European Waste-to-Energy Systems

An Overview

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EUROPEAN WASTE-TO-ENERGY SYSTEMS

The recovery of energy through the combustion of municipal solid waste is a well established technique for conserving energy. Combustion units* can produce electricity; hot water for domestic use; and steam for district heating, industrial processes, or the drying of sewage sludge.

There are fewer than 20 such waste-to-energy systems in the United States. In Western Europe, however, 243 combustion units are currently recovering energy from municipal solid waste. The oldest of these facilities went into service before World War II. Exhibits 1 and 2 present some key facts about Western European countries and their waste-to-energy units.

If the use of this technique is to spread in this country (and the needs to conserve energy and protect the environment suggest that it should) the lessons of Western European systems can be valuable to those planning for similar systems in the U.S. The Buildings and Community Systems Branch of ERDA's Office of Conservation therefore engaged Resource Planning Associates, Inc. (RPA) to make case studies of representative waste-to-energy systems in Western Europe. These case studies examine the technical and economic aspects of combustion units in detail. Individual copies are available from:

ERDA Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

This overview discusses some common features of the Western European systems. We first consider the combustion techniques available and the end uses to which the recovered energy is put. Next, we discuss briefly the economics of the systems. Finally, we present a census of the systems currently operating or under construction in Western Europe.

* For our purposes, a combustion unit is a facility built at one time in a single location. One building (or plant) may thus contain more than one unit and one unit may contain more than one furnace. A single city may have several combustion plants, each housing several units. These units may be radically different in design, and therefore we consider them separately.

Area, Population, and Population Density of Western European Countries

	Area (thousand km ²)	Population (thousands of inhabitants)	Density (inhabitants per km ²)
Austria	84	7,528	90
Belgium	30	9,804	327
Denmark	43	5,045	117
Finland	337	4,682	14
France	547	52,507	96
Greece	132	8,962	68
Ireland	70	3,086	44
Italy	301	55,361	184
Luxembourg	3	342	132
Netherlands	41	13,541	330
Norway	324	3,987	12
Portugal	92	8,735	95
Spain	505	35,225	70
Sweden	450	8,161	18
Switzerland	41	6,481	158
United Kingdom	244	55,933	229
West Germany	249	62,041	249

SOURCE: INSEE (French National Institute of Economic Statistics).

Waste-to-Energy Systems in Western Europe

Country	Number of Units*	Number of Plants**
Austria	2	2
Belgium	3	3
Denmark	45	31
Finland	2	2
France	29	20
Italy	16	14
Luxembourg	1	1
Netherlands	7	6
Norway	13	8
Spain	3	2
Sweden	22	16
Switzerland	33	29
United Kingdom	9	9
West Germany	58	38
Total	243	181

* A unit is a facility built at one time in a single location.

**A plant is the building in which one or more waste-to-energy units is installed.

SYSTEM CONFIGURATIONS

Waste-to-energy systems generally consist of a furnace, heat recovery equipment (usually a boiler), and some system for making use of the energy recovered (e.g., a steam pipe network or a turbo-generator). Most systems have some form of air pollution control. A few have shredders to process the municipal solid waste before it enters the furnaces.*

FURNACES

The furnace grate which agitates and transports the waste during combustion is the essential part of a combustion unit. These grates must be able to accept the wide variety of objects and substances which make up municipal solid waste.

Five manufacturers account for eighty-five percent of the grates installed in Western Europe. The breakdown is as follows:

Martin (West Germany)	14%
Vereinigte Kessel Werke (West Germany)	16%
Von Roll (Switzerland)	24%
Bruun & Sørensen (Denmark)	18%
Volund (Denmark)	13%
Other	15%

The market share of each manufacturer has remained relatively constant, except for Volund which has installed fewer systems in the last five years. The share of Bruun & Sørensen would be smaller if capacity were being measured since their system is used mostly for small units.

Among the other West European manufacturers are:

● Bartholomeus (Italy).	● Heenan (U.K.)
● Carbonisation Entreprise et
Céramique (France)	● Stein (France)
● Lurgi (West Germany)	● Lokomo (Finland)
● Nichols (U.K.)	● Esslingen (West Germany)
● Alberti Fonsard (Italy)	● Destructor (Sweden)
● Sulzer (Switzerland)	● Kraus-Maffei (West Germany)
● Kohlen Scherdungs Gesellschaft
(West Germany)	● Venien (France)

No single grate system seems best for all types of combustion units. For example, the VKW Design is used mainly in large units, while the Bruun & Sørensen design is used mainly in small units. There have been small modifications but no basic changes in grate design. The tendency seems to be for each firm to improve the flexibility and responsiveness of grates so that they can adapt to changes in waste characteristics. Some of the principal grate designs are described in the following pages.

* In France, for example, only 4 of the 29 combustion units use shredders.

Alberti System

The single-section grate is composed of fixed and moving elements arranged in steps. Combustion takes place on the upper bars which are fixed, while the lower moving bars insure the agitation of the waste.

Alberti System

Bruun and Sørensen System (Denmark)

The grate has two or three sections with six horizontal axles in each. Grate prongs are screwed to the axles. Transport and agitation are assured by means of a hydraulic system causing axles n° 1, 3, and 5 in each section to turn clockwise while n° 2, 4 and 6 turn counter clockwise.

Bruun and Sørensen System (Denmark)

Carbonisation Entreprise et Céramique (CEC) System (France)

The grate has one section, but there may be two or more grates arranged in parallel. The grate is composed of successive sliding, rocking, and fixed elements. The sliding and rocking elements are synchronized so that the sliding elements move over the rocking elements when these are retracted. By this movement, the sliding elements insure the transport of the waste and the rocking elements insure the agitation.

CEC System

Esslingen System (West Germany)

The single-section grate is composed of semi-circular rocking elements. The movement of these elements insures transport and agitation of the waste. Each element is made of bars placed side by side through which combustion air circulates.

Esslingen System

Heenan Nichol System (U.K.)

The grate is composed of three or more sections arranged in steps. The first section distributes and dries the waste, the following sections are used for combustion. Each section is composed of rocking elements which insure the agitation of the waste. Each pair of elements moves reciprocally so that at any moment, half of the elements are moving. The odd numbered elements are linked and move in unison, followed by the even numbered elements, which are also linked.

Heenan Nichol System

Martin System (West Germany)

The grate is composed of a single section, but there may be more than one grate in parallel alignment. Each grate is composed of alternate fixed and moving bars, the moving bars sliding up over the fixed bars. The reverse action of the grate, insures a continuous agitation of the waste as it falls under gravitational force. The bars contain passages so that air circulates within the bars and enters the combustion zone through slits between the bars.

Martin System

Vereinigte Kessel Werke (VKW) System (West Germany)

The grate consists of rigid rollers, arranged in series with horizontal axes. The roller bodies are faced with cast iron grate bars. The speed of the individual rollers is variable. Combustion air enters through the grate bars of the rollers and can be regulated for each roller.

VKW System

Volund System (Denmark)

This system is similar to the Von Roll system. The grate is in two sections, the first for drying the waste, the second for combustion. Instead of a third section, there is a rotary kiln to insure a complete burnout of the waste.

Volund System

Von Roll System (Switzerland)

The grate is composed of three sections, the first for drying and igniting the waste, the second for combustion, and the third for burnout. Each section is composed of parallel bars, alternately fixed and moving, in a single row. The moving bars have a horizontal action, insuring the agitation of the waste. Combustion air is introduced through holes in the front and sides of the bars.

Von Roll System

HEAT RECOVERY EQUIPMENT

In nearly all the combustion units, energy is recovered through the medium of steam. In practice, this can mean either the classic fire-tube boilers or the newer waterwall boilers. Since the furnace and boiler form a closed system, it is possible to calculate a thermal energy balance and determine the percentage of the heat content of the waste introduced into the furnace that is actually recovered as usable energy. Sample thermal energy balance sheets are shown in Exhibits 3 and 4.

A few combustion units (e.g., Tergnier in France) do without a boiler and use the hot combustion gases directly for the drying of sewage sludge.

END USE

The main uses of the recovered energy are to generate electricity; to heat water for domestic use; and to produce steam for district heating, an industrial process, or the drying of sewage sludge. A number of other uses (e.g., heating swimming pools and greenhouses) have been tried or suggested. The following diagram shows one typical way of using recovered energy.

