SMALL SCALE WASTE-TO-ENERGY TECHNOLOGIES

Claudine Ellyin

Advisor: Prof. Nickolas J. Themelis

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Department of Earth and Environmental Engineering

Columbia University

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EXECUTIVE SUMMARY

The dominant technology for large Waste-to-Energy (WTE) facilities is combustion on a moving grate of "as-received" municipal solid wastes (MSW). However, there are circumstances where a low-capacity plant is required. This study examines the technical, economic, and environmental aspects of some small-scale WTE technologies currently in operation. The investigation included both existing grate combustion plants and novel processes, in particular, the Energos technology.

The Energos technology was developed in Norway, in order to provide relatively small communities with an economically efficient alternative to conventional grate combustion (also called 'mass-burn' incineration) with equally low emissions to the atmosphere and flexibility in feedstock. All Energos plants treat MSW plus additional streams of commercial or industrial wastes. Prior to thermal treatment, the materials are shredded in a high-torque, low-rpm shredder and ferrous metals are removed magnetically. The feedstock is partially oxidized on a moving grate in the gasification chamber where the fixed carbon is completely burnt off. The volatilized gases flow into a second chamber where they are fully combusted and the generated heat is transferred to a heat recovery system where steam is produced.

The Energos grate gasification and combustion technology is currently in operation at six plants in Norway, one in Germany, and one in the UK; they range in capacity from 30 tons/day per unit to a high of 118 tons/day per unit. As expected, the capital cost per ton of annual ton of capacity increases with decreasing plant capacity, while there is a linear relationship between energy recovery and capacity. These low capacity WTE facilities require a relatively small footprint of less than one hectare (<2.5 acres) and can be built at a capital cost per ton that is as low, or possibly lower, than that of large mass burn WTE facilities. Some other small-scale technologies examined in this study were the Novo Energy inclined fixed grate combustion technology, the emergence of various small scale thermal processes in Japan (e.g., Ebara), and the modular systems of Envikraft/Scan American Corp., KI Energy, and IST Energy GEM.

An analysis of a compilation of over 330 WTE plants in Europe by the International Solid Waste Association showed that there are about 170 small scale plants in Europe. It was determined that 84 plants (nearly 25% of the total number of plants included in the ISWA survey) have an annual capacity of less than 50,000 tons and another 85 plants range in capacity from 50,000 and 100,000 tons. The total capacity of these small scale plants is just over 8.5 million tons of feedstock combusted.

By analyzing the ISWA data further, in terms of plants which co-combust MSW with wastes other than commercial and industrial wastes (e.g., hospital waste and sludge cake from wastewater treatment plants), it was concluded that approximately 33% of European waste-to-energy plants in the ISWA survey are small scale plants that co-combust hospital waste. These plants ranged in annual capacity from 5,000 to 95,000 tons and, on the average, hospital waste amounted to about 3% of the combusted materials. Also, of the 24 plants in the ISWA survey that reported co-combusting sludge cake (from wastewater treatment plants) 25% are of low capacity, ranging from 50,000 to 79,000 tons per year. The co-combusted sludge cake ranged from 0.2% to 12% of the total feed.

By assessing these small scale technologies, it was concluded that, under certain circumstances, the construction of small scale WTE plants is beneficial because it avoids the economic and environmental impacts associated with the long distance transfer of waste.

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1 INTRODUCTION

1.1 Current Status of Waste Management

According to the 2008 national data on municipal solid waste (MSW), reported in the Columbia/BioCycle national survey *State of Garbage in America,* the U.S. generates 389.5 million tons of MSW. Of this total, 69 percent is landfilled, 24 percent is recycled and composted, and 7 percent is combusted via waste-to-energy (WtE) systems[1]. Therefore, of the nearly 60% of MSW that is available for conversion to energy, currently only 7% of this is converted[2].

Past studies by the Earth Engineering Center (EEC) have shown that globally about 200 million tons of municipal solid waste (MSW) is treated thermally to recover energy and produce an estimated 40 million tons of WTE ash. Another one billion tons are landfilled.

In view of the location of Columbia University in New York State, it is of interest that New York City currently sends its MSW to out of state landfills at a cost of $110/ton, although, for about $60-70/ton the City could have WTE plants built, either in NY or NJ, to serve the City[3].

1.2 Hierarchy of Sustainable Waste Management

It is important to emphasize the "Expanded Hierarchy of Sustainable Waste Management[4]" depicted below in Figure 1. This figure shows that the first priority in terms of sustainable waste management is the reduction of waste. Secondly, the emphasis is on the recovery or recycling of materials, and once this is achieved, the priority shifts to the aerobic and anaerobic composting (or digestion) of source separated organics (e.g., wet food and yard wastes). It is only then that the emphasis shifts to the recovery of energy through a thermal waste conversion process, as this system should only accept non-recyclables. Again, emphasizing that a waste to energy system is complimentary to recycling and utilizes the calorific value in "black bag" municipal solid waste (approximated as 10 MJ/Kg or 2800 kWh/ton[5]). Therefore, "waste to energy" systems are superior to landfills. It is important however to distinguish between landfills which capture and utilize the landfill gas (methane) as opposed to those which do not perform energy recovery.

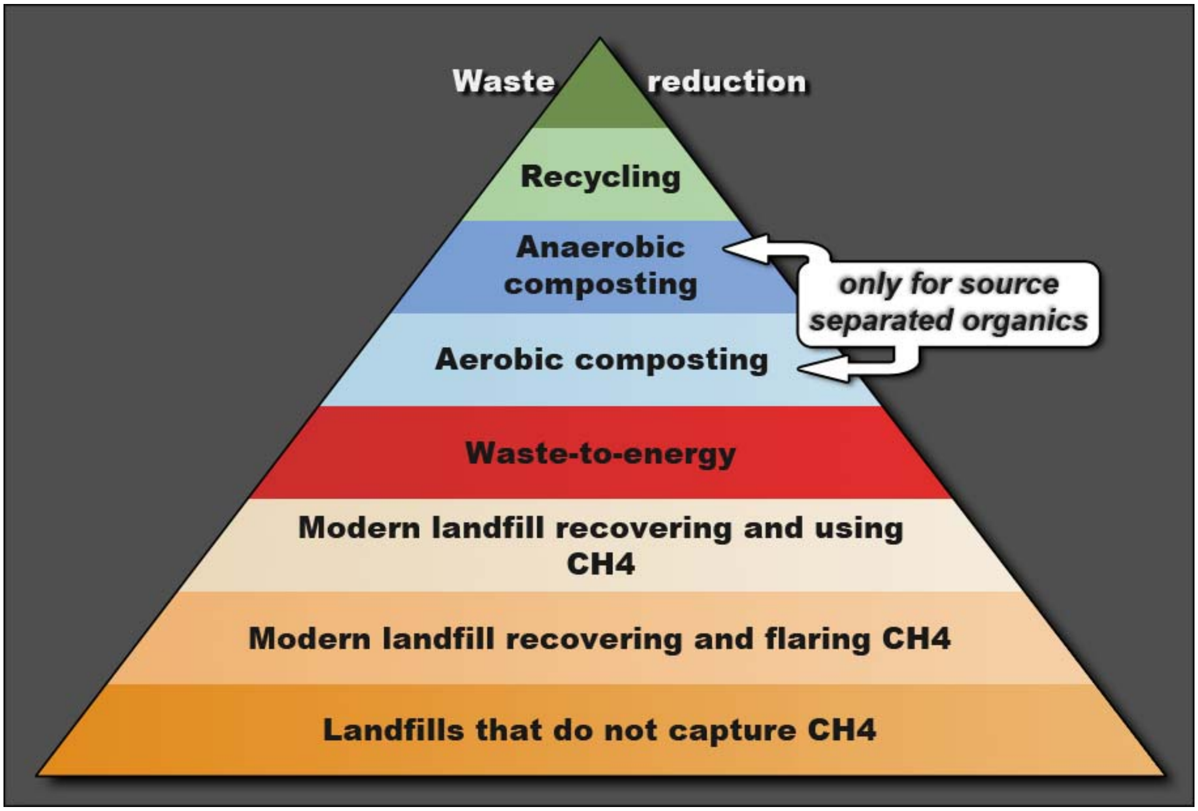


Figure 1 Expanded Hierarchy of Sustainable Waste Management[4]

1.3 Waste to Energy Fundamentals

There are three principal ways to recover the energy content of MSW by treating it thermally, as shown below. These include pyrolysis, gasification and combustion. These processes are differentiated by the ratio of oxygen supplied to the thermal process divided by oxygen required for complete combustion. This ratio is defined as the "lambda" ratio and in the case of pyrolysis, it is equal to zero. Gasification is conducted at substoichiometric conditions and full combustion is carried out using a lambda greater than one.

- Pyrolysis $\lambda = 0$, no air, all external heat
- Gasification $\lambda = 0.5$, partial use of external heat
- Combustion $\lambda = 1.5$ +, no external heat

where λ represents: oxygen input/ oxygen required stoichiometrically for complete oxidation of all organic compounds in MSW.

1.4 Operating Small Scale Technologies

This study is an analysis of various low capacity WTE technologies in operation and is based on information in the literature as well as contacts with operators of these plants. This includes an evaluation of plant capacity, technology, ownership and operation, capital and operating costs, plant footprint, environmental impacts, and overall benefits of these small scale plants. This paper concentrates on the most prominent of the technologies, the Energos technology. In addition to the analysis of Energos and the statistical analysis conducted from the 2006 International Solid Waste Association (ISWA) data set[6], other small-scale technologies which were investigated within this report are listed below in bold. It should be noted that the technologies listed in italics were investigated in 2004 by an Australian Company, CSIRO Technology[7]. It appears that very few investigations to date have been conducted specific to small scale waste to energy systems. As such, CSIRO Technology could provide for a good point of contact for the Waste to Energy Research and Technology Council.

Small Scale Operating Facilities:

- ***Energos (Norway)***
- **Novo Energy (USA)**
- **Envikraft (Denmark)**
- **Scan American Corp. (USA)**
- **KI Energy (Portugal)**
- **IST Energy (USA)**
- *Eddith Thermolysis (France)*
- *Foster Wheeler (Finland)*
- *Compact Power (UK)*
- *Naanovo Energy (Canada)*
- *Entech Renewable Energy Systems (Australia)*
- *Ntech Environmental (Spain)*
- *WasteGen (UK)*
- *TPS (Sweden)*

2 THE ENERGOS GRATE COMBUSTION AND GASIFICATION TECHNOLOGY

Energos is part of the ENER-G group, headquartered near Manchester, UK. This technology was developed in Norway in the 1990s in order to provide an economic alternative to mass-burn WTE with equally low emissions to the atmosphere and flexibility in feedstock. All operating plants treat MSW plus additional streams of commercial or industrial waste[8, 9]. The current operating plants range in capacity from 10,000 to 78,000 tons per year[10].

2.1 Technology Description and Emissions Abatement

The feedstock to an Energos plant is post-recycling MSW mixed with a smaller amount of other waste streams. These include industrial wastes and residues from materials recovery facilities (MRF). Prior to thermal treatment, the materials are shredded in a high-torque, low-rpm shredder and then ferrous metals are removed magnetically [9,11].

The Energos thermal treatment process consists of two stages: Partial oxidation and gasification of the waste in the primary chamber on a moving grate at sub-stoichiometric oxygen conditions (air to fuel ratio=λ=0.5-0.8) where combustion of the fixed carbon on the grate results in total organic carbon (TOC) of <3% in the WTE ash[9,12]. The volatile gases generated in the gasification chamber are then combusted fully in an adjoining chamber and the heat in the combustion gases is transferred to steam in a heat recovery system. Temperatures reach up to 900^{o}C in the gasification chamber and up to 1000^{o}C in the oxidation chamber[9]. Formation of NOx is kept relatively low (at about 25 % of the EU limit)[13], any dioxins in the feed are destroyed in the combustion chamber, and the rapid cooling achieved in the energy recovery system minimizes formation of dioxins. The schematic diagrams of the Gasifier and Thermal Oxidizer, and Heat Recovery Steam Generation units are shown in Figures 2 and 3, respectively.

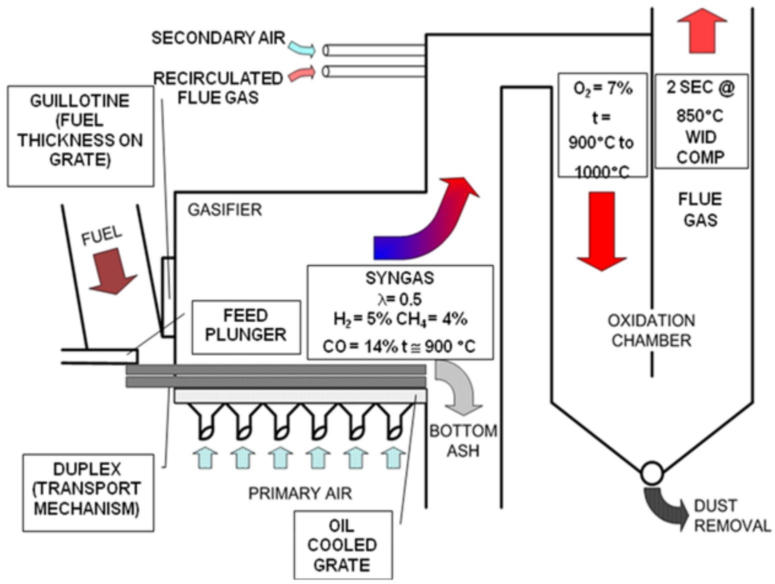


Figure 2 Energos Gasifier and Thermal Oxidizer[9,12]

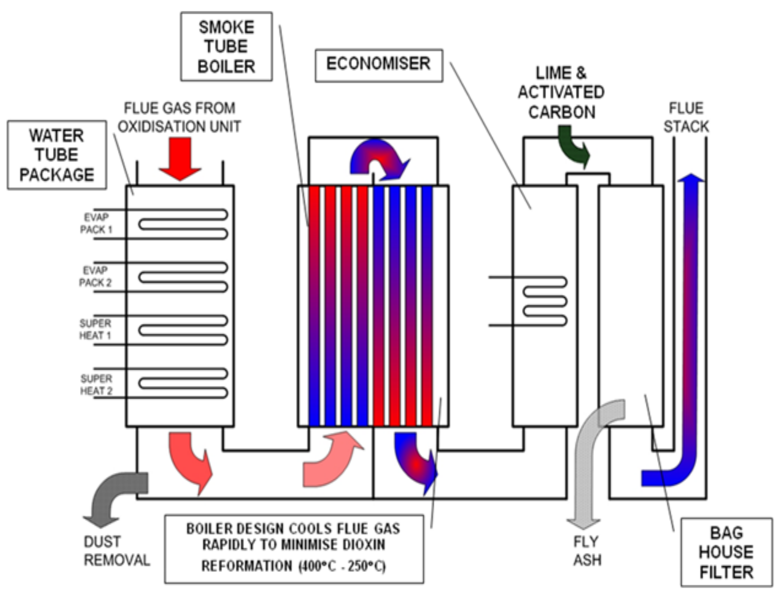


Figure 3 Energos Heat Recovery Steam Generation (HRSG) [9,12]

Downstream of the heat recovery steam generator (Figure 3), the flue gas enters the dry flue gas cleaning system that consists of dry scrubbing with lime, activated carbon injection, a bag filter, and a filter dust silo[13]. The lime absorbs acidic compounds in the flue-gas and the activated carbon adsorbs dioxins and heavy metals[14]. Emissions are monitored continuously. Table 1 shows typical emission measurements at the Energos Averoy Plant in Norway. These measurements were taken by an independent agency (TUV NORD Umweltschtz)[8] for the Norwegian Environmental Agency and are reported at 11% oxygen[8].

Table 1 Energos Emissions Summary[8]

Parameter	EU Limits, mg/Nm^3	Energos
Dust	10	0.24
Hg	0.03	0.00327
Cd + Tl	0.05	0.00002
Metals	0.5	0.00256
CO	50	2
HF	1	0.02
HCl	10	3.6
TOC	10	0.2
NOx	200	42
NH3	10	0.3
SO2	50	19.8
Dioxins, ng/Nm^3	0.1	0.001

2.2 Operating Energos Plants

The reported availability of the operating Energos plants is about 90% (8,000 hours per year)[8]. There are six plants in Norway, one in Germany, and one (retrofitted plant) in the UK. In addition, there are plans for six new plants in the UK by 2013 [10,14] of 80,000-100,000 tons capacity [15]. A summary of the existing Energos plants, thermal energy generation, and capital costs is provided in Table 2.

