23) MARTIN® Residue Discharger
24) Residue Conveyor
25) Residue Pit
26) Residue Handling Crane
27) Turbine Generator
28) Feedwater Treatment Plant
29) Feedwater Storage Tank
30) Boiler Feed Pump

Source: Ogden-Martin Systems, Inc. literature.

Schematic of Mass-Burning System Source [2] sections that are either stationary or move in such a fashion as to agitate the waste material and keep it moving down the grate. Generally, the thickness of the layer of waste material decreases as the waste moves along the grate and is burned. Primarily combustion air is supplied to the burning layer of waste by forced-draft fans (7) through the undergrate air zones (8). The air supplied through the undergrate air zones also acts to cool the grate and decrease through the grates are small enough that the grates forms a higher resistance to air flow than does the layer of burning refuse. This promotes a more uniform distribution of air flow through the grate.

The residue left after burning on the grate is quenched by water in the residue discharger (23) and is carried by a conveyor (24) to the residue pit (25). Siftings, i.e., fine materials that fall through the grate, are also collected by this system. Residues may be magnetically separated to remove ferrous metals and the remainder is hauled to a landfill.

In addition to the primary combustion air supplied below the grate, secondary combustion air is injected through nozzles (10) above the grate to promote turbulence for mixing and complete combustion of the volatile gases in the furnace (9).

There are two basic types of furnaces: waterwall and refractory line. In the waterwall furnace, water tubes from the boiler extend into the combustion zone and provide a cooled wall, while extracting heat from the combustion process. The tubes are coated with a protective material to reduce corrosion. In the refractory lined furnace, the boiler and furnace are separated and there are no boiler tubes in the furnace. To prevent excess heat losses from these types of furnaces, they are lined with refractory bricks.

Heat is extracted from the combustion gases and generates steam as it passes through a boiler system. In the system in Figure (2)., the hot gases pass sequentially through four section of the boiler (11). The first section is the waterwall section where the hot gases are initially cooled primarily by radiation. In the second section, water is evaporated to form saturated steam, while in the third section, the steam is superheated. The fourth section is the economizer where the boiler feedwater is initially heated.

In the system shown in Figure 2, the water circulating through the boiler is used to generate electricity. Steam exiting from the superheater is sent to a steam turbine which drives an electrical generator (27). The steam leaving the turbine is condensed and combined with makeup water from the feedwater treatment plant (28). It is stored in a feedwater storage tank (29) before being pumped by a boiler feed pump (30) into the economizer section of the boiler. As an alternative, or in combination with electric generation, the steam generated by the boiler may be used directly for district heating or industrial process heat.

The combustion gases carry flyash along with them. The flyash can be deposited on the surfaces of the boiler tubes, decreasing their efficiency in extracting heat from the gases. To prevent excessive buildups of flyash, the boiler tubes are cleaned using soot blowers. The flyash falls into hoppers at the bottom of the boilers and is conveyed to the residual discharge.

After leaving the boiler, the flue gases are treated before being discharged by an induced draft fan to the environment through the stack (21). Various combinations of pollution control devices are used. Generally, these devices can be divided into two groups:

(1) those for removal of acid gases

(2) those for removal of particulate material.

In the system shown, after leaving the boiler system the flue gases enter a conditioner (15) where water is added to cool the gases. the gases then flow lime dust [stored in the silo (17)] is blown in. Acid gases then pass through the fabric filter baghouse (18) where both the reacted lime dust particles and flyash are removed. The fabric bags are shaken mechanically or pneumatically and the particulate material drops into hoppers and is conveyed to a storage silo (22) where it awaits disposal in a landfill.

