Small Scale Energy-from-Waste

Drivers and barriers

IEA Bioenergy

IEA Bioenergy: Task 36: Integrating Energy Recovery into Solid Waste Management Systems

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Drivers and barriers

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Summary

The International Energy Agency Bioenergy Task 36 – 'Integrating Energy Recovery in to Solid Waste Management Systems' (Task 36) reviewed small scale energy from waste (EfW) systems in (Stein and Tobiasen, 2004). That review examined the technology and economics of small-scale energy conversion systems and reported on the level of commercial availability in IEA Bioenergy Task 36 member countries. There has been a demand for an update on that report for a while. However, since there has not been a major leap in technology since that report, the aim of this updated task report is focused on the drivers and barriers regarding small scale EfW.

A yearly capacity of 100,000 tonnes per year (t/y) has been set as the limit for small scale Energy from Waste in this topic report. The drivers and barriers has mainly been done through three case studies, one each in France, Sweden and the UK, but literature and people working within the field of EfW have also been consulted on the subject.

There are clear policy drivers which are influencing EfW development in general, but the decision to develop facilities on a small scale are more relevant to local politics and situation. The factors behind the development of different small scale facilities will differ, as evidenced in the three examples of France, Sweden and the UK.

It is recognised that the costs, both operational and capital, are higher for small scale EfW facilities, but that despite this, there are often other drivers which take precedence over economics alone. Whilst it may be challenging in some cases to demonstrate value for money, other benefits will support a case for small scale EfW.

In the future, financial incentives, and energy and resource drivers may further drive the development of smaller scale EfW facilities using Advanced Conversion Technologies. These technologies enable flexibility in the way in which outputs from EfW are uses, and are likely to be at a smaller scale. For example, the conversion of syngas for use as a fuel in dedicated gas engines, for conversion in to liquid fuels, or use as ammonia or methanol, which can be used in transport fuels and/or as a chemical feedstock. Energy and resource drivers will also add to this, in additional to waste management and landfill diversion targets.

Geography can be a driving factor for small scale EfW, but in many cases there are additional drivers.

Security of supply is a factor to consider. A larger plant might have the economics of scale, but uncertainties in the supply will affect the economic risk assessment and might thus make it harder to initially finance the investment.

The advantages offered by small scale EfW, such as the treatment of waste close to the point of generation, the generation of jobs in the local community, and lower transport distances, all serve to increase the public acceptance of such facilities. With their smaller footprint, smaller scale EfW facilities can be more easily integrated in to existing industrial areas.

Technical issues are not deemed to be a specific barrier. Technologies deployed at small scale are established, and include conventional combustion facilities such as moving grate and oscillating kilns, and Advanced Conversion Technologies.

Introduction

In 2004, the International Energy Agency Bioenergy Task 36 – 'Integrating Energy Recovery in to Solid Waste Management Systems' (Task 36) published a topic report "Review of small scale waste to energy conversion systems" (Stein and Tobiasen, 2004). The aim of that topic report was to review the technology and economics of small-scale energy conversion systems and report on the level of commercial availability in IEA Bioenergy Task 36 member countries. The objectives were to collate information on selected small scale waste treatment systems and to produce a status report of the technical and economic potential of such systems for waste treatment.

There has been an interest expressed from different parties to update that earlier task report since there is a growing interest in small scale energy from waste in different parts of the world. Although there have not been significant technology developments within the area, there are many other aspects that need to be considered when establishing a small scale EfW plant. In this study, case studies from France, Sweden and United Kingdom are presented. The main focus in the case studies has been on the drivers behind the development of these plants, as opposed to which technologies were used. In particular we examined factors such as local geography, ways to offset the higher per tonne cost and the impact of public perception. This has allowed us to highlight how the drivers and barriers for small scale EfW differ between different countries and regions in this report.

SCOPE

Our definition of small scale EfW for this study was plants treating less than 100,000 tonnes per year (t/y). The study only considers aspects concerning thermal treatment plants (combustion, gasification, and pyrolysis). It does not include anaerobic digestion.