Table 2 Operating Energos Plants [9, 10, 15]

Plant Location (start up year)	Waste Input Streams	Total Annual Capacity, tons (no. of lines)	Approximate Site Area (m^2) [1]	Thermal Energy Produced (MWh/year)	MWh,th per ton	Investment per ton of annual capacity[2]	Investment per MWh, th produced
Ranheim, Norway (1997)	Paper mill rejects + various commercial wastes	10,000 (1)	N.A.	25,000	2.5	$1,350	$540
Averoy, Norway-Nordmore Region (2000)	Mixed MSW + various commercial wastes	30000 (1)	6,000	69,000	2.3	$1,033	$450
Hurum, Norway (2001)	Mixed MSW + commercial waste from airport + paper rejects	39000 (1)	6,000	105,000	2.7	$657	$238
Minden, Germany (2001)	50% Residual MSW + RDF (paper and plastic waste)	39000 (1)	6,000	105,000	2.7	$673	$243
Forus, Norway-Stavanger Region (2002)	Residual MSW + commercial wastes	39000 (1)	6,000	105,000	2.7	$825	$314
Sarpsborg 1, Norway (2002)	MSW + commercial wastes	78000 (2)	9,000	210,000	2.7	$525	$195
Sarpsborg 2, Norway (2010)	MSW + commercial wastes	78000 (2)	9,000	256,000	3.3	$525	$195

[1] *Since site area is project specific, approximate site area has been estimated by use of the following data provided by Energos: Single Line site area is 6,000 sq meters and double line site area is 9,000 sq meters. The data shown in this Table will be further refined during continuing thesis research.*
[2] *Assuming Investment per ton for Sarpsborg 2 Plant is the same as Sarpsborg 1.*

2.3 Economics

The Energos plants are reported to have treated over 1.8 million tons of post-recycling wastes and produced 3,800 GWh (both thermal and electric). This has resulted in a reduction of greenhouse gas (GHG) emissions, over landfilling, by an estimated 990,000 tons of equivalent carbon dioxide emissions[10]. As shown in Table 2, the Sarpsborg plants are the least capital-intensive Energos plant with reported capital investment of $525 per ton of annual capacity and $195 per MWh of thermal energy produced. Figure 4 shows the capital investment and thermal energy recovery at seven Energos plants of various capacities.

As expected, the capital cost per ton of annual ton of capacity increases with decreasing plant capacity, while there is a linear relationship between energy recovery and capacity. However, it is believed that low capacity plants can be built at a capital cost per ton that is as low, or even lower, as that of large mass burn WTE facilities.

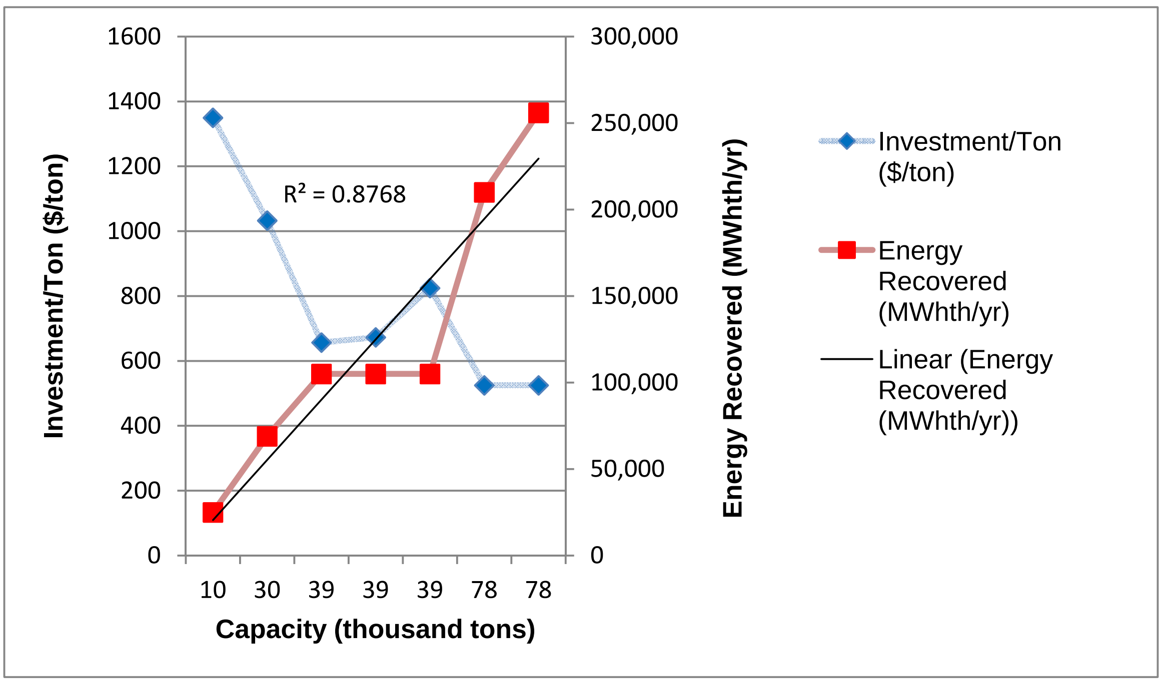


Figure 4 Energos Performance

2.4 Ownership and Operation of Existing Energos Plants

Energos works with various waste management companies, local authorities and industries. Energos provides district heating as well as steam to local industries, including chemical, pharmaceutical, paper, and food processing plants[16]. Table 3 below provides information regarding the ownership and waste and energy contractual arrangements of the Energos plants in Norway and Germany.

Table 3 Energos Ownership and Operation [17, 18, 19, 20]

Plant Location	Ownership	Ownership Description	Waste Contracts	Waste Contract Description	Energy Contracts	Energy Contract Description
Ranheim, Norway	100% Energos	See ownership	Peterson Ranheim Linerboard + Local Commercial Waste	Peterson Ranheim is a local paper mill.	Peterson Ranheim Linerboard	See energy contract description.
Averoy, Norway (Nordmore Region)	90% Energos + 10% NIR	NIR is the Nordmore Region's waste management network	MSW from NIR + Local MSW and Commercial Waste	See ownership description	Skretting AS	Local Fishmeal Plant
Hurum, Norway	100% Daimyo AS	Privately owned waste management, energy and recycling business	MSW from ROAF, Commercial waste from OSL , Paper Rejects from Various Companies	ROAF is a waste management company. OSL is a waste supplier at the Oslo Airport	Hurum Fabrikker AB	Paper Manufacturer
Minden, Germany	100% AML Immobilien GmbH	Provides waste management services	50% residual waste from local municipalities and 50% from GVR	GVR is the operator of Mubeck MBT	BASF	Chemical Company
Forus, Norway (Stavanger Region)	44.5% Lyse Energi, 44.5% IVAR IKS, 11% Westco	Westco offers waste disposal services	Residual MSW from IVAR IKS and local commercial waste	IVAR IKS is a paper manufacturer	Lyse Energi AS	Local Energy Company
Sarpsborg I, Norway	100% Ostfold Energi AS	Local Energy Company	Various Local Municipal and Commercial Waste	See waste contracts	Borregaard Fabrikker AS	Chemical Company
Sarpsborg II, Norway	100% Hafslund ASA	Utility Company	See ownership description	See ownership description	Borregaard Fabrikker AS	Chemical Company

2.5 The Energos Plant at Forus, Norway (Stavanger Region)

In an effort to reduce landfilling, IVAR ("Waste Disposal Authority") provides the Stavanger region of Norway (population: 120,000) with a waste management system that is based primarily on source separation[8]. Households in the Stavanger region are provided with four bins[8]:

a) Garden and kitchen waste.
b) Paper and cardboard.
c) Hazardous materials, batteries, paint, oil etc.
d) Residual waste.

Garden and kitchen wastes are collected and delivered to a composting plant; paper and cardboard are recycled. Households are encouraged to recycle bulky waste at "household recycling centers[11]." The Stavanger household waste collected in 2007 and its composition are shown in Table 4 and Figure 5, respectively.

Table 4 Stavanger Household Waste Collected in 2007[21]

Waste Category	Total (tons)
Organic Waste	14,160
Paper	9,412
Glass	1,121
Plastics	463
Metal	1,356
Textiles	780
Hazardous Waste	173
WEEE	1,994
Wooden Objects	3,970
Total Material Recycling	33,429
Residual Waste for Energy Recovery	17,930
Total	51,358
Material Recycling	**65%**

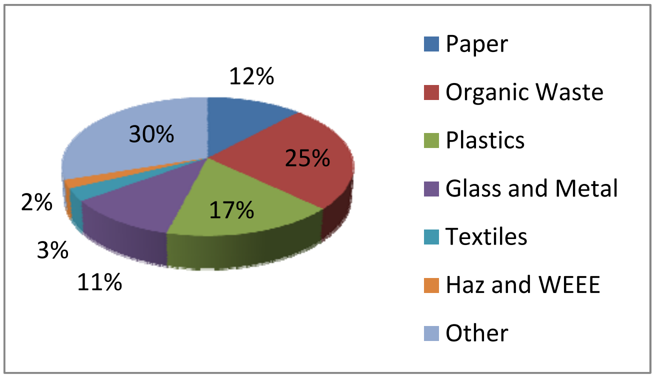


Figure 5 Composition of Stavanger Residual Waste (2007)[21]

As noted in Tables 2 and 3, the Stavanger WTE plant opened in 2002 in partnership with Lyse AS, the local energy company. Table 2-4 showed that recycling and composting reduce the municipal solid waste of Stavanger to less than 18,000 tons/year. The other 21,000 tons treated at the Energos plant are non-recyclable industrial residues from the region.

The Stavanger, Forus plant is a combined heat and power (CHP) system. During periods of low heat demand, steam is used to produce electricity and this electricity is then sold to the grid and used by local consumers. Electricity income is enhanced by "renewable obligation certificates" (ROCs)[11].

3 NOVO ENERGY

Novo Energy is a WTE company headquartered in Colorado and holds the patents and licenses for what was the Barlow technology package[22]. The technology is currently implemented in four states (Minnesota, Oklahoma, Virginia, and Pennsylvania)[23]. The Novo Energy technology is in small scale operation at the Pope Douglas Resource Recovery Facility in Minnesota with an annual combustion capacity of 39,600 tons[24] and the Harrisonburg Resource Recovery Facility in Virginia with an annual combustion capacity of 66,000 tons [25].

3.1 NOVO Energy Inclined Fixed Grate Combustion Technology

The feedstock of this system moves by gravity, utilizing an inclined grate, where the waste moves down the surface of the combustion chamber using timed pulses of air. The pulsing action ensures maximum burnout and facilitates migration of the waste down the inclined surface of the combustion chamber. The pulse technology is depicted in Figure 6, below. An advantage of this system is that it utilizes no moving parts in the combustion zone, thereby minimizing maintenance issues and costs[22].

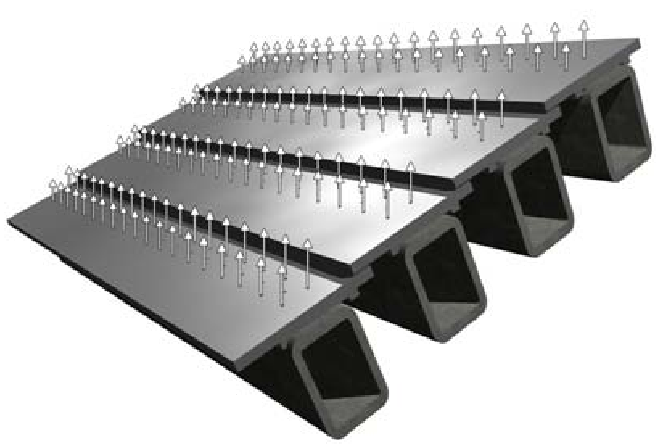


Figure 6 Aireal® Pulse Technology[26]

A series of the pulse technology comprises an entire grate system as depicted in Figures 7 and 8, below.

Figure 7 Series of Aireal® Pulse Technology Segments[26]

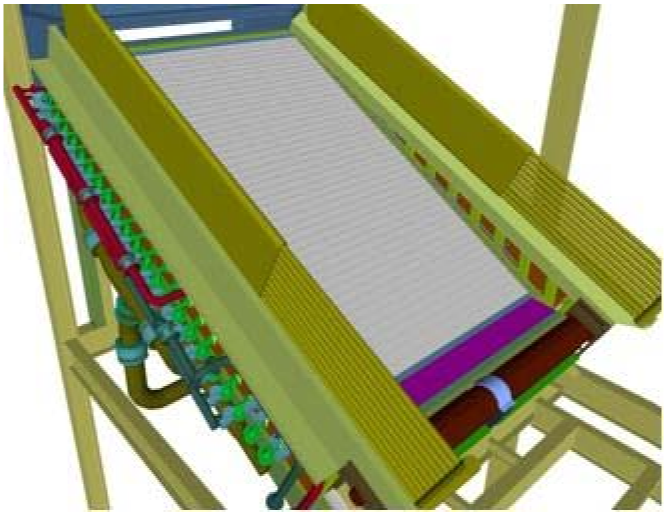


Figure 8 Novo Energy Inclined Fixed Grate[26]

3.2 NOVO Energy-Pope Douglas Resource Recovery Facility (Minnesota)[24]

- Currently undergoing expansion to double facility capacity (80,000 tons/yr)
- **Service Area**: Pope and Douglas Counties, MN
- **Owner/Operator**: Pope-Douglas Solid Waste
- **Financing**: Authority Funds
- **Combustion System**: Mass Burn, Refractory lined, Aireal® Combustion System (ACS)
- **New Expansion Process Line**: 1
- **Additional Generating Capacity**: 1000 kW
- **Steam Capacity**: 60,000 lbs/hr

- **Steam Customer**: 3 M Manufacturing & Douglas County Hospital
- **Material Recovery**: Existing
- **Air Quality Control**: Dry Sorbent Injection, fabric filter, CEMS

3.3 NOVO Energy-Harrisonburg Resource Recovery Facility (Virginia)[25]

- **Current capacity is 66, 000 tons/yr**
- **Service Area**: City of Harrisonburg and Rockingham County, VA
- **Owner/Operator**: City of Harrisonburg, VA
- **Financing**: Municipal Bond
- **Combustion System**: Mass Burn, Refractory lined, ACS
- **Process Lines**: 2
- **Steam Capacity**: 57,000 lbs/hr
- **Steam Customer**: James Madison University
- **Material Recovery**: Post Combustion Ferrous Metal Recovery
- **Air Quality Control**: All dry scrubbing system, carbon injection, fabric filter, CEMS

4 SMALL SCALE PLANTS IN JAPAN

Japan has made a significant impact worldwide in the development and implementation of thermal treatment processes. Japan thermally treats over 60% of the approximately 65 million tons of MSW it generates, and recycles the remaining 40%[27]. Though the majority of Japan's thermal treatment systems utilize the well-known Martin Grate combustion technology, there are several which do not and also operate in small scale, providing further proof that WTE can be economical in low capacity. These data are shown in Table 5, below.

Table 5 Small Scale Thermal Treatment Technologies Used in Japan[27]

Technology	Number of plants	All plants, tons/day	Average tons/day per plant
JFE Volund grate (stoker)	54	10,100	187
Nippon Steel Direct melting	28	6,200	221
JFE Hyper Grate (stoker)	17	4,700	276
Rotary kiln	15	2,500	167
JFE Thermoselect (gasification)	7	1,980	283
All other fluid bed	15	1,800	120
Ebara fluid bed	8	1,700	213
JFE Direct Melting (shaft furnace)	14	1,700	121
Hitachi Zosen fluid bed	8	1,380	173
JFE fluid bed (sludge & MSW)	9	1,300	144
All other Direct Melting	9	900	100
Fisia Babcock (2 forward, 1 roller grate)	3	710	237
Babcock & Wilcox air cooled grate	43	690	16

5 MODULAR AND MICROSCALE SYSTEMS

The author has defined micro-scale waste to energy systems as those systems with a capacity in the order of 1,000 tons/year. It should be noted that many of these systems are "modular" in design, in that the units are mobile and therefore can be assembled where needed[28].

Similar systems which were not analyzed in detail in this report and that have only recently been developed for military applications include: Ontario based Eco Waste Solutions and Idaho based Dynamis Advanced Mobile Waste and Power Stations[29, 30].

5.1 KI Energy

KI Energy is a microscale scale MSW and biomass WTE company [31, 32]. KI Energy's systems include the following technologies[33]:

- Fixed Bed Gasifier
- Fluidized Bed Gasifier
- Fluidized Bed Combustor

One of the authors of the paper recently visited a KI Energy Plant at the Marmara Research Center near Istanbul, Turkey. The site visit included a tour of a microscale fixed bed gasifier (pictured in Figure 9) with a mixed feedstock of biomass and low value heating coal.