An alternative device for removing particulate material from the flue gases is the electrostatic precipitator. With this device, the particles are electrically charged, while the plates of the precipitator are oppositely charged. The

Table [2] Energy Production for Mass-Burning Systems by Ogden Martin Systems, Inc Source [2]

Plant Location	Plant Capacity TPD	Steam Pressure psig	Steam Temp deg F	Electricity Generated MW	Steam Generated lb/hr
Hillsborough, FL	1200	615	750	23	--
Alexandria, VA	975	600	700	20	--
Bristol, CT	650	865	830	13	--
Marion Co., OR	550	655	700	11	--
Stanislaus Co., CA	800	865	830	15	--
Tulsa, OK	1125	530	700	16.5	240,000
Indianapolis, IN	2362	510	710	--	500,000
Babylon, NY	750	655	700	14	--

particles are thus attracted to the plates and are collected on them. The plates are mechanically rapped and the particles fall into hoppers as with the baghouses. Electrostatic precipitators are not usually in combination with the dry gas scrubbers (lime dust reactors) as fabric filter baghouse are.

Mass-Energy Balances

As was mentioned in the system description, energy from burning waste is used to produce steam which is then either used to generate electricity or to provide steam for district heating, or industrial process, or both. The energy production for the eight mass-burning plants that have been built or are being built by Ogden Martin Systems, Inc., are summarized in table (2). For each of these systems, the steam temperatures is between 700° F and 830° F, with most of the systems operating nearer 700° F. Steam temperatures are limited to these values to lessen the effects of corrosion and slagging of the boiler tubes.

An estimate of the overall efficiency of the plants may be obtained by using the typical higher heating value of 4500 Btu/lb [4] for MSW along with the conversion factor of 3413 Btu/Kw-hr. For the plants that generate electricity only, overall efficiencies are calculated to range from 17.0 to 18.7 percent, and to average 17.8 percent.

By dividing the net electricity generated by the plant capacity, an energy production factor can be obtained. For the six plants listed in table (2) that produce electricity

Table [3] Design and Construction Costs for Mass-Burning Systems Facilities by Ogden Martin Systems, Inc Source [2]

Plant Location	Plant Capacity TPD	Design and Construction Cost (Dollars in Millions)
Hillsborough, FL	1200	80
Alexandria, VA	975	75.9
Bristol, CT	650	58.8
Marion Co., OR	550	47.7
Stanislaus Co., CA	800	82.2
Tulsa, OK	1125	75.5
Indianapolis, IN	2362	83.8
Babylon, NY	750	83.9

only, this factor ranges from 18.7 to 20.5 Kw/TPD, with an average of 19.5 KW/TPD.

The total residual material from a mass burning facility is expected to be approximately 23 percent of the input stream. This figure is a weight percentage, and since the bulk density of the residual material is much higher than that of the input stream, the volume of material to be removed to a landfill is reduced to approximately 10 percent of the original volume.

Costs of a Facility

The cost of a facility may be broken into two parts. The first is the capital cost, which includes the cost of design and construction, and the costs of financing. The second is the recurring expenditures for operating and maintaining the facility. These costs are offset by revenues generated through the sale of electricity or steam and disposal or tipping fee.

Design and construction costs for eight mass burning facilities being built or built by Ogden Martin Systems, Inc. are listed in table (3). These costs do not include the costs of financing. The costs for these plants range from $48 million to $84 million. Normalized costs (cost divided by capacity) vary from $35,500 to $111,900 per TPD [1]. The lowest normalized cost is for the Indianapolis plant, which will produce only steam and does not produce electricity. Excluding this plant, the normalized costs would range from $66,700 to $111,900 per TPD [1].

Operating and maintenance costs include the following: salaries and benefits, operating labor, maintenance, equipment replacement, taxes and licenses, insurance, professional services, overhead (administrative and support), costs for water, electricity, and fuel consumed by the plant and costs for disposal of residue. The average operating and maintenance costs obtained from a 1986 survey were $22/ton [1]. This figure is in line with a value of about $25/ton (1980 dollars) that is given for a 720 TPD mass burning plant.