The drivers and barriers included in this study were identified in the case studies and through literature and personal communication with persons working within the area of EfW. Since all members in Task 36 are currently European countries, the case studies also reflect that.

Another limitation of this work is that micro-scale plants (i.e. those treating some kg of waste each day) are not included. These facilities are often only for disposal purposes and the energy is not recovered. They are not uncommon in developing countries, where a simple and inexpensive solution is needed, for example when treating health-care waste; however then they are often built without any form of treatment of the emissions formed. The World Health Organisation has published a study regarding emissions from these types of plants (Batterman, 2004).

Background

THE ROLE OF ENERGY FROM WASTE IN THE WASTE MANAGEMENT SYSTEM

Waste has been disposed of by burning for hundreds of years. The first purpose built incinerators, however, were built in the 1900's, with the first incinerator in the United Kingdom being built in Nottingham in 1874 (Herbert, 2007). These early plants were primarily intended for sanitation purposes but the reduction in volume and weight was also an important factor. Some plants recovered energy or heat, but with limited efficiency and little control of emissions. In the 1980s, legislation to control emissions from incineration was introduced by the EU. This has since then been modified and demands on controls and more stringent emission limit values have been applied to the current "Industrial Emissions Directive (2010/75/EU)" (IED).

Improvements to both efficiency and environmental performance over the last few decades have resulted in the thermal treatment and energy recovery from waste in EfW plants being well established commercially across the globe. In Europe alone there are estimated to be more than 400 EfW facilities (CEWEP, 2012). There are still differences in the role of thermal treatment facilities though, as while one hundred percent of Swedish thermal treatment plants are recovering energy, (Avfall Sverige, 2014) it is reported that only 24.5% of the waste incineration plants in Japan are recovering any energy from waste treated (Tabata, 2013).