Energy Balance for the Munich South IV Incinerator in 1975

Inputs	Metric System	English Equivalent
Coal	None	
Natural gas		
Amount (volume)	142,538.6 thousand m ³	5033 mmcf
Heat value	8914 kcal/m ³	1002 Btu/cu ft
Total heat	1,270,631 Gcal	5.04 x 10 ¹² Btu
% total heat in	84.8	
Oil (heavy)		
Amount consumed	85.3 metric tons	93.9 short tons
Heat value	9894 kcal/kg	17,810 Btu/lb
Total heat	844 Gcal	3.35 x 10 ⁹ Btu
% total heat in	0.1	
Waste		
Amount consumed	122,648 metric tons	135,105 short tons
Heat value	1844 kcal/kg	3319 Btu/lb
Total heat	266,138 Gcal	1.06 x 10 ¹² Btu
% total heat in	15.1	
Total heat input	1,497,613 Gcal	5.94 x 10¹² Btu
Outputs	Metric System	English Equivalent
Electrical energy out		
Total produced	633,780 MWh	
Total delivered	605,331 MWh	
Self-consumed energy	28,449 MWh	
Self-consumed heat	12,117 Gcal	4.81 x 10 ¹⁰ Btu
Heat in electricity and self usage	558,562 Gcal	2.22 x 10 ¹² Btu
Total heat as % of total heat in	37.3	
District heat energy out (steam)	139,940 Gcal	5.55 x 10 ¹¹ Btu
% total heat in	9.4	
Boiler losses (% heat in)	9.4	
Startup/shutdown losses (% heat in)	0.4	
Condensor and other losses (% heat in)	43.5	
Total losses (% heat in)	53.3	
Total losses	798,202 Gcal	3.17 x 10 ¹² Btu
Specific heat required for electricity production		
Fossil fuel only	2282 kcal/kWh	9056 Btu/kWh
Waste only	2969 kcal/kWh	11,782 Btu/kWh

Toulouse-Le Mirail Thermal Complex
Thermal Balance Sheet, 1974-1975

Period of Operation	Quantity of Waste Incinerated (metric tons*)	Heavy Oil Consumed (metric tons)	Heat Derived from Fuel (kth**)	Heat Recovered from Waste (kth)		Total Heat Produced (kth)	Heat Sold (kth)			Network Yield	Energy Loss in the Network (kth)
				For Home Heating	For Hot Water		Home Heating	Hot Water	Total		
September 1974	7,756	36.36	288	2,261	1,084	3,633	95	1,358	1,453	0.399	2,180
October 1974	7,721	587.80	4,651	5,902	411	10,964	6,674	1,186	7,860	0.717	3,104
November 1974	7,052	1,261.55	9,983	4,188	0	14,171	11,208	1,773	12,981	0.916	1,190
December 1974	7,724	1,539.99	12,186	3,262	92	15,540	12,553	1,861	14,414	0.927	1,126
January 1975	7,791	1,581.82	12,517	4,885	532	17,934	14,203	1,997	16,200	0.903	1,734
February 1975	6,993	1,412.46	11,177	4,679	655	16,511	12,670	1,944	14,614	0.885	1,897
March 1975	7,491	1,275.43	10,092	3,994	860	14,946	11,373	1,770	13,143	0.879	1,803
April 1975	7,909	1,175.67	9,303	4,382	951	14,636	10,700	2,116	12,816	0.875	1,820
May 1975	7,864	338.01	2,675	3,690	567	6,932	3,413	1,675	5,088	0.734	1,844
June 1975	7,602	15.50	123	2,715	868	3,706	96	1,813	1,909	0.515	1,797
July 1975	6,806	9.50	75	2,488	593	3,156	77	1,301	1,378	0.436	1,778
August 1975	6,116	6.33	50	1,379	402	1,831	63	888	951	0.519	860
Total	88,825	9,240.42	73,120	43,825	7,015	123,960	83,125	19,672	102,807	0.829	21,133

SOURCE: Annual Report to the City of Toulouse by BETURE, 1974-75 (*Rapport Technique et Economique*).

* To convert metric tons to short tons, multiply by 1.1.

** One kth (kilotherm) equals 3.97×10^6 Btu.

Electricity can be produced with a condensing turbo-generator (e.g., the Cheneviers unit at Geneva, Switzerland) which uses all of the steam available. It can also be co-generated, along with low pressure steam, using a back-pressure turbo-generator (e.g., as in Munich, West Germany). However, in Europe, the production of electricity is sometimes a state monopoly and, in any case, is subject to many regulations. Institutional barriers are therefore a serious concern in the production of electricity from solid waste. For example, the high cost of generating electricity from waste (as the case studies of Munich, Germany and Geneva, Switzerland indicate) may be due as much to institutional as technical reasons.

The use of steam for domestic water heating or district heating generally works best in a new town built in conjunction with the waste-to-energy system. The steam pipe (or hot water pipe) network can then be laid down during initial construction and the community planners can incorporate the heating system into their design.

When sewage sludge is dried, either directly by the combustion gasses or indirectly in steam jacketed driers (see the case study of Brive, France), the dried sludge can be incinerated along with the solid waste. Such a system requires that the combustion unit be built in conjunction with a waste-water treatment facility.

Whatever the end use of the recovered energy, there may well be a conflict between its production and the other purpose of the plant -- reduction of the volume of municipal solid waste. If the operators see this latter as their overriding purpose, they may choose operating trade offs which maximize availability rather than the efficient production of energy.

Matching of the unit with the load demand of the energy user may often be difficult. Peak demands for electricity, for example, may not coincide with the arrival of the greatest quantities of waste (see case study of Munich). The capacity of the waste bunker to hold a supply of several days' waste may be crucial.

POLLUTION CONTROL

Since most Western European waste-to-energy systems are located in urban areas, pollution control is important and becoming more so. Regulations vary from country to country, which means that different pollution control equipment is required.

West Germany has the strictest laws in Western Europe. Stack gasses may have no more than 100 mg of particulates per cubic meter.* There are limits on emissions of carbon monoxide, chlorine compounds, and fluorine compounds. Since 1974, when these regulations went into effect, new combustion units in West Germany have required electrostatic precipitators followed by at least partial scrubbing.

* In the U.S., the national standard for incinerator emissions permits a maximum of 180 mg/m³ of particulates. Some states and cities have stricter limits.

In other countries, only particulate emissions are regulated, and scrubbers are not needed. In France, for example, the limits for particulate emissions are 600 mg/m³ for furnaces with a capacity between 1 and 4 metric tons/hour; 250 mg/m³ for furnaces with a capacity between 4 and 7 metric tons/hour and 150 mg/m³ for furnaces with a capacity above 7 metric tons/hour. Finally, in some countries, such as Denmark, the regulations are lax enough that most incinerators currently need only multicyclones. It is clear, however, that the trend in all Western European countries is toward stricter regulations of particulate emissions. This means that electrostatic precipitators will be required in nearly all cases. These devices will mean higher capital costs, but no basic technological changes in the waste-to-energy systems.

The use of scrubbers is not widespread. Although the equipment exists, it is very expensive and needs frequent maintenance. It is not certain that, at the moment, any plant operates with continuous scrubbing. For this reason, most countries are hesitant to impose strict legislation until improved scrubbers appear.

TECHNICAL PROBLEMS

The techniques commonly used to recover energy from municipal solid waste in Western Europe are mature and stable. Most combustion units have good operating records. Most improvements have been in response to changes in the characteristics of the waste (e.g., more plastics) and stricter pollution control requirements.

Boiler corrosion has been the single most pervasive problem. To understand the effect of this problem on design, we will look at the experience of the Von Roll company of Switzerland over the past 25 years.

The first basic Von Roll combustion units were designed with a refractory firebox and a second chamber housing the boiler. This was a good, reliable design, and had a very good operating record. The first unit of this generation came on stream in 1954 at Berne, Switzerland. Several more such plants were built in Switzerland and elsewhere in Europe, and Von Roll's reputation was established as a successful waste combustion design company.

However, these plants were large and costly. Since they generally produced only saturated steam, much of the heat was wasted. By the late 1950s and early 1960s, there were complaints that the design was not good enough.

Thus, a second generation was designed. In the new unit, the boiler was moved forward right into the firebox. These integrated units incorporated waterwall tubes brought down near the combustion grates and superheater tubes to generate superheated steam. The new units were smaller and cheaper, and promised to heat much more efficiently.

The first unit of this generation was ordered in 1962, for Winterthur, Switzerland. Operation was to begin in 1965. The second unit, also ordered in 1962, was for Frankfurt, West Germany. The third was for Geneva, Switzerland. These two units were to begin operating in 1966. Altogether, a total of twenty-seven such units were ordered by the end of 1968 when the first real evidence of major problems appeared.

Corrosion of various kinds began to appear rather early in the operating life of the first of these new units. By the end of 1968, it was obvious that some design changes were needed. The first and most important corrosion noted was on the lower portion of the frontal and lateral waterwall tubes. Von Roll eventually decided that this was due to several factors. First, combustion was not completed on the burnign grate but continued in small particles and in volatile matter to a considerable height. Thus, flames were much higher than anticipated. Second, since this combustion situation was not continuous, there was a constant shifting from an oxidizing to a reducing atmosphere in the furnace. This caused severe corrosion on the metal tube walls.

Several remedies were used. The lower portions of the waterwall tubes were coated with a ceramic and refractory protective material. A secondary air source was also added above the grate to generate turbulence in the combustion air and thus to provide for complete burnout lower in the firebox. The net effects were decreased thermal efficiency and increased air flow through the system. These, in turn, required the installation of a larger induced draft fan. The electrostatic precipitators also proved inadequate to handle the greater gas flow.

Some of the corrosion was due to high temperature at the surface of the superheater tubes. The only solution for this problem was to run the furnaces at a somewhat slower rate, and this led to an effective reduction of capacity.

Von Roll's previously excellent reputation suffered as a large number of combustion units began to experience the same problems. Essentially, too many furnaces with the same defects had been built too soon.