Economic Analysis

Case 1: From table 2 & 3

Plant location : Hillsborough, FL

Plant capacity : 1200 TPD

Electricity Generated : 23 MW

Electricity selling price : $0.05/KWH

Disposal tipping fee : $25/ton

Investment : $80 million

O & M cost : $22/ton * 1200 TPD * 365 days/yr

: $9.636 millions/yr

Revenue Generated

Disposal tipping fee : 1200 TPD * $25/ton * 365 days/yr

: $10.95 Millions/yr

Electricity Generated

= 23 * 1000 KW * 8760 Hrs/yr * $0.05/KWhr

= $ 10.074 Millions/Yr

Net Revenue Generated Per Year

= Revenue from disposal tipping fee + Revenue from electricity generated - o&m costs

= $10.95 Millions + $10.075 millions - $9.636 millions

= $11.389 millions.

Simple Payback Period

$$\text{Payback period} = \frac{\$80 \text{ millions}}{\$11.389 \text{ millions}} = 7.024 \text{ years}$$

Case 2:

Plant Location : Tulsa OK

Plant capacity : 1125 TPD

Electricity Generated : 16.5 MW

Steam Generated : 240,000 lb/hr

Electricity Selling price : $0.05 /KWH

Gas cost : $4.5/MCF

Investment : $75.5 millions

Disposal tipping fee : $25/ton

O&M costs : $22/ton * 1125 TPD * 365 days/yr

= $9.034 millions/yr

Revenue Generated

Revenue Generated through Electricity

= 16.5 * 1000 KW * 8760 Hrs/yr * $0.05/KWH

= $7.23 millions/yr

Revenue generated through steam

Heat content in steam at 530 Psig = 1204 Btu/lb

Boiler efficiency of 0.8 is used to calculate the savings.

$$= \frac{1204 \text{ Btu/lb} * 240{,}000 \text{ lb/hr} * 8760 \text{ hrs/yr} * \$4.5/10^6 \text{ BTU}}{0.8}$$

= $14.24 millions/yr

Revenue From Disposal Tipping Fee

= 1125 TPD * 365 days/yr * $25/ton

= $10.27 millions/yr

Net Revenue Generated Per Year

= Revenue from electricity + revenue from steam + revenue from disposal tipping fee - O&M expenses

= $7.23millions/yr + $14.24millions/yr + $10.27 millions/yr - $9.034 millions/yr

= $22.7 millions/yr

Simple Payback Period

$$= \frac{\$75.5 \text{ millions}}{\$22.7 \text{ millions/yr}} = 3.33 \text{ years}$$

The payback is less here mainly because of cogeneration.