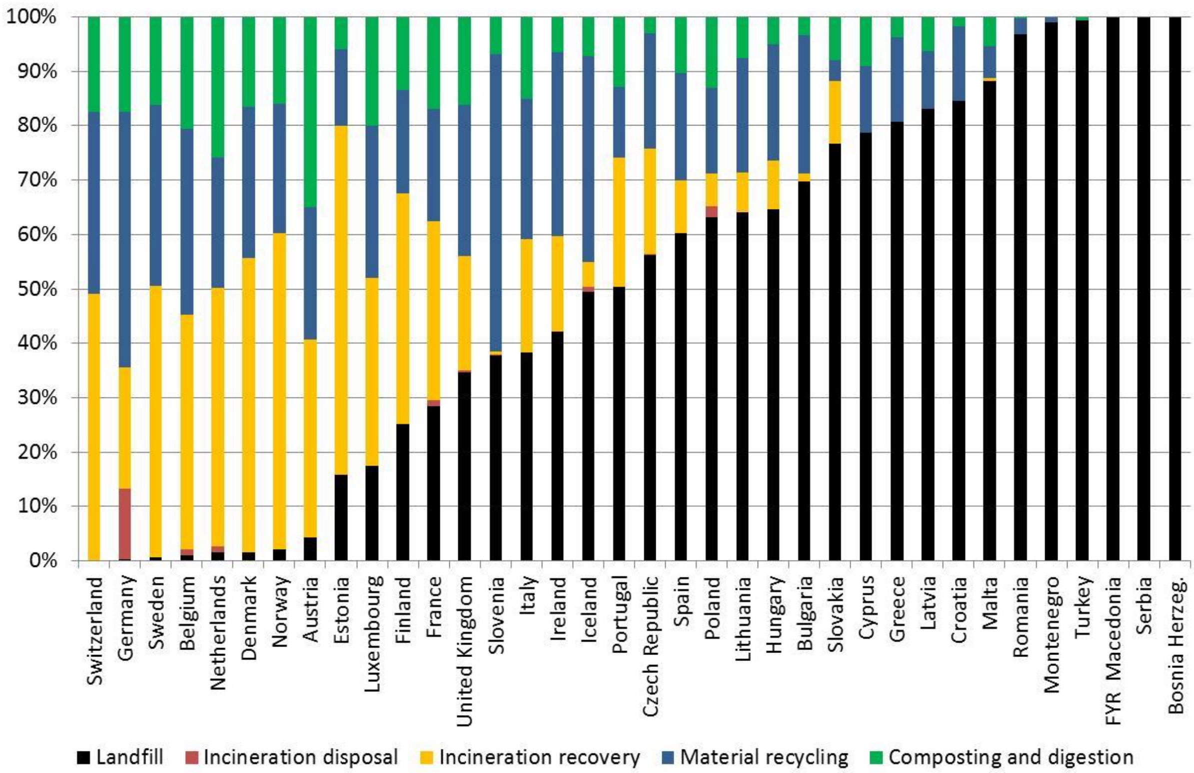

Figure 1 Treatment of municipal solid waste in EU 2013 (Eurostat, 2013).

In EU countries that have achieved high landfill diversion rates, this has been accomplished by developing material recycling, biological treatment, and EfW in parallel, see Figure 1. This shows that EfW is a vital part of successful integrated waste management. The share of waste treated by EfW differs between different countries depending on local conditions and local regulations and policy.

Energy recovery from waste was also put in to focus when the EU Waste Framework (WF) Directive (2008/98/EC) was revised in 2008. In the revised WF Directive a limit was set on the energy efficiency of EfW plants. If a plant fails to achieve this energy recovery efficiency, it is considered as a disposal plant rather than an energy recovery plant, on the same level as landfill in the waste hierarchy (see Figure 2). The limits were also set so that new plants were expected to have higher recovery efficiency than existing plants.

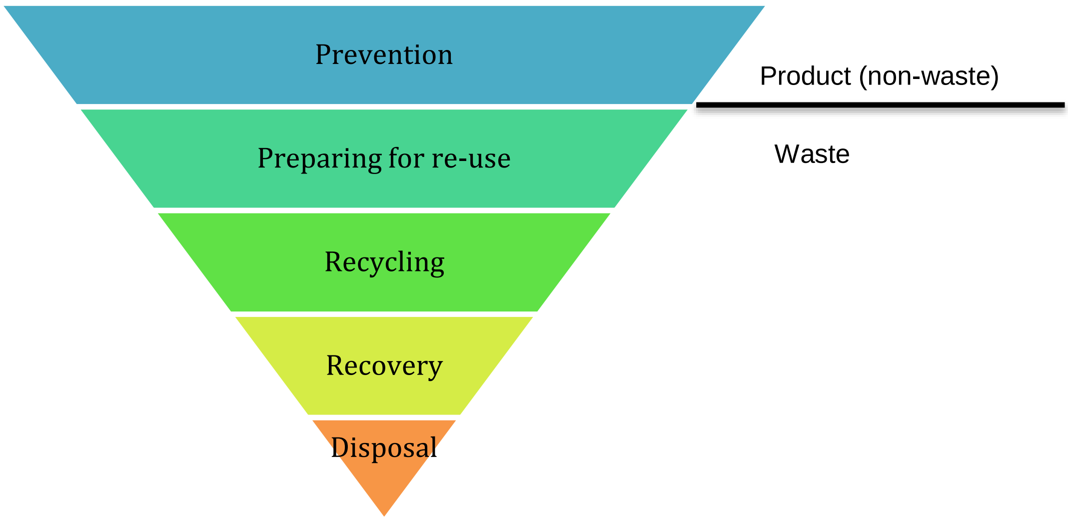

Figure 2 Waste hiearchy in EU with the principle to move towards the higher tiers (prevention being the most beneficial)

SMALL SCALE EFW

Waste is mainly an urban challenge, which means it is an increasing problem as world urban populations are growing. Urban populations are estimated to produce over 3 million tonnes per day (Nature, 2013). Therefore large EfW facilities have tended to be developed in proximity to major urban areas. However, when the volume of waste, transportation costs or public opposition rule out large-scale mass-burn EfW, small-scale technologies can offer smaller communities in rural, semi-urban or remote areas an alternative to landfill. The challenge for small scale systems is to effectively meet emissions limits and regulations while dealing with the higher specific capital costs that developers of small scale systems often face.