Von Roll's answer was threefold. First, for the integrated furnaces, all of the superheater and economizer bundles were moved to the third passage and the refractory protection and secondary air systems in the firebox were redesigned. The waterwalls were kept, but the major corrosion problems were reduced.

Von Roll began to update the older refractory furnaces with tail-end boilers. This redesign resulted in a new type of unit, the first of which was ordered by Fürth and the second, shortly thereafter, by Landshut in West Germany. These units have refractory fireboxes and tail-end boilers, but produce superheated steam. A new system for cleaning the tubes by physically knocking the tube bundles to shake off soot was incorporated. The extraordinary success of this design is shown by the fact that the Landshut I furnace has operated for 28,374 hours (as of August 1976) without ever having to be shut down for cleaning the tubes.

Third, another new generation of furnaces was designed in the early 1970s. These units have waterwalls, but the rest of the tube bundles are arranged so that they can also be cleaned by knocking. The first of these units began operations in Quebec, Canada in 1974. Units of this design are now operating in Saugus, Mass. (near Boston) and Dijon, France. Dijon is the only plant of this design generating electricity; the others recover heat through steam.

According to Von Roll, the big advantage of the refractory furnaces is their reliability. The plant at Lausanne, Switzerland which is now nearly eighteen years old, is still available nearly 90 percent of the time. The best that the early integrated boiler designs have been able to achieve is about 75 percent, and the best that Von Roll will guarantee in a contract, even for their newest integrated boiler design, is 80 percent.

As the example of Von Roll shows, there are two opposing tendencies in the design of combustion units. One is to put the boiler right in the firebox, with waterwall tubes brought down near the burning grate. The other is to locate the boiler away from the refractory firebox in a second chamber. The first design increases the efficiency of energy conversion and reduces capital costs. It seemed in recent years to be the better option. However, because of corrosion problems, the second option, which was never rejected by such manufacturers as Volund or Bruun & Sørensen, may have a second life.

ECONOMICS

The economics of a waste-to-energy system can be considered under two headings. The first is the choice of combustion rather than some other treatment for solid wastes. The second is the addition of energy recovery equipment if combustion has been chosen. The considerations are quite different.

The chief alternative to combustion for municipal solid waste is land-filling. Western Europe has historically had high population densities and, as a result, a shortage of land for disposal of solid waste. Thus, the costs of the chief alternative to combustion have been higher there than in the United States.

As the U.S. population density increases, this difference will narrow. If landfill sites can only be found at greater distances from the generators of waste, growing transportation costs will further narrow this difference. The trend to require accounting for environmental costs may well close the gap entirely. As a result, more and more American communities will choose combustion for the disposal of their solid waste.

In this case, the question will arise, is it worthwhile to recover the energy produced in the combustion. The answer depends upon the availability of an appropriate end use for that energy.

Direct use of heat energy avoids the inevitable losses in the generation of electricity. The very difficulty we have had in obtaining good information on the cost of waste-generated electricity in our case studies of Geneva, Switzerland and Munich, West Germany suggests that burning waste may be a very expensive way to produce electricity.

If the heat can be used for domestic hot water, district heating, or an industrial process near to the combustion plant, the economics may be more favorable. The recovery of energy from waste can be most cost-effective if the end use is well integrated with the combustion unit (and even the waste collection system). Increasing fuel costs can only reinforce this trend. For example, the solid waste of a Western European town of 150,000 inhabitants can provide district heating for 10,000 housing units. If those housing units and the combustion unit were part of a well integrated plan, the economics might be quite favorable (see the case study of Toulouse-Le Mirail).

The recovery of materials from the residues of combustion may slightly enhance the cost-effectiveness of waste to energy systems. Many plants recover ferrous metals for sale as scrap.

In France, the *Bureau des Recherches Géologiques et Minières (B.R.G.M.)*, the equivalent of the U.S. Bureau of Mines, has built a pilot plant to recover glass, ferrous metals, aluminum, and other non-ferrous metals from the residues of incineration. This plant has operated satisfactorily since 1974 and a large scale system is contemplated for Paris (Ivry). However, the economics are not very favorable under present market conditions and it is feared that the revenues will not be sufficient to amortize the investment.

Exhibit 5 summarizes the economics of several units examined in RPA's case studies.

Cost Summary of Sample Waste-to-Energy Systems

(1975 unless otherwise noted)

City and Population	Number and Size of Units	Tonnage of Waste Incinerated Annually	End Use of Recovered Energy	Capital Cost	Direct Operating Cost	Total Cost
Toulouse, France 400,000	3 x 8.15 metric tons/hr (3 x 9 short tons/hr)	100,000 metric tons (110,000 short tons)	District heating, domestic hot water, electricity for use in plant	FFr 34/metric ton* (\$6.80/short ton)	FFr 7/metric ton* (\$1.40 short ton)	FFr 41/metric ton* (\$8.20/short ton)
Brive, France 160,000—area	2 x 3.5 metric tons/hr (2 x 3.9 short tons/hr)	30,000 metric tons (33,000 short tons)	Drying of sewage sludge	FFr 27.50/metric ton (\$5.83/short ton)	FFr 32/metric ton (\$6.77/short ton)	FFr 59.50/metric ton (\$12.60/short ton)
Geneva, Switzerland 340,000—canton	2 x 8.3 metric tons/hr (2 x 9.15 short tons/hr)	115,000 metric tons (126,000 short tons)	Electricity for sale	SF 22.61/metric ton (\$6.87/short ton)	SF 41.64/metric ton (\$12.70/short ton)	SF 64.25/metric ton (\$19.57/short ton)
Kørsør, Denmark 20,000	1 x 2 metric tons/hr (1 x 2.2 short tons/hr)	6,500 metric tons (7,150 short tons)	District heating	Kr 82/metric ton (\$12.30/short ton)	Kr 38/metric ton (\$5.70/short ton)	Kr 120/metric ton (\$18/short ton)
Munich, West Germany 1,315,000	2 x 25 metric tons/hr 3 x 40 metric tons/hr (2 x 27.5 short tons/hr 3 x 44 short tons/hr)	450,000 metric tons (496,000 short tons)	Electricity for sale, district heating	DM 35/metric ton (\$11.75/short ton)	DM 12/metric ton** (\$4.25/short ton)	DM 47/metric ton** (\$16/short ton)

* Only two furnaces were in operation in 1975.

**Average of direct operating costs at North and South plants.

CENSUS OF WESTERN EUROPEAN COMBUSTION UNITS

The number of waste-to-energy systems now in service in Western Europe is an indicator of the soundness of this technology. We have tallied 243 units (located in 181 plants or buildings) in service, under construction, or planned for the near future.

Luxembourg, Denmark, Switzerland, the Netherlands, Sweden, and West Germany make the most use of combustion with energy recovery. These countries have more than 20 tons of hourly capacity per million inhabitants, or enough to recover energy from the waste produced by 40 percent of the population (see Exhibit 6).

Several factors seem to have encouraged the use of this technology in these countries. They all have concentrated population, their cities are reasonably wealthy, and they have strong manufacturing industries (in particular, the major firms licensing grate design are headquartered in these countries).

Furthermore, they benefit from favorable conditions for the sale of energy. They all have cold weather, which makes district heating attractive, and local electricity producers (unlike the state monopolies of France or Italy), which makes the sale of electricity easier. Costs of alternative means of disposal, such as landfills, are high. Belgium, Spain, Austria, and Finland have very few units, and Greece and Portugal, none.

The combustion units are usually located in large cities which often have more than one (e.g., Berlin, Munich, Paris, Stockholm, Oslo). There are two exceptions to this pattern, Denmark and Switzerland. In Denmark, several small towns have incineration units. In Switzerland incinerators are centrally located and serve rural areas. The unit at Monthey, Switzerland, for example, generates electricity with energy recovered from the solid waste of 57 villages.

RATED CAPACITY

We have divided combustion units into five categories according to capacity:

- less than 5 metric tons/hour
- between 5 and 10 metric tons/hour
- between 10 and 15 metric tons/hour
- between 15 and 25 metric tons/hour
- larger than 25 metric tons/hour

If the average generation of waste in Western Europe is 1 kilogram (2.2 lb) per person, per day, a combustion unit with a capacity of 5 metric tons (5.5 short tons) per hour can serve 100,000 persons in a 20-hour operating day. We would therefore expect to find combustion units with capacities under 5 metric tons per hour in cities under 100,000 inhabitants and those with capacities over 25 metric tons per hour in cities over 500,000 inhabitants. Although only 15 percent of the units in Western Europe have a capacity over 25 metric tons per hour, they account for 47 percent of total capacity.