5.1.1 KI Energy Micro Scale Fixed Bed Gasifier Design Details[32]:

- **Feedstock:** Biomass (Woodwaste, Hazel nutshells) and Lignites
- **Fuel Feeding Rate:** 1100 ton/yr
- **Thermal Capacity:** 300 kWth
- **(Electricity) Production:** 50 kWe
- **Commissioning Date:** 2008
- **Investment Cost:** 750,000 euros

Figure 9 Micro Scale Fixed Bed Gasifier

5.1.2 Fixed Bed Gasification Technology Description

There are two types of fixed bed gasifiers: counter current and co-current. These systems differ in terms of the direction of gas flow. Current development of these technologies focuses on solving issues such as fuel feeding, gas cleaning, and the treatment of by-products[34].

In the fixed bed, gasification occurs in four different zones for the following different gasification reactions:

- Drying
- Pyrolysis
- Oxidation
- reduction

These four reactions take place within different layers of the fuel bed and with increasing temperature.

Figure 10 below shows both co-current/downdraft gasification (on the left) and counter-current/updraft gasification (on the right).

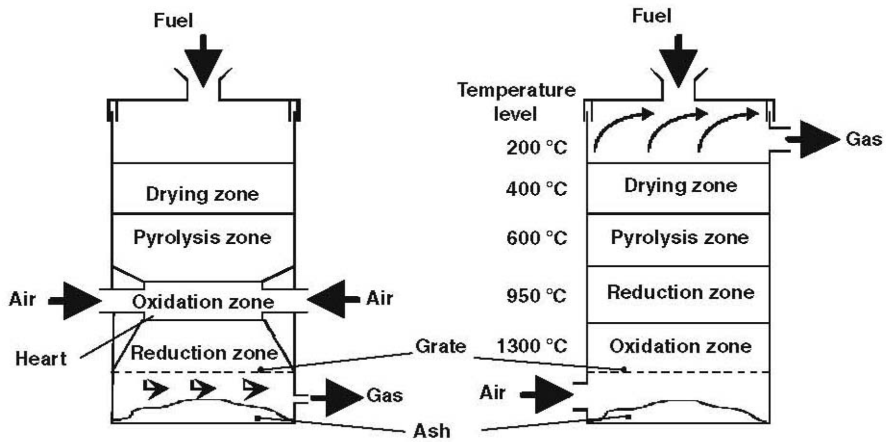


Figure 10 Downdraft and Updraft Gasification[34]

5.1.2.1 Counter-Current Gasification (Updraft Gasifier)

The most common design for the counter-current (or updraft) gasifier is the vertical reactor. Here, the fuel is fed from the top of the reactor and the air is fed from the bottom. The opposing fuel and gas flows within the reactor separate the reaction zones. The term "updraft gasification" stems from the rising gas produced from within the reactor, which exits from the top. These counter-current gasifiers have the advantage of not requiring the pre-processing of fuel. Therefore, these systems can accept a variety of fuel types, sizes, and moisture contents. However, the disadvantage of these systems is that the volatile matter gasified in the pyrolyis zone becomes part of the rising gas and therefore contains a large amount of tar products[34].

5.1.2.2 Co-Current Gasification (Downdraft Gasifier)

In co-current gasification, the fuel and the gas move in the same direction. Here, the gas stems from the bottom of the reactor, which is why it is often referred to as "downdraft gasification." With this type of system, the heat transfer between the feedstock and the gasifying agent is less than it is with counter-current gasification and therefore, the gasification efficiency is lower. Also, due to the higher temperatures in the oxidation zone, there is a greater chance for slag to form within this co-current gasification system than within the counter-current gasification system[34].

Co-current gasifiers also require more fuel preparation than the counter-current gasifiers. However, the gas produced within this system contains much less tar than the counter-current gasifiers, which is a significant advantage[34].

5.1.3 Fluidized Bed Technology

In a fluidized bed reactor, gas flows upward through the bottom of a vertical cylinder at a flow rate which gradually increases. Dependent upon the air velocity, the bed will undergo either a fixed bed form of fluidization (as described above in Section 5.1.2), a "bubbling fluidized bed" (BFB) or "circulating fluidized bed" (CFB). With a BFB, the gas flow increases to a point where the particles lift and the bed of solids "bubble" similar to a boiling liquid[35]. In a CFB, the gas velocity is increased to a point high enough that the majority of MSW particles are lifted up by the gas flow[35]. This increase in pressure drop with increasing gas flow is illustrated in Figure 11, below.

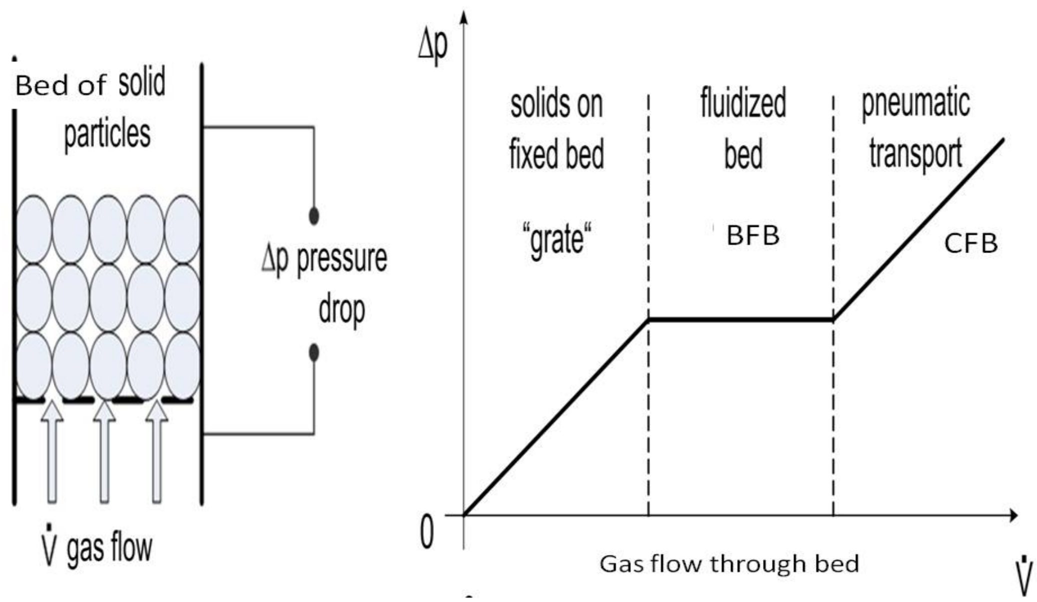


Figure 11 Increasing Pressure Drop with Increasing Gas Flow for Grate, BFB, and CFB Systems[35]

5.2 Envikraft/Scan American Corp.

Envikraft is a Danish engineering company specializing in small scale modular waste to energy systems which co-treat MSW, industrial and hazardous waste. This system can be provided for 1-20 MW thermal input capacities[36].

5.2.1 Envikraft/Scan American Corp.-Senja Avfall, Norway Plant Data16

The data below was supplied to the EEC for the operating facility in Norway. This plant meets Canadian A-7 and EU emission standards[37].

- Plant Capacity: 16,000 tons/yr
- Waste Calorific Value: 11.5 MJ/kg
- Steam Production: 7,150 kg/h

- Heat Production: 4.7 MW
- Power: 350 kW
- Thermal Output: 5.1 MW
- Bottom Ash : 20%
- Fly Ash: 0.7%

5.2.2 Envikraft/Scan American Corp. Technology Description

The Envikraft Technology is a fixed hearth incineration system[38]. This process utilizes horizontal ram pushing for waste feeding and rotating augers above the incinerator bed in order to mix the waste and provide for complete ash burnout. The auger system is pictured below in Figure 12.

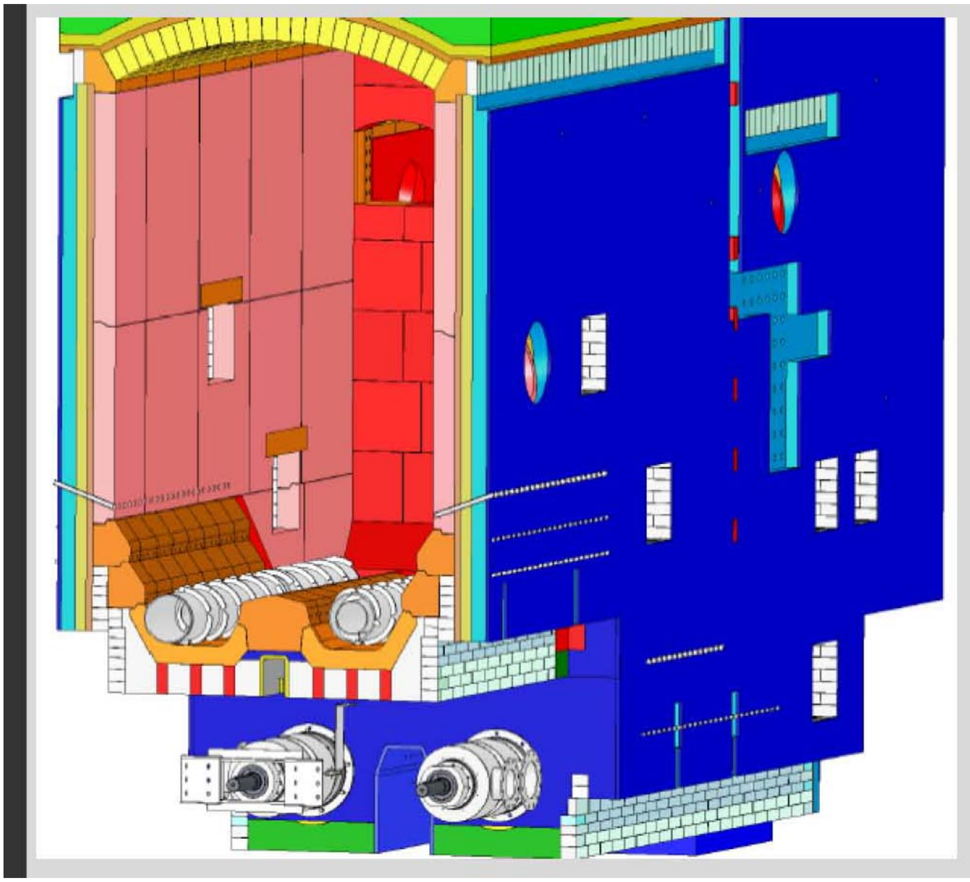


Figure 12 Envikraft Auger System[36]

5.3 IST Energy GEM

IS Energy, headquartered out of Massachusetts, provides a mobile microscale downdraft gasification system which is about the size of a large garbage dumpster (as shown below in Figures 13 and 14). Two units which had been functioning as the demonstration models at the company's headquarters have recently been sent to the Edwards Air Force Base in California and to the Plymouth County Correctional Facility in Massachusetts for operation[39].

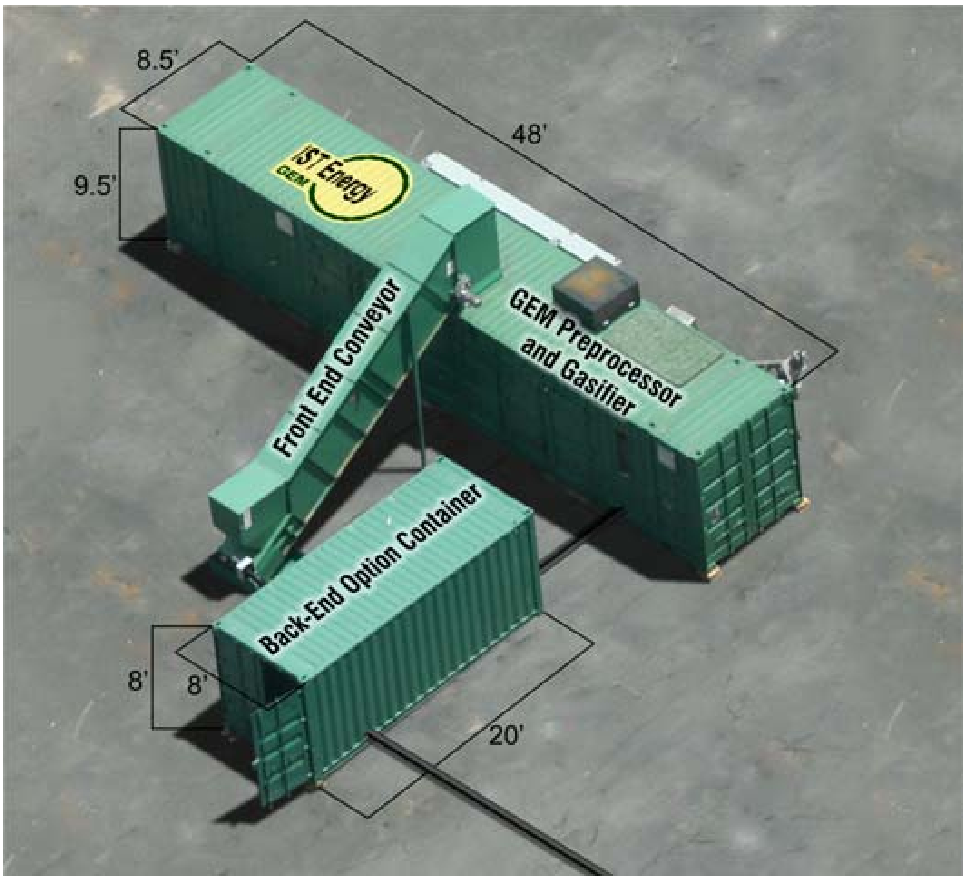


Figure 13 IST Energy's Mobile GEM 3T120 Gasification System[40]

Figure 14 Energy's Mobile GEM 3T120 Gasification System[41]

Table 6 Specifications for the IST Energy (Microscale) Mobile GEM 3T120 Gasification System[40]

Capacity	3 tons/day
Waste Conversion Rate	200 lb/hr dry
Allowable Moisture Content of Waste	5% to 40%
Nominal Pellet Size	Approx. 1/2"diameter
Combined Heat and Power (CHP) Efficiency	up to 60%
Net Electrical Output - CHP	72 kWe[1]
Net Thermal Output - CHP	614,000 Btu/hr[1]
Net Thermal Output - Boiler	1,200,000 Btu/hr[1]
Max Gasification Temperature	1650° F
Motive Force for Gas Movement	Blower or Engine Vacuum
Gas Cooling Method	Gas-to-Air Heat Exchanger
Gas Cleaning Method	Dry Filter
Solid Waste Constituents	Ash + Small Amount of Char (5% by weight)
Tar Content After Gas Cleaning Operations	< 250 ppm
Nominal Gas Energy	180 Btu/Std ft^3
Combustible Gas as % of Total Gas Output	20% CO; 14% H_2; 7% CH_4

6 SMALL SCALE PLANTS STATISTICAL ANALYSIS FROM ISWA DATA SET

Grate combustion is also used in small scale WTE plants that serve populations as small as 10,000 people. Number of Plants vs Plant Capacity in Europe6, [27]
is an analysis of 2004 data compiled by the International Solid Wastes Association (ISWA)[6]. It should be pointed out that the number of ISWA plants totals 431, but capacity data was submitted for only 331 plants. For example, pages 5 and 13 of the "*Energy from Waste State of the Art-Report Statistics 5th Edition, August 2006," International Solid Waste Association, Working Group on Thermal Treatment of Waste*" show a total number of plants in Austria to be nine, though "total incinerated waste quantity data" is only submitted for four plants in Austria (page 18 of ISWA report). The tabulation and analysis for the 331 plants is provided in Appendix 1, Table 10 -Analysis of All Data Compiled in ISWA Compilation of 2004 WTE Data.

The plant capacities of these plants were divided in segments of 0-50,000, 50,000-100,000 tons, etc. and the results are plotted in the form of number of plants vs. capacity range. It was determined that 83 plants (about 25% of the total number of ISWA plants for which capacity data was submitted) have an annual capacity of less than or equal to 50,000 tons (roughly less than 100,000 people) and 85 plants have an annual capacity between 50,000 and 100,000 tons (both of these data points are circled below in Figure 15). As such, over half of the ISWA plants are operating in small scale (Figure 16).

The cumulative capacity of these small scale plants is just over 8.5 million tons of feedstock combusted (dotted arrow in Figure 15). The cumulative capacity of the total number of ISWA plants was about 50 million tons (solid line in Figure 15).