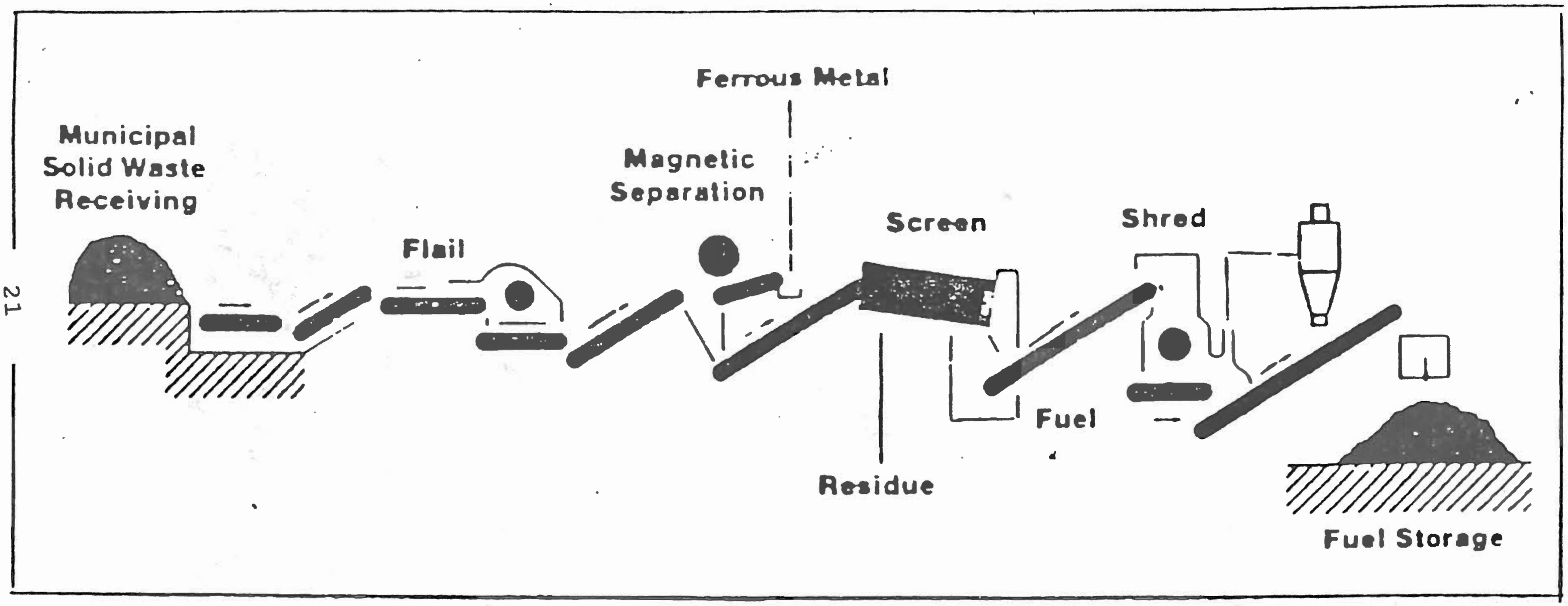
REFUSE-DERIVED FUEL (RDF) TECHNOLOGY

With the RDF system, the waste material is processed before it is introduced to the furnace for burning. A schematic of the fuel preparation is shown in Figure 3.

The waste is delivered to the facility and is unloaded onto the floor of an enclosed receiving area. As with mass burn system, large bulky items such as appliances are separated out first. The remaining waste is loaded onto a conveyor which feeds it to a flail type primary shredder. This shredder breaks open bags containing waste, breaks glass and exposes the material for further processing. The material then goes to a separation system where ferrous metal are removed magnetically and diverted for further processing.