Units under 15 metric tons per hour account for 26 percent of the total European capacity and 64 percent of the units. These figures show that, although

Total Capacity and Per Capita Capacity

Country	Population (in millions)	Number of Units Installed or Under Construction	Percentage of Units in Europe	Total Installed Capacity (metric tons/hour)*	Total Capacity Installed or Under Construction (metric tons/hour)	Percentage of Total Capacity Installed in Europe	Relative Capacity per Capita (metric tons/hour/no. of inhabitants)
Austria	7.5	2	1	55	55	2	7.3
Belgium	9.8	3	1	19	46	1	1.9
Denmark	5.0	45	18	243	277	7	48.2
Finland	4.7	2	1	26	26	1	5.6
France	52.5	29	12	452	494	14	8.6
Greece	9.0	0	0	0	0	0	0
Ireland	3.1	0	0	0	0	0	0
Italy	55.3	16	7	150	250	5	2.7
Luxembourg	0.3	1	1	20	20	1	58.8
Netherlands	13.5	7	3	315	315	10	23.3
Norway	4.0	13	5	12	12	—	3.0
Portugal	8.7	0	0	0	0	0	0
Spain	35.2	3	1	38	46	1	1.1
Sweden	8.2	22	9	183	218	6	22.4
Switzerland	6.5	33	14	255	320	8	39.3
United Kingdom	55.9	9	4	182	192	6	3.2
West Germany	62.0	58	24	1300	1360	40	20.9
Total		243	100	3250	3631	100	

*To convert metric tons to short tons, multiply by 1.1.

Number of Individual Furnaces, by Capacity and Country

Country	Furnace Size (metric tons/hour)*						Total
	0-5	5-10	10-15	15-20	20-25	Over 25	
Austria		3		2			5
Belgium	1	5					6
Denmark	35	10	7	1			53
Finland		4					4
France	13	26	10	4		2	55
Italy	18	10	9				37
Luxembourg			2				2
Netherlands		5	8	4	6		23
Norway	12	1					13
Spain		1	3				4
Sweden	20	8	3	4			35
Switzerland	31	9	10	3			53
United Kingdom	2	5	12				19
West Germany	9	20	37	20	13	5	104
Total	141	107	101	38	19	7	413**

* To convert metric tons to short tons, multiply by 1.1.

**Many units have more than one furnace.

Exhibit 8

Total Capacity by Unit Size and by Country

Country	Plant Size (metric tons/hour)*				
	0-5	5-10	10-15	15-25	Over 25
Austria				25	30
Belgium	2			17	27
Denmark	105	46	38	16	72
Finland		10		16	
France	29	76	27	119	233
Italy	10	31	36	94	79
Luxembourg				20	
Netherlands		8	12	21	274
Norway	5	7			
Spain		8	13	25	
Sweden	60	26	12	17	103
Switzerland	45	78	51	146	
United Kingdom	3	13	10	60	106
West Germany	35	78	47	411	789
Total	294	381	246	987	1713

*To convert metric tons to short tons, multiply by 1.1.

Capacity Entering Service Since 1961

(Metric tons/hour)*

	Before 1961	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Projected
Austria				25								30						
Belgium	17													2				27
Denmark	24			3		5	13	17	4	5	90	15	18	13	4	28	4	34
Finland			16					10										
France				38	27	68			10	100	44	9	14	18	92	17	5	42
Ireland																		
Italy	20	12						4		11	8		25	68		3		100
Luxembourg																	20	
Netherlands					52				38	64		120	21		12	8		
Norway						**	8		1		1	**	**	**				
Spain																38		8
Sweden	10		4	5		3	13	12	5		18	39	38	25	11			35
Switzerland	33				4	8	16		4	45	12	29	6	17		33	50	65
United Kingdom										8		70	5	27		52	20	10
West Germany	16	100		27	55	54	105	155	48	75	137	111	40	192	19	100	65	60
Total	120	112	20	98	138	138	155	198	110	308	310	423	167	362	138	279	164	381

* To convert metric tons to short tons, multiply by 1.1.

**Fractional amount.

New Units and Capacity Installed Since 1961

Number of new
units installed

Amount of new
capacity installed
in metric tons/hour

the very large units handle the bulk of the waste from which energy is recovered, systems for smaller towns (150,000 inhabitants) exist in large number. Energy recovery is not limited to large cities. In fact 34 percent of all European units have a capacity of under 5 metric tons per hour. Exhibits 7 and 8 present information on the sizes of individual furnaces and of combustion plants by country.

In Denmark and Norway, small incinerators predominate. Some burn as little as a quarter of a metric ton per hour. In Germany, France, and the Netherlands, large units are most common. The largest European plant, located in Rotterdam, the Netherlands, has 6 units of 20 metric tons per hour capacity each. The largest single furnace is located in Paris, France (Ivry II) and has a capacity of 50 metric tons per hour.

In the census of waste-to-energy systems, we have listed capacity in terms of metric tons of waste per hour. We have used this measure, rather than yearly output, because different units operate at different percentages of theoretical capacity and for different numbers of hours in a year (depending mostly upon the number of shifts worked). Where daily operating patterns are known, we have included the daily capacity as well.

STARTING DATES

Energy recovery from waste began, in a small way, in France, Denmark, and Italy before the Second World War. During the 1950s it was introduced in Germany, Sweden, and Switzerland. Other Western European countries, first used this technique in the 1960s. The U.K. did not begin until the late 1960s.

The number of units entering service increased from 1961 to 1970 when it peaked. The number entering service has declined slightly since 1970 (see Exhibits 9 and 10). The wide fluctuations are normal for such major investments.

SOURCES OF INFORMATION

Most of the information presented on the maps and census tables which follow has been obtained from the grate manufacturers. Where we were unable to obtain a particular type of information about a system, no entry appears in the list.

**MAPS OF
WASTE-TO-ENERGY SYSTEMS
IN
WESTERN EUROPE**

EUROPE

AUSTRIA

DENMARK

FRANCE

ITALY

**LUXEMBOURG
BELGIUM**

NETHERLANDS

NORWAY
SWEDEN
FINLAND

SPAIN
PORTUGAL

[illegible]

UNITED KINGDOM

WEST GERMANY

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Austria	1. Vienna 1,600,000	Von Roll	3 x 8.3 t/hr (3 x 200 t/day)	Electricity, hot water, steam for sale and for internal use; hospital heating	1963	
	2. Vienna-Spittelau	Martin	2 x 15 t/hr (720 t/day)	District heating and electricity; steam: 38.6 t/hr per unit	1971	Domestic waste, lower heating value: 1000-1800 k cal/kg
Belgium	1. Brussels 2,000,000	Von Roll	2 x 8.3 t/hr (2 x 200 t/day)	Steam, electricity for sale; steam for internal use	1957	
	2. Bruges 120,000	Martin	3 x 9 t/hr (650 t/day)	Steam: 25 t/hr per unit	under construc- tion	Commercial waste
	3. Willebroek	VKW	1 x 2.3 t/hr	Air preheating	1972 (commis- sioned)	Industrial waste, lower heating value: 2000 k cal/kg
Denmark	1. Herning 53,000	Bruun & Sørensen	1 x 3 t/hr (1 x 72 t/day)		1963	Domestic waste
	2. Herning extension 1	Bruun & Sørensen	1 x 3 t/hr (1 x 72 t/day)		1971	Domestic waste
	3. Herning extension 2	Bruun & Sørensen	1 x 4 t/hr (1 x 96 t/day)		1973	Domestic waste
	4. Frederkshavn	Bruun & Sørensen	1 x 3 t/hr (1 x 72 t/day)	Hot water, district heating	1965	Domestic waste
	5. Frederkshavn	Bruun & Sørensen	1 x 4 t/hr (1 x 96 t/day)	Hot water, district heating	1971	Domestic waste
	6. Fredericia	Bruun & Sørensen	1 x 4.6 t/hr	Hot water, district heating	1966	Domestic waste
	7. Rudkøbing	Bruun & Sørensen	1 x 1 t/hr	Hot water, district heating	1966	Lower heating value: 2000 k cal/kg
	8. Rudkøbing extension	Bruun & Sørensen	1 x 1 t/hr	Hot water, district heating	1971	Domestic waste

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Denmark	9. Ebeltoft	Bruun & Sørensen	1 x 1 t/hr	Hot water, district heating	1967	Domestic waste
	10. Højetastrup	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1967	Domestic waste
	11. Struer	Bruun & Sørensen	1 x 2 t/hr	Hot water, district heating	1967	Domestic waste
	12. Ålborg 155,000	Bruun & Sørensen	1 x 5.5 t/hr	Hot water, district heating	1968	Domestic waste
	13. Albertslund	Bruun & Sørensen	1 x 3.5 t/hr	Hot water, district heating	1968	Domestic waste
	14. Albertslund extension	Bruun & Sørensen	1 x 4 t/hr	Hot water, district heating	1974	Domestic waste
	15. Tilst	Bruun & Sørensen	1 x 0.75 t/hr	Hot water, district heating	1968	Domestic waste
	16. Ringsted	Bruun & Sørensen (Flynn and Emrich)	1 x 2 t/hr	Hot water, district heating	1969	Domestic waste
	17. Kolding 53,000	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1969	Domestic waste
	18. Kolding extension	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1972	Domestic waste
	19. Nyborg	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1970	Domestic waste
	20. Sønderborg	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1970	Domestic waste
	21. Holsterbro	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1970	Domestic waste