Small scale EfW plants are not uncommon; however the presence of small scale EfW plants varies significantly between different countries (Waste Atlas, 2015). In an energy efficiency report produced by CEWEP approximately one third of the 314 plants included were plants with an annual capacity <100,000 tonnes (CEWEP, 2012). In Japan, at least 60% (more than 1000 plants) of waste incineration plants were small scale, and were only in operation for 8 hours per day (Kusuda, 2002). Many of these have since closed, as the Japanese Ministry of Environment reported that in 2009 there were 1243 incinerators in Japan in total, compared to earlier reports, (Kusuda, 2002). There are 48 EfW facilities in Italy that treat MSW, 19 of which have a treatment capacity of < 100,000 t/y (Ciceri, 2015). In comparison, the Netherlands only has two small scale EfW plants, (ISWA, 2013). In the UK, there are 13 small scale EfW facilities, with a combined capacity of 798,000 tonnes (Local Partnerships, 2014). An indication of the variations between countries is given in Error! Reference source not found. below. However it should be noted that Figure 3 only gives the average of the plants that have supplied data, and that some countries have only a small number of plants in total.

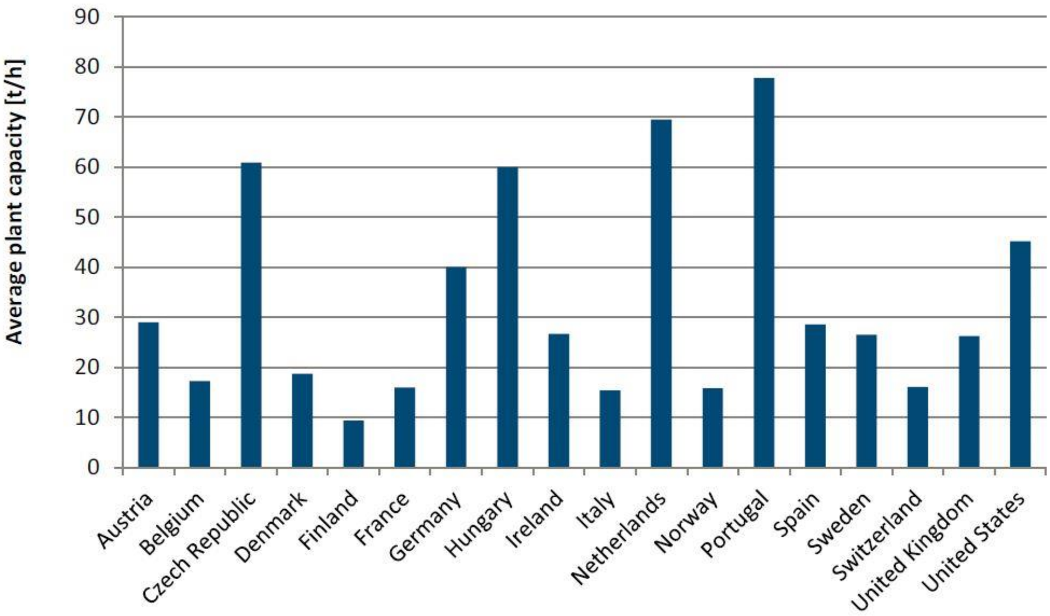

Figure 3 The average size of the plants that have supplied data to the ISWA state of the art report (ISWA, 2013).

TECHNOLOGIES USED FOR SMALL SCALE EFW

The previous task report by Stein and Tobiasen (2004) presented technology and data on eight small scale EfW facilities. With regards to technology, there has not been any significant development in the technologies applied to small scale plants. The dominating conversion technology is combustion, which can be done in moving grate fired boilers, fluidized bed boilers, rocking furnaces or other technologies. In some specific markets there have been increases in plants with alternative conversion technologies, such as gasification and pyrolysis. The experiences from these technologies in commercial operation are still fairly limited, but are increasing. Generally, these alternative technologies have to date been modular small scale plants and in order to increase capacity a number of those modules are combined to a larger unit. However larger scale units are also being developed. In Lathi , Finland, there has been a gasifier of 60 MW (fuel) that has been using biomass and waste as fuel since 1998 and since then a new gasifier for SRF/RDF fuels has been built with a capacity of 250 000 tonnes/year (160 MW fuel effect) (Kurkela, 2014).