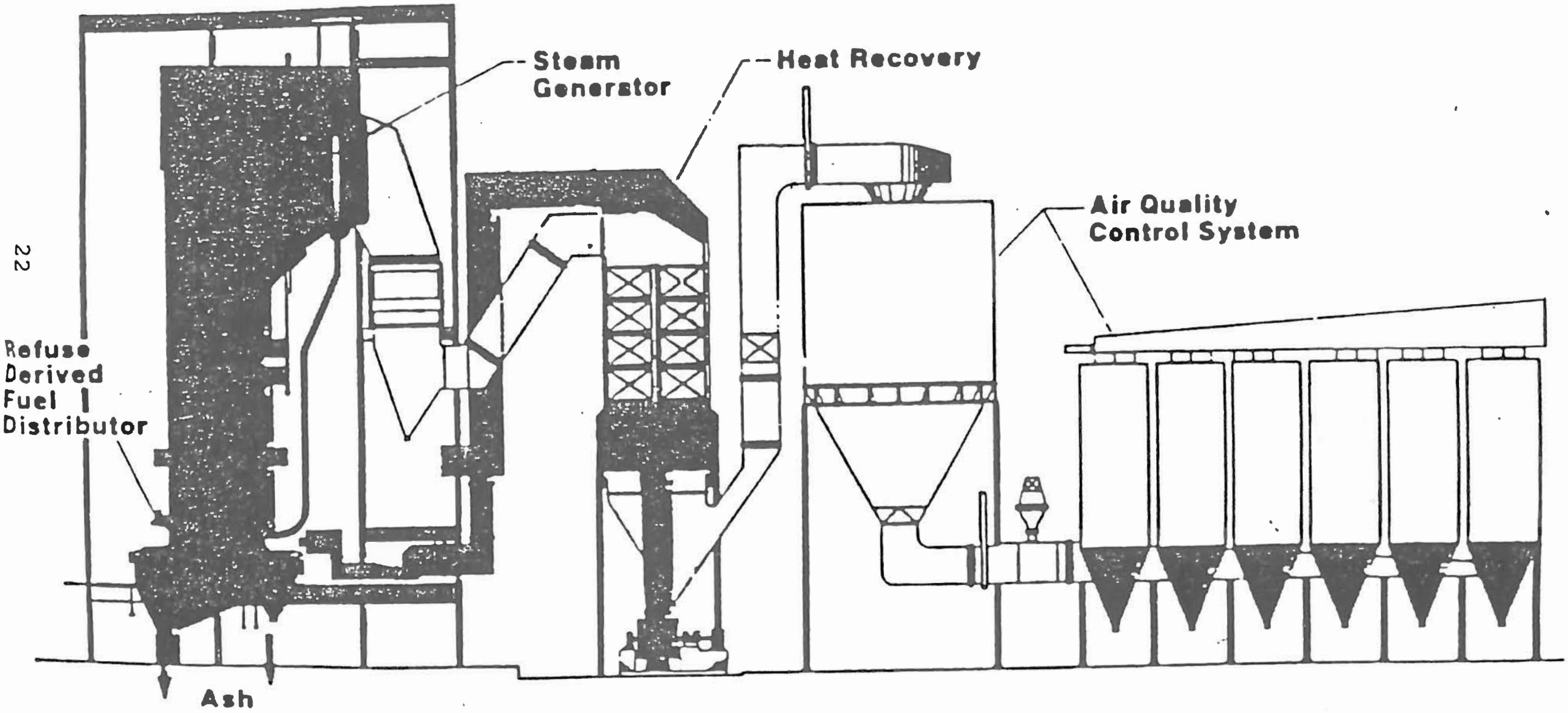
The remaining waste is then fed to a trommel, which is a large rotating drum with holes, where noncombustible material, consisting mostly of paper and cardboard is sent to another shredder where it is reduced to pieces that are a few inches in size. The shredded material is then separated from the air steam in which it is conveyed by a cyclone separator and is then taken to a fuel storage area.

Figure 4. shows a schematic of the rest of an RDF facility. The prepared fuel is pneumatically fed into a waterwall furnace. Part of the fuel burns while is suspended, while the rest falls onto a grate where burning is



Source: Combustion Engineering, Inc. literature.

Fig. 3. Schematic of Fuel Preparation for RDF Facility [2]



Source: Combustion Engineering, Inc. literature.

Fig. 4 Schematic of Refuse-Derived Fuel Facility [2] completed. The grates used in RDF systems are much different from those used in mass burning systems. The grate moves horizontally from the back of the furnace toward the front (where the fuel distributors are located). Combustion air is supplied both above the grate and below it. At the front of the furnace, the grate drops ash to an ash discharger.

Remaining parts of the RDF system are similar to those described for the mass burning system. One additional feature shown in figure 4. is heat recovery system in which the air of combustion extracts heat from the flue gases before the combustion air is injected into the furnace.

Mass-Energy Balances

Energy productions for the four RDF plants to be built by combustion engineering are given in table 4. Each of these plants will product electricity, while the Detroit plant will also produce steam for district heating.

Using the electrical generation rates, plant capacities, a higher heating value of 4500 btu/lb, an estimated internal usage of 12 percent, and a conversion factor of 3413 btu/kwh, the overall efficiencies of the three plants that will produce only electricity are 27.4 percent, 21.1 percent and 16.6 percent [2].