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Denmark	22. Holsterbro	Bruun & Sørensen	1 x 4 t/hr	Hot water, district heating	1975	Domestic waste
	23. Bronsbryerne	Bruun & Sørensen	1 x 4 t/hr	Hot water, district heating	1971	Domestic waste
	24. Slagelse	Bruun & Sørensen	1 x 3 t/hr	Hot water, district heating	1971	Domestic waste
	25. Kørør 20,000	Bruun & Sørensen	1 x 2 t/hr	Hot water, district heating	1972	Domestic waste
	26. Horsens 53,000	Bruun & Sørensen	1 x 6 t/hr	Sludge drying	1973	Domestic waste
	27. Århus-Nord 240,000	Bruun & Sørensen	16 t/hr	Hot water, district heating	1977	Domestic waste
	28. Copenhagen- Amager 600,000	Volund	3 x 12 t/hr	Hot water, district heating	1970	Lower heating value: 2500 k cal/kg
	29. Copenhagen West	Volund	3 x 12 t/hr	Hot water, district heating	1970	Lower heating value: 2500 k cal/kg
	30. Roskilde	Volund	2 x 3 t/hr	Hot water, district heating	1966	Lower heating value: 2500 k cal/kg
	31. Svendborg		1 x 3.5 t/hr	Hot water, district heating	1970	Lower heating value: 2000 k cal/kg
	32. Haderslev	Volund	1 x 7.5 t/hr	Hot water, district heating	1967	Lower heating value: 2500 k cal/kg
	33. Sønderborg	Volund	1 x 4 t/hr	Hot water, district heating	1973	Lower heating value: 2500 k cal/kg
	34. Nyborg	Von Roll	1 x 7.5 t/hr	Hot water, steam for internal use	1975	
	35. Ålborg 155,000	Volund	1 x 7.5 t/hr	Hot water, district heating	1972	Lower heating value: 2500 k cal/kg

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Denmark	36. Copenhagen West No. 4	Volund	1 x 14 t/hr	Hot water, district heating	under construction	
	37. Helsingør 53,000	Flynn and Emrich	1 x 4.5 t/hr	Hot water, district heating	1967	
	38. Helsingør	Flynn and Emrich	1 x 6 t/hr	Hot water, district heating	1975	
	39. Frederiksberg 100,000	Volund	2 x 6 t/hr	Steam, district heating	1934 (commissioned)	
	40. Hjørring	Volund	1 x 2.5 t/hr	Hot water, district heating	1965 (commissioned)	
	41. Hjørring	Volund	1 x 4 t/hr	Hot water, district heating	1976 (commissioned)	
	42. Hørsholm	Volund	2 x 3 t/hr	Hot water, district heating	1969 (commissioned)	
	43. Haderslev	Volund	1 x 4.5 t/hr	Hot water	1975 (commissioned)	
	44. Gentofte 76,000	Volund	2 x 6 t/hr	Steam	1932 (commissioned)	
	45. Dalum	Volund	1 x 2 t/hr	Hot water	1964 (commissioned)	
Finland	1. Lahti 90,000	Lokomo	2 x 5 t/hr (130 t/day)	District heating: 54,000 MW/h; steam: 11.8 t/hr per unit	1967	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Finland	2. Helsinki 765,000	Von Roll	2 x 8 t/hr (400 t/day)	Hot water for internal use, district heating; electricity: 17.2 GW/h; steam: 15.8 t/hr per unit	1962	
France	1. Paris Issy les Moulineaux 9,000,000	Martin	4 x 15 t/hr (1630 t/day)	Electricity, district heating; steam: 40 t/hr per unit	1965	Industrial waste, lower heating value: 900-2500 k cal/kg
	2. Rennes 180,000	Martin	2 x 5 t/hr (240 t/day)	District heating; steam: 16.2 t/hr per unit	1968	Domestic waste, lower heating value: 1100-2500 k cal/kg
	3. Paris Ivry II	Martin	2 x 50 t/hr (2400 t/day)	Electricity, district heating; steam: 134 t/hr per unit	1969	Industrial waste, lower heating value: 1250-2500 k cal/kg
	4. Metz 165,000	Martin	2 x 6 t/hr (288 t/day)	Electricity, district heating; steam: 18 t/hr per unit	1970	Industrial waste, lower heating value: 1000-2500 k cal/kg
	5. Dieppe 40,000	Von Roll	2 x 2.5 t/hr (2 x 60 t/day)	Sludge drying, internal use	1971	Domestic waste
	6. Mulhouse 200,000	Von Roll	2 x 5 t/hr (2 x 120 t/day)	Steam for sale, district heating, hot water, steam for internal use	1972	Industrial waste
	7. Strasbourg 355,000	Von Roll	3 x 11 t/hr (3 x 300 t/day)	Electricity for sale, district heating, hot water, electricity for internal use	1975	Industrial waste, lower heating value: 1400-1760 k cal/kg
	8. Deauville	Von Roll	2 x 2.5 t/hr (2 x 60 t/day)	Sludge drying	1976	Industrial waste
	9. Brive 160,000	Von Roll	2 x 3.5 t/hr (2 x 75 t/day)	Sludge drying	1974	Industrial waste
	10. Angers 165,000	Von Roll	2 x 5 t/hr (2 x 120 t/day)	Steam for sale and internal use	1975	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
France	11. Dijon 185,000	Von Roll	2 x 12.5 t/hr (2 x 300 t/day)	Electricity, steam for sale and internal use	1975	Domestic waste
	12. Bezons Argenteuil	Von Roll	2 x 8.3 t/hr (2 x 200 t/day)	Steam for internal use	1975	Domestic waste
	13. Arras 72,000	Von Roll	1 x 5 t/hr (1 x 120 t/day)	Steam for internal use	1976	Domestic waste
	14. Bruay en Artois 115,000	Von Roll	2 x 5 t/hr (2 x 120 t/day)	Steam for sale	1977	Domestic waste
	15. Agen	Von Roll	1 x 3.125 t/hr (1 x 75 t/day)		1977	Domestic waste
	16. Tergnier	Alberti	2 x 8 t/hr		1972	Sludge drying
	17. Nice-Est 400,000	Martin	1 x 12.3 t/hr 1 x 9.9 t/hr (595 t/day)	Steam: 26 t/hr	1977	Commercial waste
	18. Saint Afrique	Sloppe	1 x 2 t/hr		1972	
	19. Besancon 113,000	CEC	2 x 2.2 t/hr 1 x 3 t/hr (98 t/day)		1971	
	20. Toulouse-Le Mirail 400,000	VKW	2 x 8 t/hr	Electricity, district heating; steam: 21.7 t/hr per unit	1970	Lower heating value: 1000-2200 k cal/kg
	21. Toulouse-Le Mirail	VKW	1 x 8 t/hr	Electricity, district heating; steam: 21.7 t/hr	1975	Lower heating value: 1000-2200 k cal/kg
	22. Grenoble 335,000	VKW	2 x 6.25 t/hr	District heating; steam: 18 t/hr per unit	1971/72	Lower heating value: 1200-2300 k cal/kg
	23. Nancy 260,000	Luchoire	2 x 6.25 t/hr	Steam for sale	1974	
	24. Armentières 55,000	Volund	1 x 3 t/hr		1964	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
France	25. Lyon-7ème 1,100,000	Volund	4 x 10 t/hr	Steam, electricity for sale	1963	
	26. Rouen 370,000	Stein	2 x 8 t/hr	Electricity for sale	1967	
	27. Toulouse-Le Ramier				1928	About to be closed down
	28. Paris St. Ouen	Volund	4 x 12 t/hr	Steam for sale	1954	
	29. Grenoble	VKW	6.25 t/hr	District heating; steam: 18 t/hr	1978 (anticip- ated)	
	30. Lyon	Volund	1 x 10 t/hr	Steam	1973 (commis- sioned)	
Italy	1. Milan 3,600,000	Volund	2 x 10 t/hr	Steam	1938	
	2. Genoa 875,000	Von Roll	3 x 8.3 t/hr (3 x 200 t/day)	Electricity for sale; electricity, steam for internal use	1972	
	3. Bologna 550,000	Von Roll	3 x 8.3 t/hr (3 x 200 t/day)	Hot water for internal use	1973	
	4. Milan Olgettina	Von Roll	3 x 12.5 t/hr (3 x 300 t/day)	Electricity for sale; electricity, hot water, steam for internal use	1978	
	5. Forli 105,000	Von Roll	2 x 4.15 t/hr (2 x 100 t/day)	Steam for internal use	1977	
	6. Leghorn 173,000	Von Roll	2 x 3.33 t/hr (2 x 80 t/day)	Steam for internal use	1973	
	7. Rome Sorain Cecchini 3,000,000	Von Roll	6 x 4 t/hr	Steam for sale	1973	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Italy	8. Rome Slia Sarr	Alberti Fonsard	2 x 4 t/hr	Steam for sale	1970	
	9. Milan Bruzano	Volund	3 x 14 t/hr	Steam	under construc- tion	
	10. Savona 120,000	Bartolomeus	1 x 3 t/hr	Steam	1969	
	11. Reggio Emilia 130,000	Bartolomeus	2 x 4 t/hr	Steam	1969	
	12. Padua 265,000	Alberti Fonsard	1 x 12 t/hr	Steam, electricity	1961	
	13. Modena 170,000	Von Roll	2 x 6 t/hr	Steam, electricity	under construc- tion	
	14. Milan Figino	Bartolomeus	2 x 6 t/hr	Steam, electricity	1973	
	15. Como 155,000	Bartolomeus	1 x 4 t/hr	Steam	1967	
	16. Cava Dei Tirreni	Bartolomeus	2 x 1.6 t/hr	Steam	1975	
Luxembourg	1. Luxembourg 100,000	Martin	2 x 10 t/hr (480 t/day)	Electricity for sale and internal use; steam: 25 t/hr per unit	1976	Domestic waste, lower heating value: 1000-2500 k cal/kg
Netherlands	1. Rotterdam Brielselaan 1,125,000	Martin	4 x 13 t/hr (1500 t/day)	Electricity; steam: 30 t/hr per unit	1967	Industrial waste, lower heating value: 1275-2150 k cal/kg
	2. Amsterdam 1,800,000	Martin	4 x 16 t/hr (2160 t/day)	Electricity; steam: 46.5 t/hr per unit	1969	Industrial waste, lower heating value: 1760-2250 k cal/kg