Depending on the technology, the need for fuel preparation may differ. Both fluidized bed combustion, pyrolysis, and gasification technologies need a more homogenous fuel than grate combustion systems and thus are preceded by a fuel preparation plant. This could be at the same site or at a different location, with fuel being delivered to the plant. Other technologies like grate fired boilers generally do not need to process residual waste before the thermal conversion, however bulky waste needs to be shredded before being fed into the furnace.

Figure 4 shows a general illustration of an EfW (grate combustion) process. The waste is generally transported to the facility with trucks; the waste is then received in a waste bunker at the facility. In the bunker a crane is used to mix the waste before it is fed into the hopper. In newer plants the cranes are often operated automatically, while in older plants cranes tend to be operated manually. From the hopper the waste is then fed into the furnace of the boiler. Figure 4 shows a grate fired boiler, which is the most common technology used in conventional EfW plants. At the top of the grate the waste is dried, further down the volatile components are gasified and at the bottom there is a combustion of the coke left in the waste. The volatile gases are then also combusted above the grate. The hot flue gases are then transported through the boiler and are cooled by water filled walls and heat exchangers immersed into the flue gas flow. To clean unwanted components from the flue gases, the gas passes through a flue gas treatment plant. The design of the flue gas cleaning varies but will typically consist of a section of plant which physically removes dust and particulates, and other sections of plants designed to remove heavy metals, dioxins, hydrochloric acid (HCl), and sulphur oxides (SOx). After cleaning, the flue gas is emitted through a stack. When considering plants located in EU, it does not matter what type of flue gas cleaning the plant is equipped with, they will need to comply with the emission limit values set out in their environmental permit and the Industrial Emissions Directive (2010/75/EU) (commonly referred to as ‘IED’). This Directive sets the minimum demands on the plants and member states have the possibility to enforce stricter limit values in legislation or environmental permits.

The heat recovered from the combustion of waste is used to raise steam, which is then superheated. The steam is then used in a turbine to generate electricity, and afterwards heat can be recovered for industrial use, district heating, and/or district cooling.