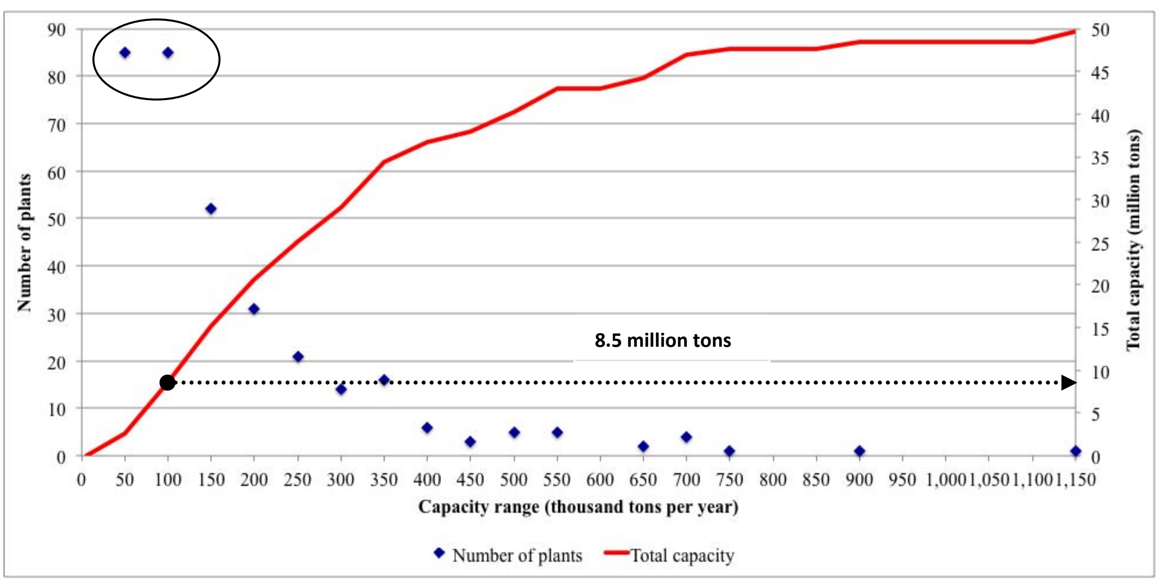


Figure 15 Number of Plants vs Plant Capacity in Europe[6, 27]

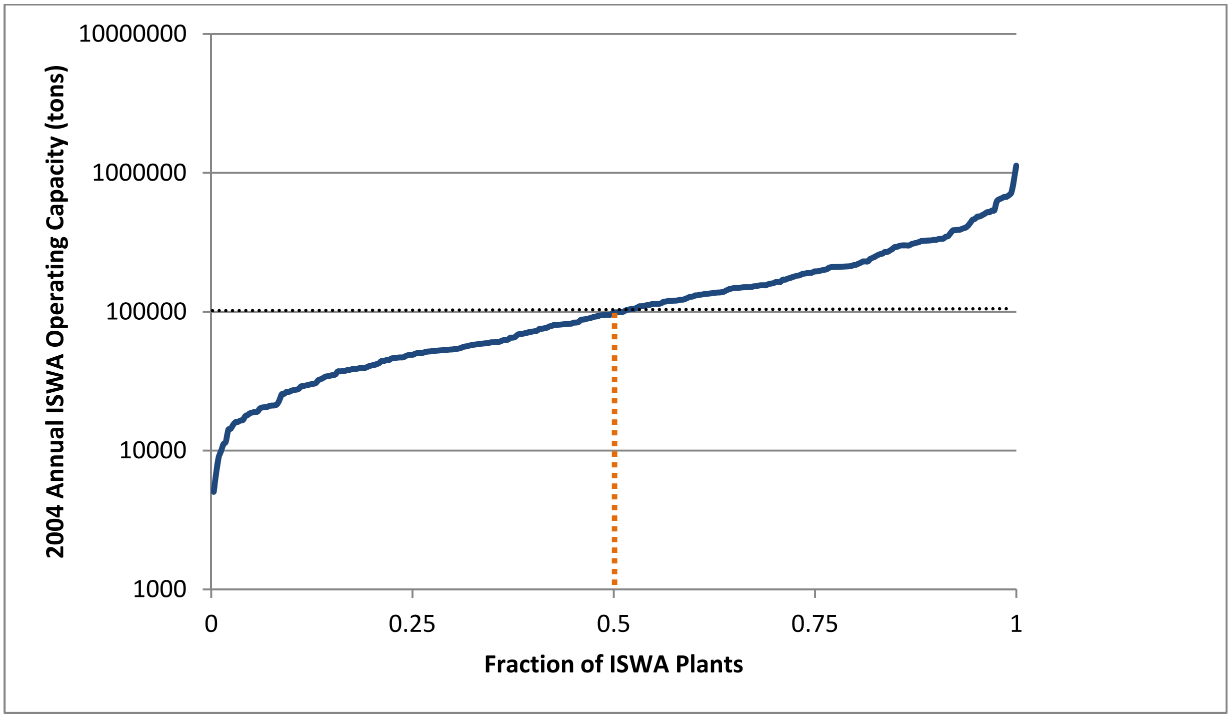


Figure 16 Fraction of Small Scale Plants in Europe

By separating and analyzing the ISWA data further in terms of plants which co-combust MSW with wastes other than commercial and industrial types of waste (i.e., sludge, hospital waste, and RDF), it was concluded that 33% of all the European co-combustion plants (including large scale plants >100,000 tons annual capacity) are small scale plants which co-combust hospital waste, as depicted in Figure 17. Also, per ISWA's 41 plants which co-combust hospital waste, 59% are of low capacity (Figure 18). The data associated with these 24 plants are provided below in Table 7.

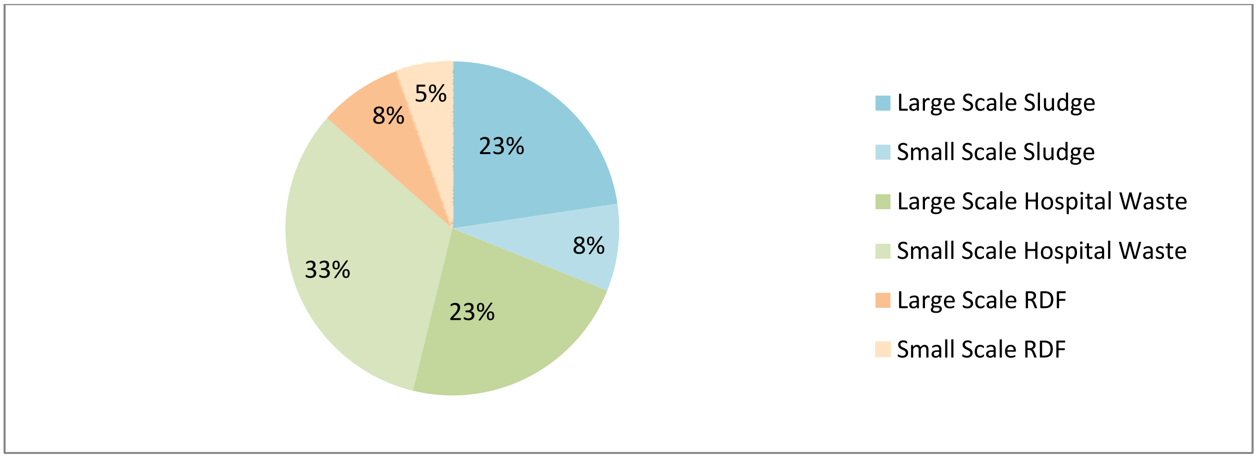


Figure 17 ISWA Small Scale vs ISWA Large Scale Co-Combustion

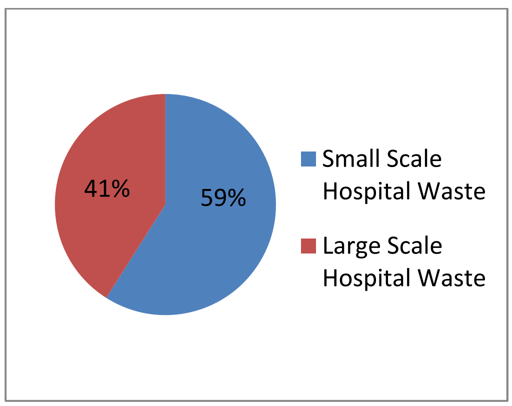


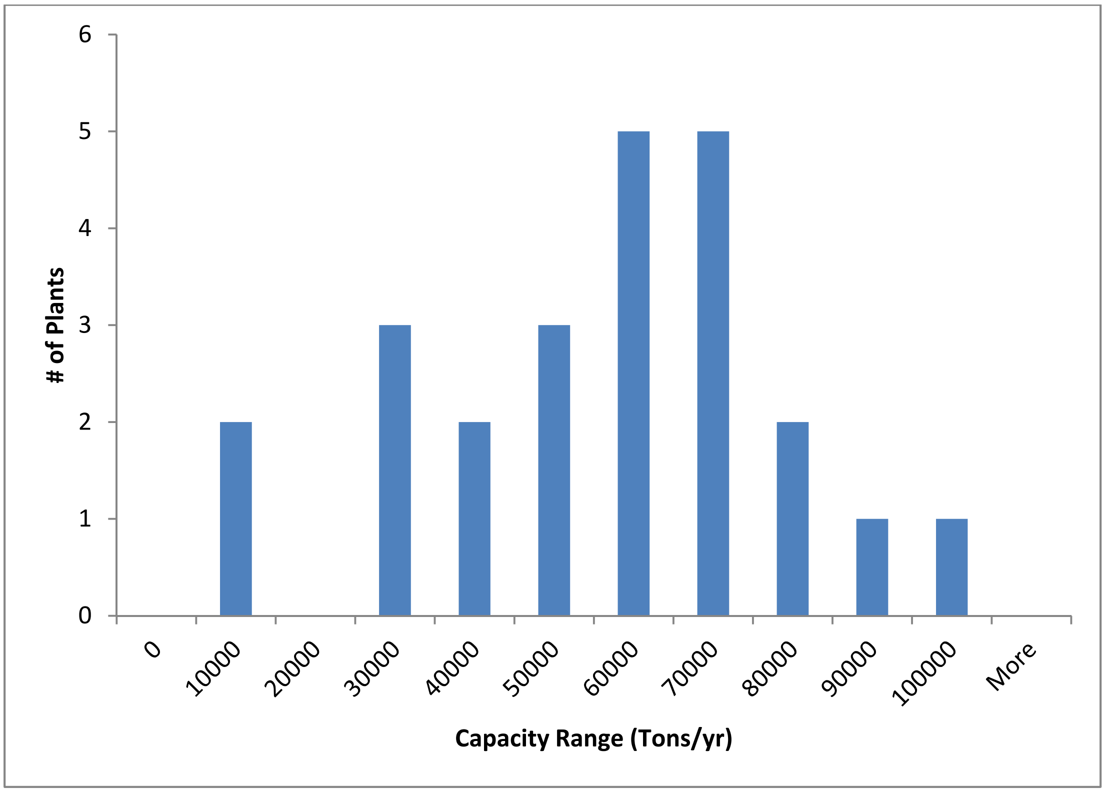
Figure 18 ISWA Small Scale vs ISWA Large Scale Facilities Co-Combusting Hospital Waste

Table 7 ISWA Small Scale Co-Combustion of Hospital Wastes

Country	Plant Name	Total, tons/y	Hospital Waste, tons/y	% of Hospital Waste
Belgium	Gent	94383	475	0.50%
Belgium	Houthalen	69195	1700	2.46%
Denmark	Hjørring	61270	479	0.78%
Denmark	Svendborg	54000	400	0.74%
France	Douchy les Mines	39295	3530	8.98%
France	Villefranche sur Saône	78301	287	0.37%
Germany	Kempten	76661	514	0.67%
Germany	Neustadt	59449	668	1.12%
Great Britain	Shetland Islands	21511	16	0.07%
Italy	Cremona	64996	529	0.81%
Italy	Desio (MI)	49019	3152	6.43%
Italy	Ferrara	20500	613	2.99%
Italy	Melfi PZ)	47000	2000	4.26%
Italy	Ospedaletto (PI)	57944	3525	6.08%
Italy	Padova	60376	2992	4.96%
Italy	Rufina/Pontassieve (FI)	9878	31	0.31%
Italy	Schio (VI)	57470	4700	8.18%
Italy	Terni	27000	1200	4.44%
Italy	Valmedrara (LC)	62300	5600	8.99%
Italy	Vercelli	58890	2600	4.42%
Norway	Frederikstad	80381	760	0.95%
Norway	Lenvik	5050	120	2.38%
Norway	Spjelkavik	34658	210	0.61%
Sweden	Karlskoga	42600	200	0.47%
Total # of Plants		Total MSW, tons	Total Hospital Waste, tons	Hospital Waste as % of total wastes
24		**1,232,127**	**36,301**	**2.95%**

It was demonstrated in Figure 19 below that most small scale plants that co-combust hospital waste have an annual capacity between 60,000 and 80,000 tons.

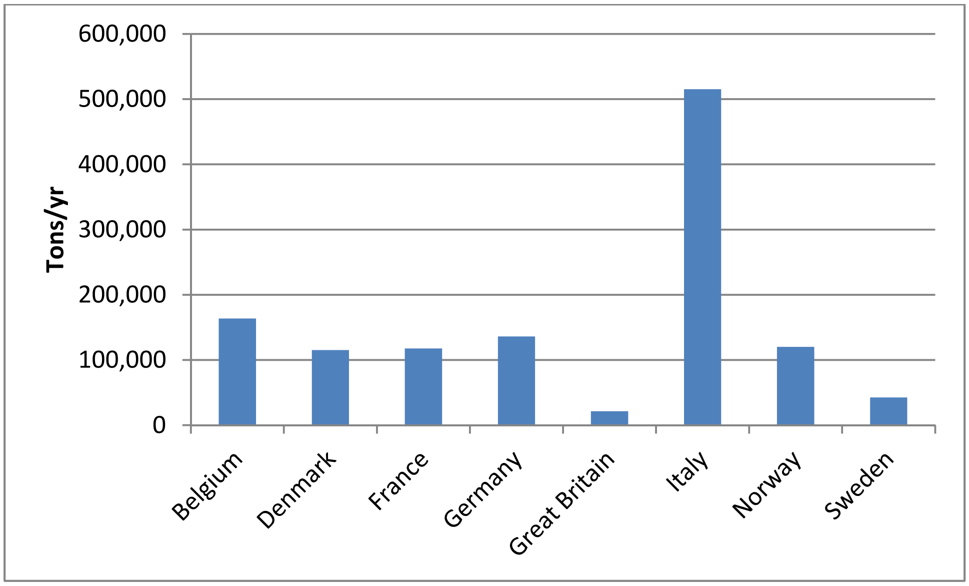
Figure 19 Histogram Small Scale Co-Combustion of Hospital Waste



Additional analysis in terms of ISWA small scale co-combustion of hospital waste is visually presented in Figures 20 and 21.

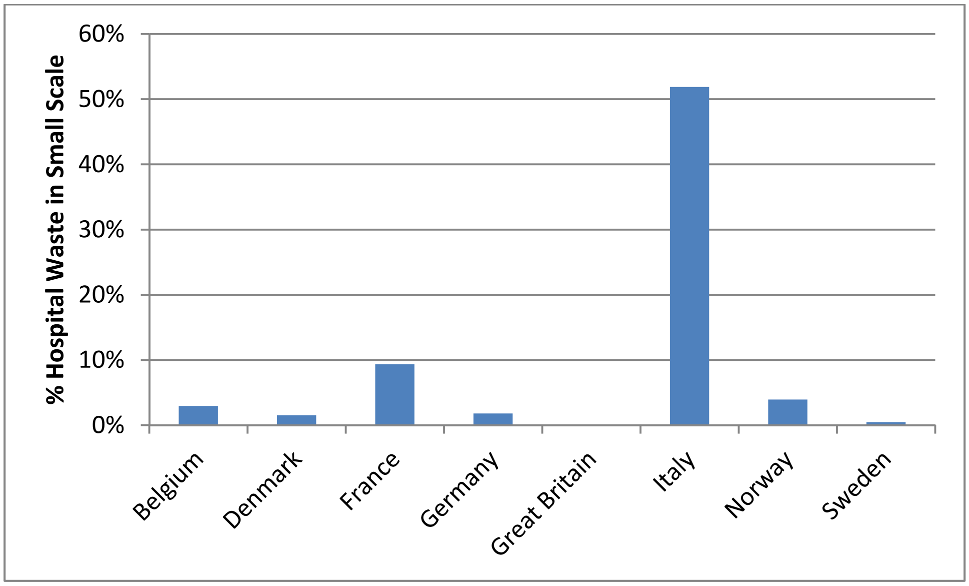
In Figure 20, the cumulative total small scale MSW annual capacity for those plants that co-combust hospital waste was plotted with respect to the ISWA country performing the small scale co-combustion of hospital waste. Figure 20 shows that Italy dominates in terms of small scale co-combustion of hospital wastes.