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Netherlands	3. Rotterdam	VKW	6 x 20 t/hr	District heating, electricity; steam: 46 t/hr per unit	1970/71 (commissioned)	Domestic waste, lower heating value: 800-3000 k cal/kg
	4. Dordrecht 175,000	Martin	3 x 7 t/hr (504 t/day)	Sludge drying	1972	Industrial waste, lower heating value: 2000 k cal/kg
	5. Roosendaal 50,000	Bruun & Sørensen	2 x 8 t/hr (192 t/day)	Hot water (not in use yet)	1975	Domestic waste
	6. The Hague I 820,000	Von Roll	3 x 12.5 t/hr (3 x 300 t/day)	Electricity, steam for sale; electricity, hot water, steam for internal use	1968	Waste oil recovery
	7. The Hague II	Von Roll	1 x 12.5 t/hr (1 x 300 t/day)	Electricity for sale; electricity, steam, hot water for internal use	1974	
Norway	1. Bergen 235,000	Bruun & Sørensen	1 x 2 t/8hr 1 x 0.25 t/hr		1965	Domestic waste
	2. Bergen	Bruun & Sørensen	1 x 4 t/hr 1 x 0.5 t/hr		1966	Domestic waste
	3. Oslo 720,000	Bruun & Sørensen	1 x 0.5 t/hr		1966	Domestic waste
	4. Bergen	Bruun & Sørensen	1 x 0.25 t/hr		1968	Domestic waste
	5. Bergen	Bruun & Sørensen	1 x 0.25 t/hr		1968	Domestic waste
	6. Oppegard	Bruun & Sørensen	1 x 0.25 t/hr		1968	Domestic waste
	7. Oslo	Bruun & Sørensen	1 x 0.25 t/hr		1968	Domestic waste

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Norway	8. Oslo	Bruun & Sørensen	1 x 0.75 t/hr		1968	Domestic waste
	9. Oslo	Bruun & Sørensen	1 x 0.5 t/hr		1970	Domestic waste
	10. Asane	Bruun & Sørensen	1 x 0.5 t/hr		1971	Domestic waste
	11. Drammen 70,000	Bruun & Sørensen	1 x 0.5 t/hr		1972	Domestic waste
	12. Trondheim 130,000	Bruun & Sørensen	1 x 0.5 t/hr		1973	Domestic waste
	13. Oslo	Esslingen	1 x 7 t/hr (1 x 170 t/day)	Electricity; steam: 19.9 t/hr	1966	
Spain	1. Barcelona I 3,165,000	Von Roll	2 x 12.5 t/hr (2 x 300 t/day)	Electricity for sale; electricity, steam for internal use	1975	
	2. Barcelona II	Von Roll	1 x 12.5 t/hr (1 x 300 t/day)	Electricity for sale; electricity, steam for internal use	1975	
	3. Palma de Mallorca 235,000	Volund	1 x 8.25 t/hr (198 t/day)	Steam	under construction	
Sweden	1. Solna 55,000	Bruun & Sørensen	1 x 4 t/hr (1 x 96 t/day)		1973	Domestic waste
	2. Solna	Bruun & Sørensen	8 t/hr (192 t/day)		1974	Domestic waste
	3. Trollhättan 50,000	Bruun & Sørensen	1 x 3.33 t/hr (1 x 80 t/day)	Hot water, district heating	1974	Domestic waste
	4. Stockholm 1,350,000	VKW	2 x 15 t/hr	Electricity; steam: 38.5 t/hr	1970 (commis- sioned)	Domestic waste, lower heating value: 1600-3000 k cal/kg

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Sweden	5. Uppsala 130,000	Bruun & Sørensen	1 x 5 t/hr (1 x 120 t/day)	Steam, district heating	1971	
	6. Stockholm Böllmora	Von Roll	2 x 4.15 t/hr (2 x 120 t/day)	District heating, hot water for internal use	1968	
	7. Umeå 60,000	Von Roll	1 x 5 t/hr (1 x 120 t/day)	District heating, hot water for internal use	1970	
	8. Linköping 105,000	Von Roll	1 x 5 t/hr (1 x 120 t/day)	Electricity, district heating, hot water for internal use	1966	
	9. Göteborg 630,000	Von Roll	3 x 12.5 t/hr (3 x 300 t/day)	Hot water for internal use; steam: 42.7 t/hr	1972	
	10. Malmö 300,000	Martin	2 x 8.5 t/hr (408 t/day)	Sludge drying	1973	Industrial waste, commercial waste, lower heating value: 3300 k cal/kg
	11. Stockholm Sundbyberg	Volund	2 x 2.5 t/hr (120 t/day)	District heating	1954 (commissioned)	
	12. Linköping	Volund	2 x 2.5 t/hr (1205 t/day)	Steam, electricity, district heating	1958 (commissioned)	
	13. Uppsala	Volund	2 x 2.5 t/hr (120 t/day)	Steam, district heating	1962 (commissioned)	
	14. Uppsala	Volund	1 x 3 t/hr (72 t/day)	Steam, district heating	1965 (commissioned)	
	15. Borås 95,000	Volund	2 x 2.5 t/hr (120 t/day)	Electricity, district heating	1965 (commissioned)	
	16. Luleå 60,000	Volund	2 x 5 t/hr (240 t/day)	Hot water, sludge drying	1969 (commissioned)	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Sweden	17. Boras	Volund	1 x 4 t/hr (96 t/day)	Electricity, district heating	1972 (commis- sioned)	
	18. Sundsvall Bark 100,000	Volund	2 x 17.5 t/hr	Steam	under construc- tion	
	19. Göteborg	Plibrico	1 x 4 t/hr (96 t/day)	Hot water, district heating	1962	
	20. Stockholm Huddinge	Destructor	1 x 4 t/hr (96 t/day)	Hot water, hospital heating	1971	
	21. Stockholm Solna	Destructor	3 x 4 t/hr (288 t/day)	Hot water, district heating	1967	
	22. Stockholm Bredäng	Destructor	1 x 3 t/hr (72 t/day)	Hot water, district heating	1965	
Switzerland	1. Dietikon 75,000	Sulzer/ Martin	2 x 2.5 t/hr (2 x 45 t/day)	Electricity	1971	
	2. Hinwil Kezo 155,000	Sulzer/ Martin	1 x 5 t/hr (1 x 120 t/day)	Electricity, steam: 12.5 t/hr	1971	Industrial waste, lower heating value: 1100-2200 k cal/kg
	3. Hinwil Kezo	Sulzer/ Martin	2 x 6.25 t/hr (300 t/day)	Electricity, steam: 22.6 t/hr per unit	1976	Commercial waste, lower heating value: 1200-3000 k cal/kg
	4. Winterthur 155,000	Von Roll	2 x 4.15 t/hr (2 x 100 t/day)	Electricity (district heating, electricity, hot water, steam for sale and for internal use)	1965	
	5. Zurich Hagenholz 421,000	Von Roll	2 x 10.8 t/hr (2 x 260 t/day)	District heating (electricity, hot water, steam for sale and for internal use); steam: 28 t/hr per unit	1969	
	6. Zurich Hagenholz II	Martin	1 x 12.5 t/hr (1 x 300 t/day)	District heating; steam: 38.2 t/hr	1973	Commercial waste, lower heating value: 1600-3300 k cal/kg

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Switzerland	7. Zurich Josefstrasse	Martin	2 x 7.5 t/hr (1 x 300 t/day)	District heating	1979 (anticipated)	
	8. Bern 152,000	Von Roll	2 x 4.15 t/hr (2 x 100 t/day)	District heating and industry (electricity, hot water, steam for sale and for internal use)	1954	
	9. Lucerne 173,000	Von Roll	2 x 4.15 t/hr (2 x 100 t/day)	Electricity (1971), district heating (1976)	1971	
	10. Basel I 460,000	Volund	2 x 8.3 t/hr (2 x 200 t/day)	Industrial heating	1942	
	11. Basel II	Von Roll	2 x 12.5 t/hr (2 x 300 t/day)	Industrial heating	1969	
	12. Buchs 80,000	Alberti Fonsard	1 x 5 t/hr (1 x 120 t/day)	Electricity, district heating, industrial heating	1975	
	13. Turgi 136,000	Alberti Fonsard	2 x 4.15 t/hr (2 x 100 t/day)	Electricity	1970	
	14. Locarno 82,000	Bartolomeus	2 x 2.05 t/hr (2 x 50 t/day)	Industrial heating	1969	
	15. Lausanne 189,000	Von Roll	2 x 4.15 t/hr (2 x 100 t/day)	Electricity, steam, hot water for internal use	1958	
	16. La Chaux de Fond 86,000	CEC	2 x 3 t/hr (2 x 72 t/day)	Electricity, district heating	1972	
	17. Colombier 85,000	Alberti Fonsard	2 x 4.15 t/hr (2 x 100 t/day)	Electricity	1971	
	18. Geneva Cheneviers I 360,000	Von Roll	2 x 8.3 t/hr (2 x 200 t/day)	Electricity for sale; electricity, steam, hot water for internal use	1966	
	19. Geneva Cheneviers II	Martin/Krauss Maffei	1 x 19.15 t/hr (1 x 460 t/day)	Steam: 54 t/hr, electricity	1978 (anticipated)	