The energy production factor obtained by dividing the estimated net electric generation rates by the plant capacities are 30.1, 23.2 and 18.3 kw/TPD for the three electric-only plants [2].

The typical chemical composition of MSW finds that inerts (residual) comprise about 23 percent of the input stream. This figure should hold for RDF plants as well as for mass-burning plants. The main difference is the location where the residuals are removed. In the RDF plant, the 5 percent of the input stream that consists of ferrous metals is removed first. Then, most of the glass, aluminium, heavy nonferrous materials, and miscellaneous materials (or about 11 percent of the input stream) are removed before the remainder is sent to the furnace.

The typical chemical composition of the refuse-derived that is introduced to the furnace is given in table 1. About 14 percent of the fuel is inert material and is removed from the furnace as ash. Assuming that the ferrous metals are reclaimed and sold, about 18 percent of the input stream is left to be disposed of in a landfill.

Table 4. Capacities and Energy Production of Refuse-Derived Fuel Plants by combustion engineering, Inc. [2].

Plant Location	Plant Capacity TPD	Number of Units	Electricity Generated MW***	Steam Generated lb/hr
Hartfort,CT	2000	3	68.5	692,000*
Detroit, MI	4000	3	65**	550,000**
Honolulu, HI	2160	2	57	500,000*
San Mateo, CA	3850	3	80	--

* Steam used for electricity generation.
** Both steam for district heating and electricity are

generated.
*** Estimated internal electrical requirements are about 12%.

Cost of a Facility

An RDF plant of a given capacity appears to cost somewhat more than a mass-burning plant of the same capacity. An example is given in the literature for a 720 TPD plant [3]. For a mass burning plant, the capital cost in 1980 dollars was estimated to be $75.7 million, while the cost for a similar RDF plant was estimated to be 83.1 million, or about 10 percent more. Also operating the facility were estimated at $30/ton for a RDF plant compared to about $25/ton for a mass-burning plant. Differences are at least partly due to the extra cost of building and operating the facility to prepare the refuse-derived fuel.

The estimated costs for the Detroit and Honolulu plants being built by Combustion Engineering have been given as $230 million and $145 million [4]. By dividing these costs by the plant capacities, normalized costs of $57,000 and $67,130 per TPD are obtained.

RDF Vs MASS-BURNING

Currently, garbage burning facilities in operation in the United States are about equally divided between RDF and mass-burning systems. In Europe, most of systems utilize mass-burning because they evolved from straight incineration plants.

One advantage of RDF systems is that the fuel burns at higher sustained temperatures, thus burning the undesirable toxic effluents during the combustion cycle. M.L. Smith of Combustion Engineering, Inc. (C-E), in his paper "Selecting the RDF technology," discusses the two principal technologies and notes that future refuse burning plants will utilize boilers specifically designed for the burning of refuse fuels. Past practices, according to Smith have sometimes used conventional boilers modified for burning garbage.

Mass-burning requires little or no preprocessing except for removal of bulky objects already discussed. Any mixing of the waste in a mass burning system is limited to mixing in the storage pit during loading of the garbage into the combustion chamber. Even though RDF requires preprocessing, it does tend to simplify the fuel burning and emission control functions. Systems burning RDF requires preprocessing, it does tend to simplify the fuel burning and emission control functions. Systems burning RDF produces 5 to 10 percent higher ash when both systems are burning similar wastes. Similarly, the availability of RDF systems in general is greater than plants using the mass-burning technology.

RDF systems tend to be more cost effective for municipal solid waste systems of 1500 TPD and up because of economy size. In many instances one boiler can handle all of the RDF processes. Mass-burning systems are more cost effective for the smaller sized plants where a single boiler is generally sized to process from 300 to 700 TPD.