Figure 20 Cumulative Small Scale Capacity vs European Country Co-Combusting Hospital Waste in Small Scale



In Figure 21, the cumulative % of hospital waste co-combusted in small scale was plotted with respect to the ISWA country performing this form of co-combustion in small scale. It can be seen below that Italy's percent distribution of small scale co-combustion of hospital wastes also dominates at over 51%.

Figure 21 Cumulative % of Hospital Waste in Small Scale vs European Country



Also, from the 24 plants in the ISWA survey that reported co-combusting MSW and sludge cake from wastewater treatment plants, 25% are of low capacity, ranging from 50,000 to 79,000 tons per year. The sludge co-combusted ranged from 0.2% to 12% of the total feed. The data for these six plants are provided below in Table 8.

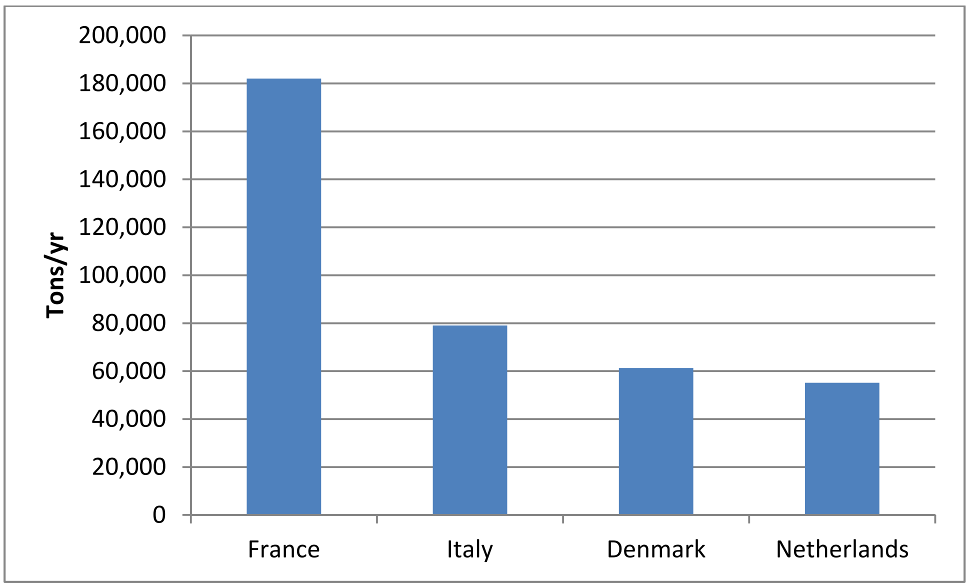
Table 8 ISWA Small Scale Plants Co-Combusting Sludge

Country	Location	Total tons/y	Sludge, tons/y	% of Sludge Co-combusted
Denmark	Hjørring	61,270	2,735	4.46%
France	Arrabloy	53,707	3,091	5.76%
France	Besançon	50,000	6,000	12.00%
France	Villefranche sur Saône	78,301	1,004	1.28%
Italy	Macomer (NU)	79,000	500	0.63%
Netherlands	Roosendaal	55,166	99	0.18%
Total (6 Plants Reporting)		**377,444**	**13,429**	**3.56%**

Additional analysis in terms of ISWA small scale co-combustion of sludge is visually presented in Figures 22 and 23.

In Figure 22, the cumulative total small scale MSW annual capacity for those plants that co-combust sludge was plotted with respect to the ISWA country performing the small scale co-combustion of sludge. Figure 22 shows that France dominates in terms of small scale co-combustion of sludge.

Figure 22 Cumulative Small Scale Capacity vs European Country Co-Combusting Sludge in Small Scale



In Figure 23, the cumulative % of sludge co-combusted in small scale was plotted with respect to the ISWA country performing the small scale co-combustion of sludge. It can be seen below that France's percent distribution of small scale co-combustion of sludge also dominates at 19%.

Figure 23 Cumulative % of Sludge in Small Scale vs European Country

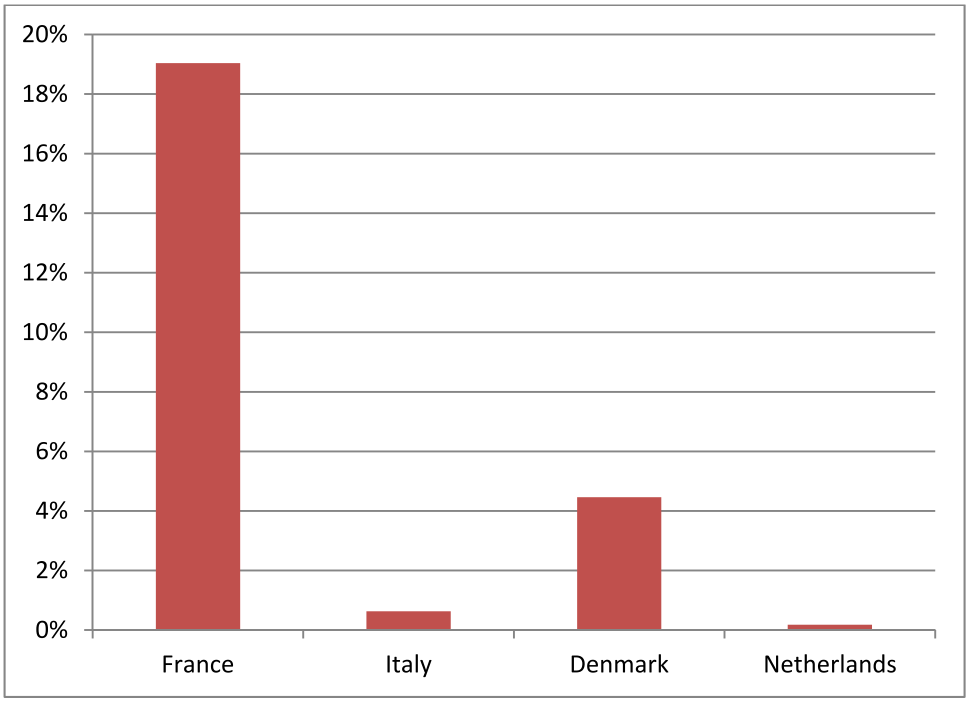
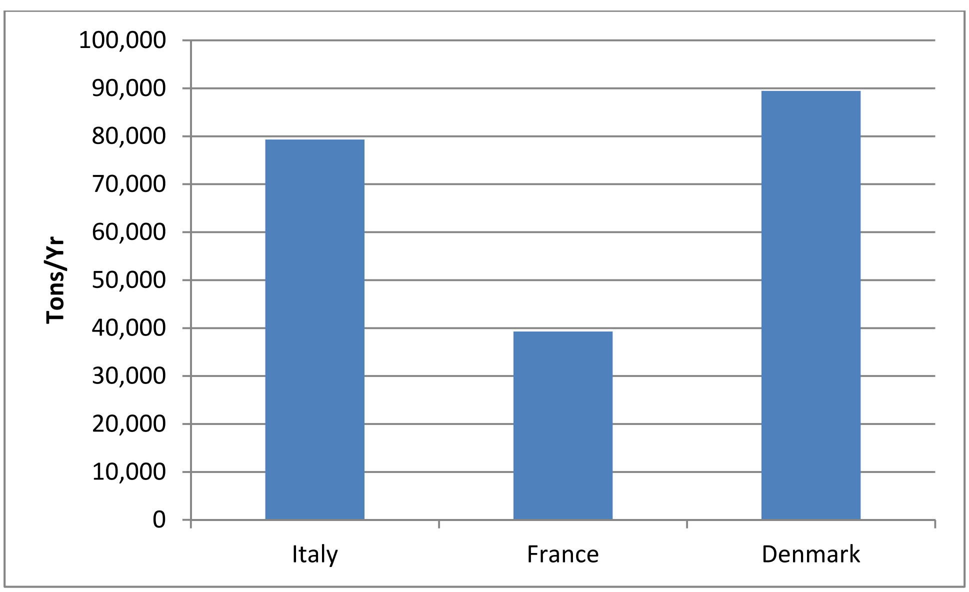


Table 9 Small Scale Plants Co-Combusting RDF

Country	Location	Total Tons/y	RDF Tons/y	RDF as % of Total Combusted
Denmark	Næstved	89,458	63	0.07%
France	Douchy les Mines	39,295	3,530	8.98%
Italy	Poggibonsi (SI)	20,436	2,728	13.35%
Italy	Vercelli	58,890	1,530	2.60%
Total (4 Plants Reporting)		**208,079**	**7,851**	**3.77%**
***The following small scale ISWA plants are combusting RDF only and therefore were not included in the above table as no co-combustion is taking place: Bergamo, Italy (7 plants), and San Vittore del Lazio , Italy (1 plant)**				
****The Schio, Italy plant is not co-combusting RDF with MSW/household waste, only hospital and "other" waste and therefore was not included in the above table.**				

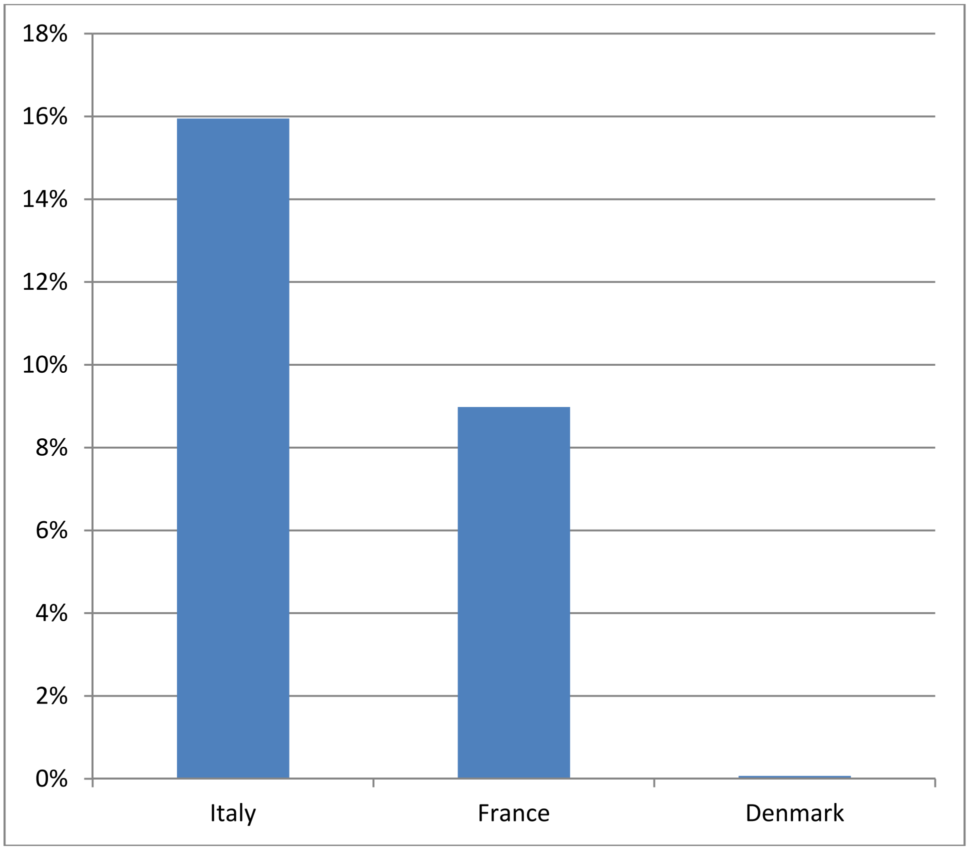
Additional Analysis in terms of ISWA small scale co-combustion of RDF is visually presented in Figures 24 and 25. In Figure 24, the cumulative total small scale MSW annual capacity for those plants that co-combust RDF was plotted with respect to the ISWA country performing the small scale co-combustion of RDF. Figure 24 shows that Denmark dominates in terms of small scale co-combustion of RDF.

Figure 24 Cumulative Small Scale Total Capacity vs Country Co-Combusting RDF in Small Scale



It can be seen below in Figure 25 that Italy's percent distribution of small scale co-combustion of RDF dominates at 16%.

Figure 25 Cumulative % of RDF in Small Scale v Country Co-Combusting RDF in Small Scale



7 BENEFITS OF SMALL SCALE PLANTS

It has been proven herein that a localized approach to waste management is beneficial as there is both expense and negative environmental impact associated with the long distance transfer of waste. The benefits of small scale facilities were well stated by Christian Reeve, the CEO of Biogen Power, a company that plans to incorporate the Energos technology at six facilities in the UK[26]: “In comparison to the traditional mass burn incinerators that are generally used at the moment, this type of facility has a very small footprint so it can be built in urban areas without looking out of place. The result of this is that the problem of waste treatment can be addressed at a local level, close to the waste source, rather than spending huge amounts of the tax payer’s money transporting waste around the country to landfill sites-an activity, in itself, that creates more traffic congestion and produces even more greenhouse gases[26].”

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APPENDICES

Table 10 Analysis of All Data Compiled in ISWA Compilation of 2004 WTE Data

ALL - Operational Data, 2004

Country	Location	Combusted materials: Total tons/y	Household tons/y	Commercial and Industrial tons/y	RDF Pellets tons/y	Sludge tons/y	Hospital Waste tons/y	Other Materials tons/y	Ash Residues: Bottom Ash tons/y	Fly Ash tons/y	Energy Produced: Steam tons/y	Electricity MWh,e	Heat MWh,th	Energy Sold: Steam tons/y	Electricity MWh	Heat MWh
Austria	Arnoldstein	40,644	40,644						9,400	3,100	130,000			7,300	12,330	1,140
Austria	Wien (Flötzersteig)	209,629	209,629						55,201	3,841	580,168		406,118	478,287		334,801
Austria	Wien (Spittelau)	268,957							60,577	5,204		36,800	518,583		11,082	508,259
Austria	Zwentendorf	323,000	190,000	129,900	2,300		800		86,600	11,830	1,111,000	-		1,111,000		
Belgium	Brugge	174,733	129,933	41,277			3,523		26,982		439,323	27,825	326,525		5,531	27,262
Belgium	Doel-Beveren	397,029							110,355	13,510	1,300,000	150,308		566,645	148,445	
Belgium	Gent	94,383	81,576				475	12,332	16,292	4,741						
Belgium	Herstal	123,787	89,645	34,142					17,552	6,705	462,622	83,495			62,387	
Belgium	Houthalen	69,195	65,195	2,300	0	0	1,700	0	16,043	2,815		25,426	14,062		19,306	14,062
Belgium	Oostende	65,000	50,000	15,000	0	0	0	0	13,000	2,000		27,000		0	20,000	0
Belgium	Roeselare	56,000	45,000	11,000					8,800	2,000			125,000			28,000
Belgium	Thurmaide	259,614	69,386	134,910		7,352	22,157	16,728	55,850	11,225		149,098			126,217	
Belgium	Wilrijk (Antwerpen)	130,952	130,952	0	0	0	0					78,504			78,504	
Czech Republic	Brno	106,740	101,769	5	0	0	254	0	24	5	306	2	242	157		190
Czech Republic	Liberec	92,260	81,809	4	0	0	0	6	36	1	269	15	239		6	169
Czech Republic	Praha	211,383	211,383	-	-	-	-	-	54		609	-	489	421	-	336
Denmark	Esbjerg	181,635			0	0	0	0	36,225	4,111				0	94,178	398,925
Denmark	Frederikshavn	35,295							12,312	810		18,065	75,194		14,935	75,083
Denmark	Glostrup	466,000						bonemeal	95,000	15,200		107,000	1,168,000		107,000	1,063,000
Denmark	Grenaa	20,975	12,493	6,166				2,240	3,900	433			49,493			
Denmark	Haderslev	56,292							9,893	770		32,216	100,554		26,702	86,111
Denmark	Hadsund	20,092	12,648	4,845					3,490	222			46,618			43,221
Denmark	Hammel	29,501							5,088	1,106			77,918			
Denmark	Herning	39,341							6,295	743		27,728	85,630		27,728	85,630
Denmark	Hjørring	61,270	31,718	26,338	0	2,735	479	0	13,676	655		34,763	112,435			106,180
Denmark	Hobro	25,450	15,745	9,705	0	0	0	0	5,360	404	0	0	68,900	0	0	47,623
Denmark	Holstebro	142,957							27,589	2,419		158,392	452,500		141,650	432,200
Denmark	Horsens	70,713							15,924	1,741		44,463	151,873		40,683	128,126
Denmark	Høje-Taastrup	53,356							10,064	1,271		0	134,705			
Denmark	Hørsholm	109,493	51,304	28,835	0	137	0	29,218	17,728	3,365		49,560	236,518			214,099
Denmark	Kolding	94,169	36,786	55,659				829	15,431	1,923		49,401	206,750		44,681	188,294
Denmark	København	401,823	208,807	177,411	0	0	1,942	13,663	80,365	21,655		149,417	813,941		149,417	792,340
Denmark	Leirvik	16,116							2,365	124						
Denmark	Middelfart	21,098	8,700	12,330					4,194	338			48,330			48,330
Denmark	Nykøbing F	105,000	40,000	53,000	0	0	0	6,000	21,000	2,100	0	40,600	211,500	0	40,600	184,900
Denmark	Næstved	89,458	48,961	40,316	63				16,904	1,387		41,406	223,726		37,348	197,427
Denmark	Odense	268,498	100,790	109,740				57,968	53,479	4,092		178,371	530,833		156,893	530,278
Denmark	Roskilde	198,443							41,358	5,627		104,200	381,518		104,200	381,518
Denmark	Rønne	21,158							3,102	355			58,333			47,346
Denmark	Skagen	11,116							2,445	240			27,835			19,530
Denmark	Skanderborg	57,002							9,986	1,183		22,147	120,050		22,147	107,275
Denmark	Slagelse	60,152			0	0	0	0	11,013	1,417		21,787	135,278			
Denmark	Svendborg	54,000	21,900	23,500			400	8,200	9,600	950		32,600	111,300		28,600	100,100
Denmark	Sønderborg	65,918							11,882	630		38,235	127,449			
Denmark	Thisted	51,821	22,474	28,479					9,014	1,183		20,516	116,483		16,453	103,583
Denmark	Torshavn	14,365							1,562	290						