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Switzerland	20. Zuchwill 285,000	Von Roll	2 x 10 t/hr (2 x 240 t/day)	Electricity for sale; electricity, steam for internal use	1976	
	21. Kirchberg Bazenheid 71,000	Martin	2 x 3.5 t/hr (2 x 84 t/day)	District heating; steam: 14.7 t/hr per unit	1976	Commercial waste, lower heating value: 1200-3500 k cal/kg
	22. Yverdon 55,000		6 t/hr		under construc- tion	
	23. St. Triphon 165,000		15 t/hr		under construc- tion	
	24. Bülach 65,000	Lurgi	2 x 2.25 t/hr (2 x 54 t/day)	Sludge drying	1969	
	25. Horgen 85,000	Ofag	1 x 3.33 t/hr (1 x 80 t/day)	Internal use	1968	
	26. Mannedorf 55,000	Von Roll	1 x 1 t/hr (1 x 24 t/day)	Internal use	1968	
	27. Olten 73,000	Ofag	1 x 4.15 t/hr (1 x 100 t/day)	Sludge drying	1964	
	28. Schaffhausen 70,000	Von Roll	2 x 2.5 t/hr (2 x 60 t/day)	Internal use	1973	
	29. Uzwil 60,000	Nichols	1 x 3 t/hr (1 x 72 t/day)	Internal use, composting, industrial sludge treatment	1970	
	30. Graubünden 28,000	Ofag	1 x 1.7 t/hr (1 x 41 t/day)	Internal use	1971	
	31. Monthey	Bartolomeus	2 x 3.75 t/hr (2 x 90 t/day)	Electricity	1975	
	32. Winterthur	Martin	1 x 16.7 t/hr (1 x 400 t/day)	Steam: 45 t/hr	under construc- tion	Commercial waste, lower heating value: 1600-3000 k cal/kg

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
Switzerland	33. Bern II	Von Roll	2 x 10 t/hr (2 x 240 t/day)	Electricity, hot water, steam for sale and for internal use	1975	
United Kingdom	1. Coventry 336,000	Martin	3 x 12 t/hr	Electricity, hot water for industry; steam: 31.5 t/hr per unit	1975	Industrial waste, lower heating value: 1900-2500 k cal/kg
	2. Nottingham 300,000	Martin	2 x 11.7 t/hr (562 t/day)	Electricity, district heating; steam: 24 t/hr per unit	1973	Industrial waste, lower heating value: 1600-2000 k cal/kg
	3. Middleton 55,000	VKW	1 x 8 t/hr	Hot water for internal use	1978 (anticip- ated)	Domestic waste, lower heating value: 1000-2000 k cal/kg
	4. Edmonton	VKW	5 x 14 t/hr	Electricity; steam: 39.5 t/hr per unit	1970/71 (commis- sioned)	Domestic waste, lower heating value: 1800-2320 k cal/kg
	5. Linwood	VKW	2 x 8 t/hr	Heat for internal use	1974 (commis- sioned)	Domestic waste, lower heating value: 2720 k cal/kg
	6. Sheffield 500,000	VKW	2 x 10 t/hr	Electricity, district heating	1975 (commis- sioned)	Domestic waste, lower heating value: 2625 k cal/kg
	7. Mansfield 60,000	Bruun & Sørensen	1 x 5.5 t/hr (1 x 132 t/day)	District heating	1972	Domestic waste
	8. Jersey	Martin	1 x 6 t/hr 1 x 4.5 t/hr (294 t/day)	Steam: 17 t/hr per unit	under construc- tion	
	9. Otley/Ilkley	Bruun & Sørensen	3.25 t/hr (1 x 78 t/day)	Hot water, district heating (not yet connected)	1973	Domestic waste
West Germany	1. Munich Nord I 1,400,000	Martin	2 x 25 t/hr (1200 t/day)	Electricity, district heating; steam: 41 t/hr per unit	1964	Commercial waste, lower heating value: 900-1800 k cal/kg (combined waste and coal firing)

Census of Combustion Units with Energy Recovery in Western Europe

Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
West Germany	2. Munich Nord II	Martin	1 x 40 t/hr (960 t/day)	Electricity, district heating; steam: 81 t/hr	1966	Commercial waste, lower heating value: 900-2200 k cal/kg (combined waste and coal firing)
	3. Stuttgart 1,650,000	Martin	1 x 20 t/hr (480 t/day)	Electricity, district heating; steam: 50 t/hr	1965	Commercial waste, lower heating value: 800-2200 k cal/kg
	4. Stuttgart extension	VKW	1 x 20 t/hr	Electricity, district heating; steam: 125 t/hr with oil; 55 t/hr with waste	1970 (commissioned)	Domestic waste, separate furnace with oil firing, lower heating value: 1400-2500 k cal/kg
	5. Hamburg I 1,800,000	Von Roll	2 x 8.3 t/hr (2 x 200 t/day)	Electricity for sale; electricity, heat, steam for internal use	1958	Domestic waste
	6. Hamburg II	Von Roll	3 x 8.3 t/hr (3 x 200 t/day)	Electricity for sale; electricity, heat, steam for internal use	1963	Industrial waste
	7. Hamburg III	Martin	1 x 12 t/hr (288 t/day)	Electricity, district heating; steam: 27 t/hr	1967	Industrial waste, lower heating value: 1200-3190 k cal/kg
	8. Hamburg IV Stelling Moor	Martin	2 x 19.5 t/hr (1180 t/day)	Electricity; steam: 32-40 t/hr per unit	1973	Domestic waste, lower heating value: 1500 k cal/kg
	9. Dusseldorf 650,000	VKW	4 x 10 t/hr	Electricity, district heating; steam: 16 t/hr per unit	1972	Industrial waste, lower heating value: 800-2000 k cal/kg
	10. Rosenheim	VKW	1 x 4.5 t/hr	District heating, electricity; steam: 7.5 t/hr	1964	Industrial waste, lower heating value: 800-1600 k cal/kg
	11. Rosenheim extension	VKW	1 x 6 t/hr	District heating, electricity; steam: 12 t/hr	1970	Industrial waste, lower heating value: 2000 k cal/kg

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Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
West Germany	12. Hagén 200,000	VKW	3 x 6 t/hr	District heating; steam: 16 t/hr per unit	1967	Commercial waste, lower heating value: 800-2000 k cal/kg
	13. Munich South V	Martin	1 x 40 t/hr (960 t/day)	District heating, electricity; steam: 81 t/hr	1969	Commercial waste, lower heating value: 900-2000 k cal/kg
	14. Munich South IV	Martin	1 x 40 t/hr (960 t/day)	District heating, electricity; steam: 81 t/hr	1971	Commercial waste, lower heating value: 900-2000 k cal/kg
	15. Neunkirchen 42,000	Martin	1 x 5 t/hr (120 t/day)	District heating; steam: 175 t/hr	1970	Commercial waste, industrial waste, lower heating value: 2000 k cal/kg
	16. Dusseldorf	VKW	1 x 10 t/hr	Electricity; district heating, steam: 12 t/hr	1965	Domestic waste, lower heating value: 800-2000 k cal/kg
	17. Berlin-Ruhleben 2,000,000	VKW	4 x 16 t/hr	Electricity; district heating, steam: 25 t/hr	1967	Domestic waste, lower heating value: 800-2000 k cal/kg
	18. Berlin-Ruhleben extension 1	VKW	2 x 16 t/hr	Electricity; steam: 26-32 t/hr per unit	1969 (commis- sioned)	Domestic waste, lower heating value: 800-2500 k cal/kg
	19. Berlin-Ruhleben extension 2	VKW	2 x 16 t/hr	Electricity; steam: 26-32 t/hr per unit	1972 (commis- sioned)	Domestic waste, lower heating value: 800-2500 k cal/kg
	20. Dusseldorf	VKW	1 x 12.5 t/hr	Electricity; steam: 25-30 t/hr per unit	1972 (commis- sioned)	Domestic waste, lower heating value: 1000-2100 k cal/kg
	21. Berlin Lichtenberg	VKW	2 x 15 t/hr	Electricity; steam: 32 t/hr per unit	1974 (commis- sioned)	Domestic waste, lower heating value: 800-1800 k cal/kg