APPLICATION IN INDUSTRIES

Disposal of solid waste is a phenomenal problem in industries due to the escalating disposal cost and the liability associated in disposing solid waste at landfills. To dispose solid waste in the city of Tulsa it costs $4.25/sq. yard [OSDH]. From table 5 one ton of solid waste occupies approximately

1,690,000Sq. yards/193,000tons = 8.75 sq. yard. So to dispose one ton of solid waste in a landfill at Tulsa it will cost $37/ton. For a large plant generating more than 10 TPD of solid waste it will be economical to build a waste to energy plant. A mass burning facility is ideal for a plant with 10 TPD capacity [5]. This chapter discusses the cost of the facility and the payback period for building a waste to energy plant with a 10 TPD capacity.

Table 5. Overall Plant performance of GM Corp. Truck and Bus Group. Source [5].

Total tons of refuse processed	193,000
Cubic yards, landfill space conserved	1,690,000

Case Study:

Waste generated : 10 TPD

Disposal cost : $37/ton

Plant generates both electricity and steam.

Cost for building a waste to energy (mass burning) plant.

From chapter 4

the normalized cost for building a mass burning waste to energy plant ranges between $66,700 to $111,900 per TPD. The average cost is $89,300 per TPD.

Cost for building the facility

= $89300/TPD * 10 TPD = 0.893 millions

Electricity Savings

From chapter 4 average energy production factor = 19.5 KW/TPD

Electricity savings

= 19.5 KW/TPD * 10 TPD * 8760 hrs/yr = 1,708,200 KWH/yr

= 1,708,200 KWH/yr * $0.05 /KWH = $85,410/yr

Steam savings

From table 2 for the plant at Tulsa which burns 1125 TPD steam generated = 240,000 lb/hr.

lbs of steam that can be generated in this plant

= 10 TPD * 213 lb/hr-TPD = 2130 lb/hr at 530 psig

Steam savings

$$= \frac{1204 \text{ Btu/lb} * 2{,}130 \text{ lb/hr} * 8760 \text{ Hrs/yr} * \$4.5}{0.8 \;\; * 10^{6} \text{ btu}}$$

= $126,367/yr

where the gas cost is $4.5/MCF and the boiler efficiency is 0.8 (if the industry uses a separate boiler to generate steam for production purposes.

Landfill savings

= $37/ton * 10 TPD * 365 Days/yr = $135,050 /yr

O&M expenses

= $22/ton * 10 TPD * 365 days/yr = $80,300.

Net savings

= Electricity savings + steam savings + landfill savings

- O&M expenses

= $85,410/yr + $126,367/yr + $135,050/yr - 80,300/yr

= $266,527 /yr.

Payback Period

= $0.893 millions/$266,527/yr

= 3.35 years.

CONCLUSION

Municipal solid waste generated within the United States has increased 57 percent over what it was 25 years ago with 325 million tons expected per year by the year 2000 and the increase continuing thereafter. Stiffer EPA regulations are causing shutdown of many landfills, older landfills are reaching their capacities and there is a shortage of land for new landfills. Consequently, many municipalities are considering waste-to-energy incinerators for burning their garbage.

As costs for landfill disposal increases, disposal of waste in garbage-burning plants that generate electricity becomes more attractive. The consensus among waste disposal experts is that sanitary landfill costs will escalate at a faster rate than that of the general rate of inflation. Some of the main reasons for the predication are higher land cost, increasing costs for transporting garbage outside the urban areas and the higher permit and operating costs resulting from more stringent regulation.

Waste-to-energy plants, on the other hand, can play a part in steadying or decreasing costs since capital costs are fixed and waste disposal costs tend to be more stable. In addition, such plants generate revenue from tipping fees, sale of electricity and steam and in some cases, sale of recycled metal and glass. A refuse-to-energy facility can promote other local developments - fro example, by providing less expensive power for small businesses and industrial parks - as well as addressing the community's health, economical and waste disposal problem.

More than 90 percent of this country's waste is still being dumped in landfills. The waste-to-energy plants currently in operation are only one tip of the iceberg.

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