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Denmark	Vejen	38,164							7,520	1,089		19,069	71,944		16,086	58,333
Denmark	Aalborg	134,774	74,025	60,749					36,422	4,538		41,545	283,508		36,510	283,508
Denmark	Århus	183,047	92,973	90,274			361		30,472	4,399		63,067	374,303		60,217	374,113
Denmark	Aars	53,461							9,298	699		17,625			17,625	58,978
Finland	Turku	49,000	49,000						10,000	2,000			104,700			
France	Antibes	135,067	135,067	0	0	0	0	0	29,168	5,717	0	0	0	0		
France	Argenteuil	173,000							45,000	4,000		33,000	64,000			
France	Arrabloy	53,707	41,683	8,933		3,091			4,661	4,484		12,067	123,321		4,490	
France	Aurillac	6,840	6,700	140									11,800			8,700
France	Bègles	275,000							47,000	6,580		135,000				
France	Besançon	50,000	55,000			6,000			12,000	1,500		5,000	50,000			
France	Bessières	155,000	155,000						32,000	3,700		80,000				
France	Briec de l'Odet	52,800							12,493			17,563			14,010	
France	Carrières sous Poissy	115,000							24,000	2,800		50,000				
France	Cenon	134,242	123,138	0	0	11,104	0	0	35,358	3,108	304,331	8,102	108,417	0	0	108,417
France	Cergy Pontoise	152,300	143,500	8,800					37,000			46,800	165,000		34,850	165,000
France	Chaumont	73,100	73,100						14,000			30,500			25,000	
France	Concarneau	46,000	46,000						5,213				85,000			33,700
France	Confort Meilars	18,809	18,332	477					4,573	461						
France	Coueron	98,954	59,217	35,882	0	0	0	3,855	23,882	2,066	277,931	21,055	239,791	51,517	15,015	
France	Douchy les Mines	39,295	33,608	2,157	3,530		3,530		9,295	1,236						
France	Dunkerque	83,353	79,981	3,221					24,858	1,743						
France	ECHILLAIS	29,750	29,750						6,875							17,250
France	Fourchambault	20,650	20,650									2,333			1,905	
France	Grand Quevilly	293,215	290,460	2,755					73,500			172,160			137,520	
France	Guerville	52,365	52,365						7,366			22,276	145,000		12,806	
France	Guichainville	90,000							23,500	2,800		42,000			31,000	
France	Halluin	332,976							84,310			170,459			127,110	
France	Henin-Beaumont	54,443	48,478	5,964					12,035	1,843						
France	Issy-Les-Moulineaux	537,094	533,411	3,683		532			128,291	12,068		82,853	918,711		41,236	847,870
France	La Rochelle	59,000	59,000						16,080				140,700			57,200
France	La Séguinière	29,185	29,185						6,995	1,743		0	59,388			
France	Le Mans	103,840	97,712	6,128					29,317			10,262	160,500		4,217	17,518
France	Lescar	82,000	82,000						20,000	2,000		25,000				
France	Limoges	87,727	87,727						17,530			10,500	157,000		3,700	34,500
France	Livet	16,022	16,022													
France	Ludres	101,200	96,040	5,160					25,600			35,000	257,000		25,000	82,000
France	Marignier	41,928	41,928						7,764			6,838				4,724
France	Maubeuge	87,379	71,314	16,065					19,888	3,716	226,429	43,510	0		36,323	
France	Montauban	37,500							5,500	1,500			17,000			
France	Montbéliard	53,200							7,840	2,980		0	86,520			53,500
France	Montereau Fault Yonne	15,321							4,742							
France	Monthyon	122,126							32,000	4,200		36,054	46,758			
France	Nice	325,900	322,000	3,900								67,000			43,000	118,000
France	Paris	690,123	684,844	5,279		990			152,046	15,922		181,385	1,266,643		134,759	930,764
France	Plouharnel	23,000	23,000						6,405							
France	Pluzunet	52,000	52,000						10,000			17,639			12,900	6,000
France	Poitiers	37,200	37,200										57,000			46,400
France	Pontarlier	32,680	37,500						4,700	1,300			60,000			23,000
France	Pontcharra	18,059	18,059						2,236							

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France	Pontivy	27,877	27,589	288					4,286	1,226	69,435			52,466		
France	Pontmain	62,946	61,240	1,706					16,921	2,340	170,361			116,318		
France	Pontx-les-Forges	39,866	38,475	1,391					7,826	1,850	97,647	13,436			13,436	
France	Rambervillers	95,000							20,000	2,000		16,000			16,000	
France	Reims	80,550	80,550									3,550	47,000			47,000
France	Rennes	132,709	132,709									37,996	256,177		26,193	81,571
France	Rungis	118,390	118,390						23,343				170,586			105,600
France	Saint Ouen	622,653	619,226	3,427		463			143,753	11,482	1,647,549	59,591	1,210,120		22,136	1,248,783
France	Saint Pourcain sur Sioule	51,300	39,500	11,800					9,500				121,000			80,600
France	Saint Saulve	128,679	126,155	2,524					29,562	2,183	84,160	40,139			32,146	
France	Sainte Gemmes sur Loire - ANGERS	83,489	81,333	2,156					19,911	2,954						64,836
France	Saran	99,380	97,900	1,480					22,600			44,500			37,000	
France	Sarcelles	154,101	154,101						35,053			5,733	196,805		501	113,971
France	Schweighouse sur Moder	70,000							18,500	2,500		10,000	60,000			
France	Sens	17,700	17,700						3,550				26,500			17,500
France	Sète	39,200	38,000	1,200									52,000			11,500
France	St Thibault des Vignes	147,953	127,169	20,784					33,188	5,494	427,474	11,432			3,155	226
France	Strasbourg	282,329	255,041	27,288					77,449	7,911	921,498	85,601	607,300	261,830	67,889	
France	Taden	103,200		8,245		9,525			0	2,350	126,785	35,398				
France	Thiverval-Grignon	191,000	128,000	57,000		5,600			37,500	5,210		45,300	66,700		28,300	66,700
France	Thonon Les Bains Cedex	38,700	38,700						6,330				82,900			50,500
France	Tignes	8,900	8,900													
France	Toulouse Mirail	209,600	205,000	4,600					50,800			246,000	360,000		10,000	150,000
France	Tronville en Barrois	30,000							6,500	600			28,000			
France	Vaux-le-Penil	128,000	126,000	2,000					33,000	5,000	385,000	70,000	0		61,700	
France	Villefranche sur Saône	78,301	76,262	397		1,004	287		17,632	2,743	227,541	16,237	173,663	22,678	13,340	
France	Villejust	81,500	59,600	21,900					27,000				68,000			
France	Vitré	26,500	28,000						4,400	1,200		1,200	25,250			25,250
Germany	Augsburg	201,879							48,242		681,100					
Germany	Bamberg	114,000							27,000		400,000				9,500	72,600
Germany	Berlin-Ruhleben	520,000									1,000,000					
Germany	Bielefeld	325,000							82,000		1,229,316				118,402	299,647
Germany	BKB Hannover	230,000							60,000		468,000				159,000	45,000
Germany	Bonn	240,000							62,902		742,548					
Germany	Bremen	310,300							74,700		1,150,000				1,457	190,669
Germany	Bremerhaven	300,000							95,000		980,000				66,000	230,000
Germany	Burgkirchen	212,372	117,000	95,000					46,129	6,600	729,498	105,000		93,473	73,917	
Germany	Böblingen	139,775							27,912	3,145	473,000	53,375			34,956	120,801
Germany	Coburg	117,886							28,218		336,866				33,259	85,051
Germany	Darmstadt	177,516							47,283		600,000				34,024	62,880
Germany	Düsseldorf	413,000	323,922	89,043					94,000	24,120	1,058,000			1,019,836		
Germany	Eschbach	150,000														
Germany	Eschweiler	368,007							99,269		1,164,538					
Germany	Essen	668,773							163,976		2,009,000				176,939	481,373
Germany	Frankfurt	211,000							51,000		500,000					
Germany	Greppin	16,600				12,456			8,000		45,000			25,000		
Germany	Göppingen	120,000							30,000						40,000	70,000
Germany	Hagen	119,500							40,000	3,767	340,000					70,000
Germany	Hamburg	323,400							84,084	12,202			769,520			664,072

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Germany	Hamburg	325,590							72,000		970,000				48,600	444,270
Germany	Hamburg	150,000							41,000		471,000				40,500	64,000
Germany	Hameln	159,366							37,000		522,314				13,590	285,000
Germany	Hamm	255,370							66,300		642,000				82,000	
Germany	Helmstedt	298,000							80,000		930,000				150,000	
Germany	Herten	262,023							64,861		1,028,868				80,539	9,882
Germany	Ingolstadt	211,000	106,665	57,970				6,183	54,000	4,711	690,000	105,795			78,000	128,000
Germany	Iserlohn	230,000							65,357		457,000				62,586	151,028
Germany	Kamp-Lintfort	221,145				4,700			59,613		767,887	111,000	111,000		81,100	116,391
Germany	Kassel	150,000							36,755		514,912				72,552	154,396
Germany	Kempten	76,661	36,645	27,922			514	11,580	19,147		302,253	50,871	41,078		36,345	41,078
Germany	Kiel	133,000							33,464						19,972	212,694
Germany	Krefeld	346,231	281,124	24,542		16,873	1,263	22,429	96,954	10,332	993,043	131,983	305,741		75,281	179,431
Germany	Köln	671,698							146,147		2,199,289				316,705	277,279
Germany	Lauta	225,000							56,000	10,038	675,000	58,000	0	0	120,000	0
Germany	Leuna	195,000							54,600		660,000				120,000	
Germany	Leverkusen	210,000							56	2,3	620,000	44			9,5	150
Germany	Ludwigshafen	150,300							45,000		470,000					
Germany	Magdeburg	300,000													170,000	300,000
Germany	Mainz	200,000							62,000		720,000					
Germany	Mannheim	317,102	236,115	80,987					82,690	7,336	1,250,000	59,146	884,844	717,958	65,000	680,000
Germany	Neunkirchen	121,000							31,893		384,537				43,779	41,607
Germany	Neustadt	59,449	37,544	16,169			668	5,068	15,083	1,204	194,000	26,000	29,600		17,600	29,200
Germany	Nürnberg	216,000							46,000		740,000					490,000
Germany	Oberhausen	496,000							130,000		1,400,000				178,000	150,000
Germany	Offenbach	190,000							49,463		500,000				44,465	138,817
Germany	Olching	92,961							23,974		314,502				33,234	9,479
Germany	Pirmasens	170,000							47,400		554,000				71,600	13,300
Germany	Rosenheim	58,568							12,600	5,929	195,000				28,000	116,000
Germany	Schwandorf	388,900							79,946		1,334,350				142,287	38,997
Germany	Schweinfurt	155,000							41,540		460,000				42,700	231,960
Germany	Solingen	94,500							21,010						41,650	30,061
Germany	Stapelfeld	350,000							100,000		980,000				82,000	150,000
Germany	Stassfurt	300,000							90,000		930,000				71,836	156,800
Germany	Stuttgart	195,000							39,452		566,500				86,500	243,700
Germany	Stuttgart	27,320							6,785							
Germany	Tornesch	76,000	46,200	22,500				7,300	18,050	2,240	205,000	28,200	49,800		10,500	48,500
Germany	Ulm	111,625	68,412	44,679					25,665	3,075	383,792	51,489			32,455	98,899
Germany	Unterföhring	644,142							153,307						108,481	838,144
Germany	Völklingen	210,488	188,132	19,134		452	2,270		56,540	8,428	646,790	119,470			91,629	
Germany	Weißenfels	300,000							80,000		987,000				160,000	3,100
Germany	Weißenhorn	91,419							18,456						40,000	
Germany	Wuppertal	389,900							106,000		1,308,000				135,700	30,100
Germany	Würzburg	155,000							38,500		474,000				62,800	32,850
Great Britain	Billingham	230,361	-	-	-	-	-	-	66,642	7,446	-	155,579	-	-	142,360	-
Great Britain	Huddersfield	135,814	-	-	-	-	-	-	31,637	5,397	-	85,824	-	-	74,823	-
Great Britain	London	485,111			0	0			118,767	17,201	1,311,928	262,442	N/A	N/A	222,442	N/A
Great Britain	Shetland Islands	21,511	17,702	3,793			16		4,936	403			51,459			51,459
Hungary	Budapest	160,054							38,125	4,177	391,539	54,068	301,048		40,291	47,684
Italy	Arezzo	38,000	38,000						9,723	1,226		16,800			15,193	

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Italy	Bergamo	48,000			48,000							49,352				
Italy	Bolzano	81,000							21,764	1,350		35,577	24,431		23,590	24,431
Italy	Brescia	721,000	420,000	43,000					141,200	33,400		537,000	394,000		475,000	394,000
Italy	Busto Arsizio (VA)	94,898	81,955	8,811				4,132	17,299	3,702		51,880			37,938	
Italy	Castelnuovo Garfagnana (LU)	11,600	11,600						3,640	260		2,420			901	
Italy	Colleferro (Roma)	69,000			69,000				11,000	6,000		71,472			63,623	
Italy	Colleferro (Roma)	72,000			72,000				9,000	4,000		31,816			27,632	
Italy	Como	72,268	72,268						16,181	1,469		26,091	712		25,945	
Italy	Coriano (RN)	126,027	119,852				0,847	5,328	36,964	2,331		57,048			46,527	
Italy	Corteolona (PV)	37,400			37,400				2,393	5,345		40,288			36,283	
Italy	Cremona	64,996	53,836	10,630			529					18,380	47,014		18,380	47,014
Italy	Dalmine BG)	137,500	113,300	24,200					23,800	5,300		109,552			102,672	
Italy	Desio (MI)	49,019		10			3,152	45,857	13,761	31		7,399			1,438	
Italy	Ferrara	20,500	19,887				613		5,871	480						
Italy	Ferrara	38,840							10,374	1,569		11,904			11,205	
Italy	Forli	41,400	35,000	6,400					9,900	2,090		8,933	7,736		8,933	7,736
Italy	Granarolo Emilia (BO)	179,676	164,536				2,418	15,076				39,619	59,391			
Italy	Livorno	44,806			44,806				10,134	1,392		18,608			7,538	
Italy	Macchiareddu (CA)	212,600	190,000	13,600		9,000						43,880			25,936	
Italy	Macomer (NU)	79,000	76,800	1,300		500		400				7,010			6,505	
Italy	Massafra (TA)	44,190			44,190				23,000	7,686		39,648			37,488	
Italy	Melfi PZ)	47,000	25,000				2,000	12,000								
Italy	Mergozzo (VB)	28,999							7,797	575		9,476			3,462	
Italy	Milano	335,000							55,968	5,681	36,317	281,403			232,176	36,317
Italy	Modena	122,042	115,000	2,000			5,000	0,042	31,880	3,655		31,689			30,511	
Italy	Montale/Agliana (PT)	33,300	28,600	3,090				1,340	8,318	1,048		3,681			3,635	
Italy	Ospedaletto (PI)	57,944	52,293	2,126			3,525		14,451	1,559		26,242				
Italy	Padova	60,376	54,999	2,385			2,992	2,804				23,269				
Italy	Parona PV)	186,800	137,300	49,500								121,859			102,629	
Italy	Piacenza	111,409	108,866				750	1,793	22,133	3,131		63,692			53,907	
Italy	Pietrasanta /LU)	46,849			46,849							32,766			29,699	
Italy	Poggibonsi (SI)	20,436	16,960	748	2,728							4,068			3,054	
Italy	Ravenna	169,954	117,712	7,633	44,601		8,7		685			32,109			31,752	
Italy	Rufina/Pontassieve (FI)	9,878	9,759	88			31	100								
Italy	San Vittore del Lazio (FR)	80,300			80,300				12,300	5,800		74,392			65,971	
Italy	Scarlino	51,600										24,860				
Italy	Schio (VI)	57,470			30,900		4,700	19,500	16,000	2,000		21,850			13,800	
Italy	Sesto S. Giovanni (MI).	60,300	60,300						13,971	473		30,025			21,161	
Italy	Statte (TA)	48,700	48,700						13,250	1,240		8,276			4,198	
Italy	Terni	27,000	25,600	400			1,200		4,920	655		9,863			8,562	
Italy	Tolentino/Pollenza (MC)	18,983	18,983													
Italy	Trezzo sull	152,540			152,540				29,898	6,429		113,599			107,214	
Italy	Trieste	138,200	118,600	17,400	1,000			1,300	40,000			67,654			67,564	
Italy	Valmedrara (LC)	62,300	56,700				5,600					20,592			14,414	
Italy	Venezia	52,448	50,357	2,086					13,041	1,700		12,734			9,013	
Italy	Vercelli	58,890	49,200		1,530		2,600	5,560	15,900	1,200		14,480			10,690	
Italy	Verona	131,300	119,600	300	7,800	700		3,000	4,600	3,400		83,428	1,922		69,106	
Netherlands	Alkmaar	458,218				0	0	0	117,789	6,013	1,449,557	311,114	0	0	233,777	0
Netherlands	Amsterdam	877,351	528,963	283,552	0	23,981	9,733	31,122	261,203	10,965	2,649,987	591,568	39,512		508,080	39,512