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Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
West Germany	22. Kassel 215,000	VKW	1 x 10 t/hr	Electricity; steam: 27.5 t/hr	1968 (commissioned)	Commercial waste, lower heating value: 800-2500 k cal/kg
	23. Kassel extension	VKW	1 x 10 t/hr	Electricity; steam: 27.5 t/hr	1969 (commissioned)	Industrial waste, lower heating value: 800-2500 k cal/kg
	24. Offenbach 120,000	VKW	3 x 10 t/hr	Electricity, district heating; steam: 26 t/hr per unit	1970	Commercial waste, lower heating value: 800-2200 k cal/kg
	25. Bremen 600,000	VKW	3 x 15 t/hr	District heating; steam: 40 t/hr per unit	1970	Industrial waste, lower heating value: 800-2000 k cal/kg
	26. Bremen extension	VKW	1 x 20 t/hr	District heating; steam: 88 t/day	1977 (commissioned)	Lower heating value: 3000 k cal/kg
	27. Oberhausen 250,000	VKW	3 x 22 t/hr	Electricity, district heating; steam: 50 t/hr per unit	1972 (commissioned)	Commercial waste, lower heating value: 800-2500 k cal/kg
	28. Iserlohn 60,000	VKW	2 x 8 t/hr	Electricity, district heating; steam: 20 t/hr per unit	1970	Industrial waste, waste oil, lower heating value: 800-2000 k cal/kg
	29. Iserlohn extension	VKW	16 t/hr	Electricity, district heating; steam: 50 t/hr	1973 (commissioned)	Industrial waste, waste oil, lower heating value: 800-2500 k cal/kg
	30. Krefeld 225,000	VKW	2 x 12 t/hr	District heating, sludge drying, electricity, for internal use; steam: 38 t/hr per unit	1974 (commissioned)	Industrial waste, waste oil, additional combustion of sewage sludge
	31. Kiel 270,000	VKW	2 x 5 t/hr	District heating; steam: 16 t/hr per unit	1975	Domestic waste, lower heating value: 800-2500 k cal/kg

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Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
West Germany	32. Göppingen 50,000	VKW	2 x 12 t/hr	Electricity, district heating; steam: 32 t/hr per unit	1975	Industrial waste, waste oil, lower heating value: 1200-3000 k cal/kg
	33. Essen-Karnap 700,000	VKW	5 x 20 t/hr	Electricity; steam: 130 t/hr per unit	1961 (commis-)	Industrial waste, lower heating value: 1500 k cal/kg
	34. Neufahrn	VKW	1 x 3 t/hr	District heating; steam: 8 t/hr per unit	1970 (commis- sioned)	Industrial waste, lower heating value: 1000-2500 k cal/kg
	35. Hameln 50,000	VKW	1 x 10 t/hr	Electricity; steam: 27.2 t/hr	1977	
	36. Neunkirchen 50,000	Martin	1 x 10 t/hr	Steam: 27 t/hr	under construc- tion	Commercial waste, lower heating value: 1500-2500 k cal/kg
	37. Bonn-Bad Godesberg 300,000	Volund	2 x 10 t/hr	District heating, industry	1966	Industrial waste
	38. Gluskstadt	Claudius Peters	1 x 2.5 t/hr	Sludge drying	1963	Domestic waste
	39. Mannheim 330,000	KSG	2 x 12 t/hr	District heating, electricity	1965	Industrial waste, waste oil
	40. Mannheim extension	KSG	1 x 20 t/hr	District heating, electricity	1973	Industrial waste, waste oil
	41. Darmstadt 150,000	Von Roll	2 x 10 t/hr	Electricity, district heating	1967	Industrial waste, waste oil
	42. Darmstadt extension	Von Roll	1 x 12 t/hr	Electricity, district heating	1973	Industrial waste, waste oil
	43. Frankfurt-am- Main I 660,000	Von Roll	2 x 12.5 t/hr	Electricity, steam for internal use and for sale	1966	Commercial waste

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Country	Location/Population	System	Rated Capacity	Energy Recovery	Starting Date	Comments
West Germany	44. Frankfurt-am-Main II	Von Roll	2 x 12.5 t/hr	Electricity, steam for internal use and for sale	1967	
	45. Nürnberg 500,000	Von Roll	3 x 12.5 t/hr	Steam for sale; electricity, hot water, steam for internal use	1968	Industrial waste
	46. Solingen 180,000	Von Roll	2 x 12.5 t/hr	Electricity, hot water for sale and for internal use	1969	Commercial waste
	47. Fürth 95,000	Von Roll	1 x 3.3 t/hr	District heating; hot water for sale and internal use	1971	
	48. Leverkusen 110,000	Von Roll	2 x 8.3 t/hr	District heating; electricity, steam for internal use	1970	Industrial waste
	49. Ludwigshafen 175,000	Von Roll	2 x 8.3 t/hr	Electricity, district heating; hot water, steam for internal use	1967	Commercial waste
	50. Landshut I 55,000	Von Roll	1 x 3 t/hr	Electricity for sale; electricity, steam for internal use	1971	Industrial waste
	51. Landshut II	Von Roll	1 x 3 t/hr	Electricity for sale and internal use	1974	Industrial waste
	52. Kempten I	Von Roll	1 x 4 t/hr	Steam for internal use	1975	
	53. Kempten II	Von Roll	1 x 5 t/hr	Steam for internal use	1976	
	54. Bremerhaven 150,000	Von Roll	3 x 10 t/hr	Steam for sale; steam, electricity for internal use	1977	
	55. Böbingen	Brule	2 x 1 t/hr	Sludge drying	1975	Commercial waste
	56. Wuppertal 420,000	VKW	4 x 15 t/hr	Electricity for sale and internal use	1976	Industrial waste
	57. Fustfeldbrück	Keller Peukert	1 x 6 t/hr	Sludge drying	1975	Industrial waste
	58. Stuttgart	VKW	1 x 20 t/hr	Electricity, district heating; steam: 125 t/hr (55 t/hr with waste only)	1965 (commissioned)	Lower heating value: 800-2200 k cal/kg

APPENDIX

OTHER TECHNIQUES OF RESOURCE RECOVERY

Besides direct combustion, there are several other processes which recover energy from municipal solid waste. These processes include aerobic fermentation (composting), anaerobic fermentation (generation of methane), the formation of refuse-derived-fuel (RDF), and pyrolysis. In most cases, these techniques are less advanced in Western Europe than in the U.S.

Composting has been used in agriculture for ages. As a technique of treating municipal solid waste, composting can yield not only soil conditioner (which should be considered a form of materials recovery) but also energy. The Brikollare Process, developed by Industrie-Werke Karlsruhe Augsburg Aktiengesellschaft (IWKA), is a technique for the joint composting of municipal solid waste and sewage sludge.

In the Brikollare process, the mixture of municipal solid waste and sewage sludge is pressed into briquettes and then palletized into units weighing up to 20 kg (45 lb). The separation of the mixture into these relatively small units promotes fast digestion (about three weeks) and, according to IWKA, eliminates unpleasant odors and harmful bacteria. The dried briquettes can be used as soil conditioner, in pig food, or as a stable element in landfills. IWKA contends that the briquettes can also serve as fuel for combustion units. At present, there is one Brikollare plant in operation in Schweinfurt, West Germany and two more plants are said to be under development.

Anaerobic fermentation producing methane has been used both with municipal solid waste and with animal wastes on farms.

Refuse-derived-fuel is also a substitute for fossil fuel. The processes used to produce RDF do not normally involve fermentation. A process for pelletizing municipal solid waste developed by Buhlers of Zurich, Switzerland is about to be tested in Eastbourne, U.K. This unit, which will have the capacity to produce 7,000 metric tons (7,700 short tons) of RDF per year, may be expanded to produce 40,000 metric tons (44,000 short tons) per year if the first stage is successful.

Public analysis tests on the RDF produced by the Buhlers process indicate that it has about half the calorific value of medium grade coal. Carbonizing the RDF pellets can increase the calorific value to about two-thirds that of high grade coal. RDF is a low sulfur fuel.

The British government's Warren Spring Laboratory has been investigating the production of RDF briquettes but the combustion trials have not been wholly satisfactory. There have also been problems with storage.

Pyrolysis has been investigated by Von Roll in Switzerland and by the Warren Spring Laboratory in England, but no plants have been built. In France, SODETEG conducted some pyrolysis experiments, but the entire project has been abandoned. Pilot plants have been built in Denmark (Destrugas process) and in Sweden (Pyrogas process). A commercial unit using the Andco-Torrax process (10 metric tons per hour) has been built in Luxembourg, but is not yet operating. Another unit is supposed to be built in Grasse, France. A unit is also being built in West Germany which will use the Arcalon process and have a capacity of 24 tons per day.

In addition to energy, a variety of materials can be recovered from municipal solid waste, either through source-separation programs or in front-end separation plants. The recovery of materials from the waste stream is a significant method of conserving both energy and raw materials.

There is considerable interest in Western Europe in front-end separation techniques. Research is being carried out in France (BRGM), Sweden (Flakt and Motala companies), West Germany (Krauss-Maffei), and England (Warren Spring Laboratory). The Flakt company has been operating a separation plant (capacity 30,000 metric tons per year) in Sweden since the beginning of 1975 and has contracted to build a full scale commercial plant (capacity 120,000 metric tons per year) in the Netherlands. Krauss-Maffei operates a pilot plant in Munich, West Germany and Cecchini operates one in Rome, Italy.