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Country	Location	Combusted materials							Ash Residues		Energy Produced			Energy Sold		
		Total tons/y	Household tons/y	Commercial and Industrial tons/y	RDF Pellets tons/y	Sludge tons/y	Hospital Waste tons/y	Other Materials tons/y	Bottom Ash tons/y	Fly Ash tons/y	Steam tons/y	Electricity MWh,e	Heat MWh,th	Steam tons/y	Electricity MWh	Heat MWh
Netherlands	Dordrecht	206,991	123,100	83,891					53,900	4,140	331,000	65,433				
Netherlands	Duiven	335,738	207,815	127,923					85,247	6,539		159,524			113,707	
Netherlands	Hengelo	307,029	216,029	91,000					73,800	8,461	941,000	181,000			153,000	
Netherlands	Moerdijk	655,791	478,553	177,238	0	0	0	0	150,721	15,886	2,118,344	0	0	2,118,344	0	0
Netherlands	Roosendaal	55,166	yes	yes	none	99	none	none	35,042	1,230		none	140,000		none	52,806
Netherlands	Rotterdam	385,000	1	0	0	0	some	some	80,000	5,400	850,000	183,000	none	none	115,000	none
Netherlands	Rozenburg	1,125,000	1	0	none	none	none	liquid was	253,000	42,000	2,952,000	497,000	none	not known	429,000	567,500
Netherlands	Weurt	269,585			269,585				60,701	16,080	982,000	190,838			158,677	
Netherlands	Wijster	483,119	not specif	not specif	0	0	0	0	140,104	9,600	1,645,448	355,971	7,180	0	299,016	0
Norway	Averøy	32,124							4,963	1,375		6,672	72,000		6,672	21,578
Norway	Bergen	105,000	85,000	18,700			1,300		17,400	2,200		41,250	276,000		41,250	96,271
Norway	Frederikstad	80,381	3,424	76,957			760		15,000	1,600	240,000	4,000	208,000	207,000	4,000	173
Norway	Lenvik	5,050	2,250	2,803			120		880	94			10,000			2,200
Norway	Oslo (Brobekk)	110,268	95,492	10,961				3,815	17,717	3,289			282,507			246,803
Norway	Oslo (Klemetsrud)	148,161	114,912	23,537			1,677	8,035	26,574	5,470		68,318	288,691		68,318	176,987
Norway	Oslo (Viken)	34,356						34,356	6,314	3,504			109,994			101,775
Norway	Sandnes	38,596	30,737	7,859					7,346	1,558	105,000	12,353	89,858		12,353	15,081
Norway	Sarpsborg	62,517							9,322	3,615		N/A	165,000		N/A	154,000
Norway	Spjelkavik	34,658	30,121	4,328			210		4,185	1,048			81,120			60,000
Norway	Trondheim	97,012	57,509	39,503					19,661	1,848			242,065			201,804
Norway	Ål	18,600	12,400	6,200					3,460	425		0	31,200			7
Portugal	Funchal	113,823							22,638	3,477	260,240	48,475			35,070	
Portugal	S. Joao de Talha	534,640	534,640						100,076	19,132	1,498,936	286,408			247,656	
Spain	Barcelona	328,832	328,832						69,388	11,516	704,858	174,037		30,859	135,366	
Spain	Bilbao	157,808	157,808	-	-	-	-	-	34,828	6,312	-	521,785	-	-	494,295	-
Spain	Cerceda (A Coruña)	506,247							68,647	32,180		319,909			288,069	
Spain	Girona	30,620							6,736	798		5,985,000			2,959,700	
Spain	Madrid	291,675			291,675				15,540	28,547		228,501			173,377	
Spain	Mataró	149,218							36,772	6,382	365,138	75,521			64,462	
Spain	Melilla	46,227							11,094	739		12,459			9,086	
Spain	Meruelo (Cantabria)	244,639	244,639		90				4,290	7,485	300,000	81,000			66,000	
Spain	Palma De Mallorca	328,747	326,691			2,056			78,721	26,684	796,666	173,887			145,810	
Spain	Tarragona	137,205	137,205						32,775	3,292		55,594	342,999		44,895	
Sweden	Avesta	46,800	25,600	21,300					7,600	1,124			136,000			
Sweden	Boden	58,000	48,000	10,000					10,000	1,000			158,000		247,000	
Sweden	Bollnäs	37,099	25,963	11,136					1,883	4,393	16,200		81,806	16,180		118,884
Sweden	Borlänge	34,951	13,353	21,598					3,703	609			116,382			116,382
Sweden	Eksjö	19,080										3,670	47,650			
Sweden	Göteborg	433,700							77,532	14,915		213,150	1,172,660		153,351	1,057,672
Sweden	Halmstad	146,804	76,396	68,714		1,224		470	2,490	373		55,277	344,173		41,014	283,658
Sweden	Haninge	14,110										0	61,950			
Sweden	Hässleholm	34,137	22,044	12,093					5,659	1,378		4,536	92,136			
Sweden	Karlskoga	42,600	30,000	10,400			200									
Sweden	Karlstad	50,408							7,794	1,610			144,217			144,217
Sweden	Kiruna	53,120										11,430	98,890			
Sweden	Kumla	136,970										41,340	229,210			
Sweden	Köping	25,653	13,478	12,175					4,461	458			75,149			75,149
Sweden	Landskrona	30,330										0	103,070			
Sweden	Lidköping	82,000										11,400	227,770			
Sweden	Linköping	217,214							46,639	6,570		14,463	634,688		0	568,050

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Country	Location	Combusted materials							Ash Residues		Energy Produced			Energy Sold		
		Total tons/y	**Household tons/y**	**Commercial and Industrial tons/y**	**RDF Pellets tons/y**	**Sludge tons/y**	**Hospital Waste tons/y**	**Other Materials tons/y**	**Bottom Ash tons/y**	**Fly Ash tons/y**	**Steam tons/y**	**Electricity MWh,e**	**Heat MWh,th**	**Steam tons/y**	**Electricity MWh**	**Heat MWh**
Sweden	Malmö	385,879	202,206	156,160			1,700	25,813	82,680	15,996		137,677	1,030,136		107,516	996,962
Sweden	Mora	16,455	11,500	4,955	0	0	0	0	2,634	378	0	0	41,494	0		39,860
Sweden	Norrköping	163,700	98,535	59,091					14,920	13,805		57,717	352,319		40,252	349,197
Sweden	Stockholm	520,221	339,306	180,915					63,666	27,287		219,700	1,404,900			
Sweden	Sundsvall	44,790										19,570	90,870			
Sweden	Södertälje	249,211		113,538	135,673				12,000	25,000	75,000		938,086	75,000		1,810,451
Sweden	Umeå	188,074							30,181	6,810		64,658	470,189		30,886	457,590
Sweden	Västervik	46,600										0	116,220			
Switzerland	Aire-la-ville	314,002							72,247	7,095	1,115,625	172,328		0	129,092	0
Switzerland	Basel	189,624							34,000	4,720		43,830	545,083		19,195	443,091
Switzerland	Bazenheid	75,233							17,000	2,300		35,600	350,000		27,000	25,000
Switzerland	Bern	109,300							21,500	2,150	413,700	30,400	198,000		12,400	191,100
Switzerland	Biel	40,993							8,788	1,419	164,825	20,208			14,789	15,507
Switzerland	Brig-Gils	27,434							n.a.	n.a.	n.a.	n.a.	n.a.		n.a.	
Switzerland	Buchs AG	119,500							23,100	2,670					47,600	61,500
Switzerland	Buchs SG	71,535							35,000	5,560	542,000	100,000		81,000	80,000	
Switzerland	Colombier	60,513							17,000	2,531	198,367	31,668	26,530		21,985	20,771
Switzerland	Dietikon	81,180							20,000	2,500	n.a.	57,000	n.a.	0	43,000	18,000
Switzerland	Emmenbrücke	84,316							18,600	1,520	265,600	43,800	43,600	0	34,500	43,100
Switzerland	Horgen	59,242							n.a.	n.a.	130,000	20,000	71,000		10,000	47,000
Switzerland	Kezo	163,132							35,000	7,000	680,000	100,000	308,000		70,000	20,000
Switzerland	La Chaux-de-Fonds	50,552							10,000	1,200		27,000	52,000			
Switzerland	Lausanne	44,117							9,846	1,004	140,502		93,855	118,108		78,872
Switzerland	Lausanne	120,000	50-100%	0-40%	0-20%	0-10%	0-10%	n.a.	24,600	2,400	548,000	n.a.	n.a.		0	0
Switzerland	Monthey	98,805							20,800	4,960	n.a.	60,756	n.a.	0	45,000	0
Switzerland	Niederurnen	99,400							n.a.	1,000	190,000	64,000		0	50,000	
Switzerland	Oftringen	68,362							18,000	1,900	200,000	54,000	160,000	0	41,000	0
Switzerland	Posieux	88,401							20,000	6,000		6,500	65,000		6,000	55,000
Switzerland	St. Gallen	75,362							19,000	2,200		34,200	55,000		24,300	55,000
Switzerland	Turgi	113,945							23,433	2,985	441,500	86,950			70,260	36,080
Switzerland	Untervaz	50,396							11,300	800	213,670	18,118	160,252	74,702	9,733	60,122
Switzerland	Uvrier	52,480							10,350	1,260	153,400	23,700		0	14,600	
Switzerland	Weinfelden	113,097							13,885	n.a.	470,000	46,000	417,000	164,100	31,000	183,300
Switzerland	Winterthur	145,327							31,750	4,621	580,000	80,000	420,000		62,000	n.a.
Switzerland	Zuchwil	196,534							49,606	N.A.	727,168	656,625			40,807	233,816
Switzerland	Zürich	163,613													32,728	325,711
Switzerland	Zürich	148,452													56,993	107,002
Total	**331 Plants Data Submitted**	**49,806,932**	**17,535,833**	**3,710,588**	**1,398,260**	**128,874**	**97,458**	**445,400**	**10,731,176**	**1,110,334**	**76,044,919**	**21,784,843**	**32,977,144**	**7,410,179**	**17,415,866**	**30,542,238**
% of total combusted or MWh/ton		100.0%	35.2%	7.4%	2.8%	0.3%	0.2%	0.9%	21.5%	2.2%	1.53	0.44	0.66	0.15	0.35	0.61
		Total tons	**MSW, tons**	**Commercial and Industrial, tons**	**RDF Pellets, tons**	**Sludge, tons**	**Hospital Waste, tons**	**Other materials, tons**	**Bottom Ash tons/y**	**Fly ash, tons/y**	**Steam produced, tons/ton combusted**	**Electricity produced, MWh,e /ton combusted**	**Heat produced , MWh,th,/ton combusted**	**Steam sold/ton combusted**	**Electricity sold, MWh /ton combusted**	**Heat sold, MWh/ton combusted**

* It should be noted that only some WTE plants reported to ISWA materials that were co-combusted. Therefore, there could be other co-combusting WTE plants that are not included in the above table.

Appendix 1 Statistical Analysis from ISWA Data Set

In the case of hospital wastes, our analysis of a tabulation of all European WTE plants by the International Solid Wastes Association[6] showed that forty-one plants reported co-combusting hospital wastes (Table 11); on the average, the hospital wastes co-combusted by these plants amounted to 1.8% of their total feedstock.

Table 11 Co-Combustion of Hospital Wastes in Europe

Country	Plant Name/Location	Total combusted (tons/yr.)	Hospital wastes (tons/yr.)	Hospital wastes as % of total
Norway	Lenvik	5,050	120	2.38%
Italy	Rufina/Pontassieve	9,878	31	0.31%
Italy	Ferrara	20,500	613	2.99%
Great Britain	Shetland Islands	21,511	16	0.07%
Italy	Terni	27,000	1,200	4.44%
Norway	Spjelkavik	34,658	210	0.61%
France	Douchy les Mines	39,295	3,530	8.98%
Sweden	Karlskoga	42,600	200	0.47%
Italy	Melfi PZ)	47,000	2,000	4.26%
Italy	Desio (MI)	49,019	3,152	6.43%
Denmark	Svendborg	54,000	400	0.74%
Italy	Schio (VI)	57,470	4,700	8.18%
Italy	Ospedaletto (PI)	57,944	3,525	6.08%
Italy	Vercelli	58,890	2,600	4.42%
Germany	Neustadt	59,449	668	1.12%
Italy	Padova	60,376	2,992	4.96%
Denmark	Hjørring	61,270	479	0.78%
Italy	Valmedrara (LC)	62,300	5,600	8.99%
Italy	Cremona	64,996	529	0.81%
Belgium	Houthalen	69,195	1,700	2.46%
Germany	Kempten	76,661	514	0.67%
France	Villefranche sur Saône	78,301	287	0.37%
Norway	Frederikstad	80,381	760	0.95%
Belgium	Gent	94,383	475	0.50%
Norway	Bergen	105,000	1,300	1.24%
Czech Republic	Brno	106,740	254	0.24%
Italy	Piacenza	111,409	750	0.67%
Switzerland	Lausanne	120,000	6,000	5.00%

Italy	Modena	122,042	5,000	4.10%
Norway	Oslo (Klemetsrud)	148,161	1,677	1.13%
Italy	Ravenna	169,954	9	0.01%
Belgium	Brugge	174,733	3,523	2.02%
Italy	Granarolo Emilia (BO)	179,676	2,418	1.35%
Denmark	Århus	183,047	361	0.20%
Germany	Völklingen	210,488	2,270	1.08%
Belgium	Thurmaide	259,614	22,157	8.53%
Austria	Zwentendorf	323,000	800	0.25%
Germany	Krefeld	346,231	1,263	0.36%
Sweden	Malmö	385,879	1,700	0.44%
Denmark	København	401,823	1,942	0.48%
Netherlands	Amsterdam	877,351	9,733	1.11%
Total (41 plants reporting)		**5,457,275**	**97,458**	**1.80%**
***Hospital waste data from the Italy, Coriano plant was not included in the above table as ISWA reported hospital waste from the Italy, Coriano plant as "0,847." This is considered negligible as part of this analysis.**				
**** Switzerland, Lausanne reported hospital waste co-combusted as percentage range of 0-10%. As such, an average of 5% was used to obtain a numerical value for hospital waste in tons co-combusted annually.**				

Analysis of the same data showed that twenty-four plants reported co-combustion of sludge from wastewater treatment plants (Table 12). On the average, the sludge combusted by these plants amounted to close to 2% of the total feedstock.

Table 12 Co-Combustion of Wastewater Sludge in Europe

Country	Plant Name/Location	Total (tons/yr.)	Tons wastewater sludge	Sludge as % of total combusted
Austria	Zwentendorf	323000	2300	0.71%
Belgium	Thurmaide	259,614	7,352	2.83%
Denmark	Hjørring	61,270	2,735	4.46%
Denmark	Hørsholm	109,493	137	0.13%
France	Besançon	50,000	6,000	12.00%
France	Arrabloy	53,707	3,091	5.76%
France	Villefranche sur Saône	78,301	1,004	1.28%
France	Taden	103,200	9,525	9.23%
France	Cenon	134,242	11,104	8.27%
France	Thiverval-Grignon	191,000	5,600	2.93%
France	Issy-Les-Moulineaux	537,094	532	0.10%
France	Saint Ouen	622,653	463	0.07%
France	Paris	690,123	990	0.14%
Germany	Völklingen	210,488	452	0.21%
Germany	Kamp-Lintfort	221,145	4,700	2.13%
Germany	Krefeld	346,231	16,873	4.87%
Italy	Macomer (NU)	79,000	500	0.63%
Italy	Verona	131,300	700	0.53%
Italy	Macchiareddu (CA)	212,600	9,000	4.23%
Netherlands	Roosendaal	55,166	99	0.18%
Netherlands	Amsterdam	877,351	23,981	2.73%
Spain	Palma De Mallorca	328,747	2,056	0.63%
Sweden	Halmstad	146,804	1,224	0.83%
Switzerland	Lausanne	120,000	6,000	5.00%
Total (24 plants reporting)		**5,942,529**	**116,418**	**1.96%**
***Excludes sludge data from Greppin Germany as this plant does not co-combust with household waste.**				
*** *Switzerland, Lausanne reported wastewater sludge co-combusted as percentage range of 0-10%. As such, an average of 5% was used to obtain a numerical value for tons of sludge co-combusted annually.**				

Analysis of the same data showed that 115 plants reported co-combustion of commercial and industrial waste (Table 13). On the average, the commercial and the industrial waste combusted by these plants amounted to 21.4% of the total feedstock.

Table 13 Co-Combustion of Commercial Waste in Europe

Country	Location	Total Tons	Commercial and Industrial, tons/y	Commercial/Industrial Waste as % of Total Combusted
Austria	Zwentendorf	323,000	129,900	40.2%
Belgium	Brugge	174,733	41,277	23.6%
Belgium	Herstal	123,787	34,142	27.6%
Belgium	Houthalen	69,195	2,300	3.3%
Belgium	Oostende	65,000	15,000	23.1%
Belgium	Roeselare	56,000	11,000	19.6%
Belgium	Thurmaide	259,614	134,910	52.0%
Czech Republic	Brno	106,740	5	0.0%
Czech Republic	Liberec	92,260	4	0.0%
Denmark	Grenaa	20,975	6,166	29.4%
Denmark	Hadsund	20,092	4,845	24.1%
Denmark	Hjørring	61,270	26,338	43.0%
Denmark	Hobro	25,450	9,705	38.1%
Denmark	Hørsholm	109,493	28,835	26.3%
Denmark	Kolding	94,169	55,659	59.1%
Denmark	København	401,823	177,411	44.2%
Denmark	Middelfart	21,098	12,330	58.4%
Denmark	Nykøbing F	105,000	53,000	50.5%
Denmark	Næstved	89,458	40,316	45.1%
Denmark	Odense	268,498	109,740	40.9%
Denmark	Svendborg	54,000	23,500	43.5%
Denmark	Thisted	51,821	28,479	55.0%
Denmark	Aalborg	134,774	60,749	45.1%
Denmark	Århus	183,047	90,274	49.3%
France	Arrabloy	53,707	8,933	16.6%
France	Aurillac	6,840	140	2.0%
France	Cergy Pontoise	152,300	8,800	5.8%
France	Confort Meilars	18,809	477	2.5%
France	Coueron	98,954	35,882	36.3%

France	Douchy les Mines	39,295	2,157	5.5%
France	Dunkerque	83,353	3,221	3.9%
France	Grand Quevilly	293,215	2,755	0.9%
France	Henin-Beaumont	54,443	5,964	11.0%
France	Issy-Les-Moulineaux	537,094	3,683	0.7%
France	Le Mans	103,840	6,128	5.9%
France	Ludres	101,200	5,160	5.1%
France	Maubeuge	87,379	16,065	18.4%
France	Nice	325,900	3,900	1.2%
France	Paris	690,123	5,279	0.8%
France	Pontivy	27,877	288	1.0%
France	Pontmain	62,946	1,706	2.7%
France	Pontx-les-Forges	39,866	1,391	3.5%
France	Saint Ouen	622,653	3,427	0.6%
France	Saint Pourcain sur Sioule	51,300	11,800	23.0%
France	Saint Saulve	128,679	2,524	2.0%
France	Sainte Gemmes sur Loire - ANGERS	83,489	2,156	2.6%
France	Saran	99,380	1,480	1.5%
France	Sète	39,200	1,200	3.1%
France	St Thibault des Vignes	147,953	20,784	14.0%
France	Strasbourg	282,329	27,288	9.7%
France	Taden	103,200	8,245	8.0%
France	Thiverval-Grignon	191,000	57,000	29.8%
France	Toulouse Mirail	209,600	4,600	2.2%
France	Vaux-le-Penil	128,000	2,000	1.6%
France	Villefranche sur Saône	78,301	397	0.5%
France	Villejust	81,500	21,900	26.9%
Germany	Burgkirchen	212,372	95,000	44.7%
Germany	Düsseldorf	413,000	89,043	21.6%
Germany	Ingolstadt	211,000	57,970	27.5%
Germany	Kempten	76,661	27,922	36.4%
Germany	Krefeld	346,231	24,542	7.1%
Germany	Mannheim	317,102	80,987	25.5%
Germany	Neustadt	59,449	16,169	27.2%
Germany	Tornesch	76,000	22,500	29.6%
Germany	Ulm	111,625	44,679	40.0%
Germany	Völklingen	210,488	19,134	9.1%
Great Britain	Shetland Islands	21,511	3,793	17.6%
Italy	Brescia	721,000	43,000	6.0%
Italy	Busto Arsizio (VA)	94,898	8,811	9.3%
Italy	Cremona	64,996	10,630	16.4%

Italy	Dalmine BG)	137,500	24,200	17.6%
Italy	Desio (MI)	49,019	10	0.0%
Italy	Forli	41,400	6,400	15.5%
Italy	Macchiareddu (CA)	212,600	13,600	6.4%
Italy	Macomer (NU)	79,000	1,300	1.6%
Italy	Modena	122,042	2,000	1.6%
Italy	Montale/Agliana (PT)	33,300	3,090	9.3%
Italy	Ospedaletto (PI)	57,944	2,126	3.7%
Italy	Padova	60,376	2,385	4.0%
Italy	Parona PV)	186,800	49,500	26.5%
Italy	Poggibonsi (SI)	20,436	748	3.7%
Italy	Ravenna	169,954	7,633	4.5%
Italy	Rufina/Pontassieve (FI)	9,878	88	0.9%
Italy	Terni	27,000	400	1.5%
Italy	Trieste	138,200	17,400	12.6%
Italy	Venezia	52,448	2,086	4.0%
Italy	Verona	131,300	300	0.2%
Netherlands	Amsterdam	877,351	283,552	32.3%
Netherlands	Dordrecht	206,991	83,891	40.5%
Netherlands	Duiven	335,738	127,923	38.1%
Netherlands	Hengelo	307,029	91,000	29.6%
Netherlands	Moerdijk	655,791	177,238	27.0%
Norway	Bergen	105,000	18,700	17.8%
Norway	Frederikstad	80,381	76,957	95.7%
Norway	Lenvik	5,050	2,803	55.5%
Norway	Oslo (Brobekk)	110,268	10,961	9.9%
Norway	Oslo (Klemetsrud)	148,161	23,537	15.9%
Norway	Sandnes	38,596	7,859	20.4%
Norway	Spjelkavik	34,658	4,328	12.5%
Norway	Trondheim	97,012	39,503	40.7%
Norway	Ål	18,600	6,200	33.3%
Sweden	Avesta	46,800	21,300	45.5%
Sweden	Boden	58,000	10,000	17.2%
Sweden	Bollnäs	37,099	11,136	30.0%
Sweden	Borlänge	34,951	21,598	61.8%
Sweden	Halmstad	146,804	68,714	46.8%
Sweden	Hässleholm	34,137	12,093	35.4%
Sweden	Karlskoga	42,600	10,400	24.4%
Sweden	Köping	25,653	12,175	47.5%
Sweden	Malmö	385,879	156,160	40.5%
Sweden	Mora	16,455	4,955	30.1%

Sweden	Norrköping	163,700	59,091	36.1%
Sweden	Stockholm	520,221	180,915	34.8%
Sweden	Södertälje	249,211	113,538	45.6%
Switzerland	Lausanne	120,000	24,000	20.0%
Total (115 Plants Reporting)		**17,302,688**	**3,710,588**	**21.4%**
*** Switzerland, Lausanne reported commercial and industrial waste co-combusted as percentage range of 0-40%. As such, an average of 20% was used to obtain a numerical value for commercial tons co-combusted annually.**				
****The above table does not include the Rosendall, Netherlands plant since a quantifiable co-combustion capacity was not reported in the ISWA Report (i.e., only "yes").**				
*****Original ISWA data reported total tons for the Odense, Denmark plants as "26, 498." This appears to be a typo, since individually, household waste (100,790 tons/y), commercial waste (109,740 tons/y), and "other" waste (57,968 tons/y) exceeds this value. The correct annual capacity for this plant is 268, 498 tons. As such, our calculation of the total tons/yr (49,806,932) is 242,000 tons greater than what is presented in the ISWA report (49,564,932).**				

Analysis of the same data showed that 10 plants reported co-combustion of RDF (Table 14). On the average, the RDF combusted by these plants amounted to 5.67% of the total feedstock.

Table 14 Co-Combustion of RDF in Europe

Country	Location	Total Tons/y	RDF Tons/y	RDF as % of Total Combusted
Austria	Zwentendorf	323,000	2,300	0.71%
Denmark	Næstved	89,458	63	0.07%
France	Douchy les Mines	39,295	3,530	8.98%
Italy	Poggibonsi (SI)	20,436	2,728	13.35%
Italy	Ravenna	169,954	44,601	26.24%
Italy	Trieste	138,200	1,000	0.72%
Italy	Vercelli	58,890	1,530	2.60%
Italy	Verona	131,300	7,800	5.94%
Spain	Meruelo (Cantabria)	244,639	90	0.04%
Switzerland	Lausanne	120,000	12,000	10.00%
Total (10 Plants Reporting)		**1,335,172**	**75,642**	**5.67%**
*** Switzerland, Lausanne reported RDF co-combusted as percentage range of 0-20%. As such, an average of 10% was used to obtain a numerical value for RDF tons co-combusted annually.**				
****The following eleven ISWA plants are combusting RDF only and therefore were not included in the above table as no co-combustion is taking place: Bergamo, Italy (7 plants), San Vittore del Lazio , Italy (1 plant), Trezzo sull, Italy (1 plant), Weurt, Netherlands (1 plant), and Madrid Spain (1 plant).**				
*****The Södertälje, Sweden plant is not co-combusting RDF with MSW/household waste, only commercial waste and therefore was not included in the above table.**				
******The Schio, Italy plant is not co-combusting RDF with MSW/household waste, only hospital and "other" waste and therefore was not included in the above table.**				

It should be noted that only some WTE plants reported to ISWA materials that were co-combusted. Therefore, there could be other co-combusting WTE plants that are not included in Tables 10-14.

Appendix B - Public Opinion of Waste to Energy

Analysis of Surveys

As part of this case study, two surveys were examined in terms of John Zaller's Receive-Accept-Sample Model[1]: 1) A poll conducted in 1994 on waste management by Cambridge Reports/Research International[2] and 2) An environmental risk perception survey conducted in 1993 with the results discussed in a journal article titled *Risk Perception Differences in a Community with a Municipal Solid Waste Incinerator*[3]

Cambridge Reports Poll

The sampling population of the Cambridge Reports poll included 1,250 adults, with interviews conducted over the telephone. This poll included 54 questions (with 52 out of the 54 directly related to waste management), and the first question being: "Now thinking of the environment, what do you think is the single most important environmental problem facing the country today?" The top three answers were water pollution (15%), air pollution (15%), and "other pollution, pollution in general, car pollution" (14%). It is especially unclear as to what was meant by this last response. (It is assumed that by responding with car pollution, the public is referring to air pollution.) Given that the top three responses were quite vague, it is evident that the majority of the respondents were not well informed regarding specific issues which negatively impact the environment. Zaller's Reception Axiom (A1) states: "The greater a person's level of cognitive engagement with an issue, the more likely he or she is to be exposed to and comprehend-in a word, to receive-political messages." It is believed that here the surveyors were simply attempting to determine what information the public has "received" in terms of matters related to the environment. The second question of the Cambridge Reports poll completely avoided the topic of environmentalism and instead simply asked about political affiliation: "Would you describe yourself as more of a liberal or more of a conservative?" (The majority of the respondents were conservative.) This question can be evaluated in terms of what Zaller refers to as "priming as a type of salience effect," or the type of priming that places the individual's ideological orientation "at the top of the head." The surveyors may have wanted to see whether the sampling population would answer the remaining questions consistent with their political values, which clearly points to Zaller's Resistance Axiom (A2). A2 conveys that the public only stays true to their predispositions when they fully comprehend the messages in front of them.

The first question specific to municipal solid waste incineration/WtE (shown directly below) was preceded by a number of questions on the raw primary materials used to manufacture plastics (i.e, fossil fuels) and landfill groundwater contamination. Zaller emphasizes that the order in which questions are asked significantly affects the responses given.

> "Another way to dispose of solid waste is to build plants that burn waste materials to produce energy. These waste-to-energy plants significantly reduce the volume of solid waste before it is disposed of, but produce an ash residue that must be placed in a landfill. Thinking about all the advantages and disadvantages of waste-to-energy incineration, do you think the benefits outweigh the risks or do the risks outweigh the benefits?"

- 53%- Benefits outweigh the risks
- 31%-Risks outweigh benefits
- 4%-Both about equal
- 12%-Don't know

It is interesting to see that the above question utilizes the term waste to energy in place of municipal solid waste incineration, therefore emphasizing that these plants not only manage waste but also produce heat and power. The question then points out that WtE plants reduce the space required for landfilling, as it is only the non-combustible ash content that requires landfilling. It is therefore not surprising that the majority of the respondents indicated that the benefits of WtE outweigh the risks.

However, the survey then states:

> "…please tell me whether you strongly agree, somewhat agree, somewhat disagree, or strongly disagree…the plastics industry has made good progress toward the development of recyclable plastics, but a great deal more needs to be done before I support a new WtE incinerator."

- 49% Strongly agree
- 39% Somewhat agree
- 6% Somewhat disagree
- 2% Strongly disagree
- Don't know

This question is clearly an example of priming, as it induced the fear that promoting WtE could potentially slow down the rate of recycling. Thus, it is not surprising that the majority of respondents strongly agreed with the statement.

Risk Perception Article/Survey

The sampling population of the Risk Perception survey included three hundred and fifty adult individuals (selected at random) who lived within five kilometers of the incineration facility. These individuals were sent an introductory letter followed by a telephone interview ten days later. The results of this survey were as follows:

- Approximately one third of the sampling population were unaware of the incinerator and these unaware individuals were less supportive of the incinerator than the aware group.
- About half of the aware group were also not supportive of the facility, with the remainder of the aware group in support of the incinerator.

The authors of this article note that the survey was conducted in order to “further understanding of community responses to technology perceived as ‘hazardous’.” In agreement with the authors, it is interesting to see that those individuals which were aware of the incinerator were more in favor of the facility than those who were unaware[3]. This can be partially explained by Zaller’s Reception Axiom which emphasizes that the more attentive or aware an individual is overall, the more likely that person will receive or comprehend a message. Or in other words, Zaller notes that an individual’s general, chronic awareness would influence his or her opinion prior to receiving the information. However, this result does not appear to be in line with Zaller’s Ambivalence Deduction (D1), which states that those who are not highly informed are more apt to accept messages that contradict their true preferences. Of course in this case, it is safe to assume that the preference of the entire sampling population is to live far away from something perceived as potentially hazardous. The authors of the risk perception article conclude “that informing the public about technology perceived as hazardous may not lead to alarm, but may in fact increase acceptance[3].

Conclusion

When relaying information to the public regarding municipal solid waste incineration (or WtE), it is of utmost importance to refer to it within the context of “The Expanded Hierarchy of Waste Management”[4]. This system clearly depicts the priorities for managing solid waste sustainably, as the first and second priorities are waste reduction and recycling, respectively. It is believed that if this were done in the Cambridge Reports poll, WtE would have been seen as even more desirable by the public. Also, the conclusion made in the risk perception directly article relates to Zaller’s argument on elite discourse in that elite messages serve as cues to the public in establishing a policy position.

References

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