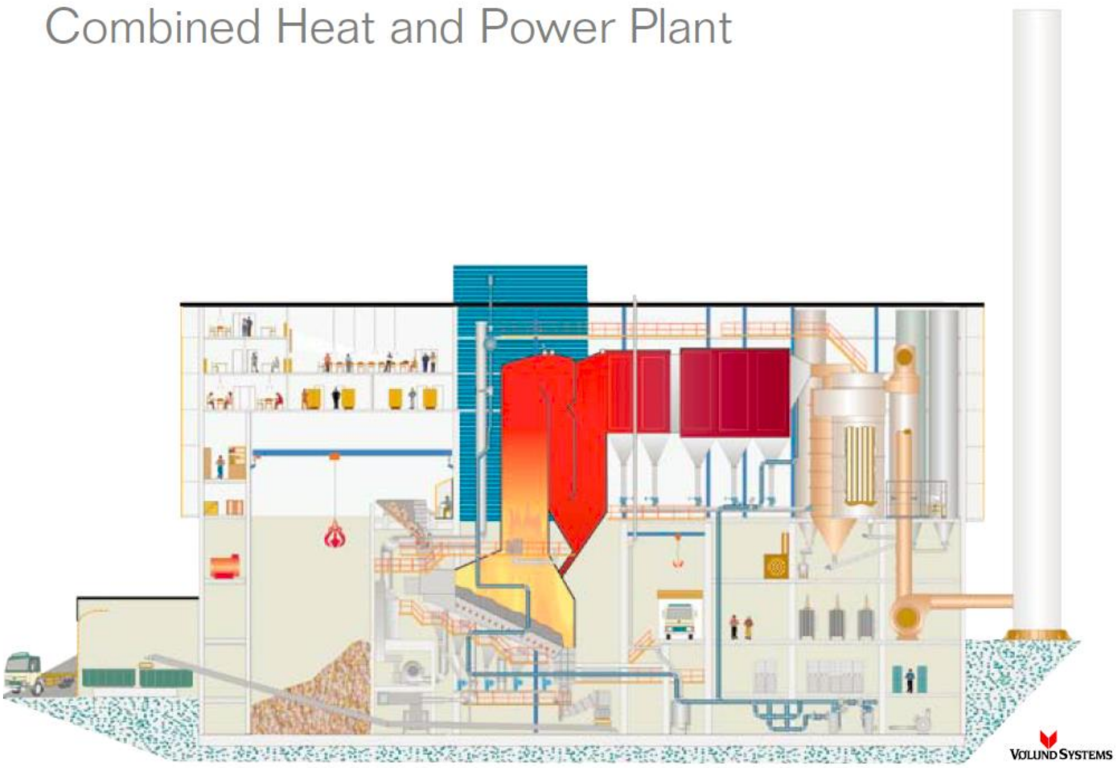

Figure 4 Schematic overview of a EfW plant. Picture provided by Babcock & Wilcox Völund.

Case studies

The following section gives a brief description of the three small scale plants participating in this study. The case studies represent plants in France, Sweden and the United Kingdom and all three plants are combustion plants. The case studies have been performed through personal interviews with representatives from the plants. The questionnaire used as a basis for these interviews are found in Appendix I. All the questions were not answered, either because of business secrets or because the data simply were not available.

EXETER ENERGY RECOVERY FACILITY, UK

Devon is a local authority in the South West of England in the UK. In July 2014, a 60,000 tonnes per annum EfW facility (Exeter Energy Recovery Facility) was opened in Exeter, the principal town in the county, see Figure 5. The facility is operated by Viridor, who manage Devon's waste disposal and treatment services for Exeter and the rest of the county. Viridor, via their parent company (Pennon Group), funded the development of the facility. The facility reverts back to Devon County Council upon expiry of the associated contract.

Figure 5 Exeter Energy Recovery Facility (Devon County Council).

Residual waste from the county is directly delivered to the facility, or via a waste transfer station, depending on location. There is no pre-sorting of the residual waste prior to receipt at the facility other that the source segregation of recyclables that is undertaken at a household level, or at the Household Waste Recycling Centres. The waste is stored in a bunker which has a 3-day capacity, before being combusted in a single-line, oscillating kiln combustion unit.

There were several principal drivers for the development of this facility:

- To reduce waste being sent to landfill, thus driving the management of this residual waste up the waste hierarchy,
- To meet Landfill Allowance Trading Scheme targets
- To recover energy from waste

In addition to European Landfill Directive targets, in 2003 the Waste Emissions and Trading Act and the Landfill Allowance Trading Scheme Regulations imposed annual targets on each Waste Disposal Authority in England to divert increasing amounts of biodegradable waste away from landfill. Landfill tax was also rising at £8/t per annum via the UK landfill tax escalator, resulting in a bill for the County Council of nearly £11M by 2013/14. In response to these drivers, a Waste and Resources Management Strategy for Devon County Council was developed. This facility was developed as an outcome of this strategy to ensure targets were met and to provide certainty of future costs. The facility is expected to export 26.8 GWh of electricity each year. There is currently no export of heat, however a project is underway to try and achieve heat export via a propose district heating network. This is most likely to be to public sector buildings (potentially Exeter University and/or a new housing estate), but there is potential to export to some commercial customers as well.

PONTENX-LES-FORGES, FRANCE

In 1997 a new small scale energy from waste plant was taken into operation in Pontenx-les-Forges (see Figure 6). The region where the plant is situated is located close to the sea, south west of Bordeaux. The region is a popular tourist area and in the summertime, the population increases with 25 % from around 58000 people to 72000 people. This also affects the waste management system, since the amount of waste then also increases significantly during the summer. This is handled by baling and storing waste during summertime.

The plant is owned by an association of municipalities, SIVOM des cantons du pays de Born, and is operated by the private operator Tiru. In 2013 the plant treated 42,760 tonnes of waste and in addition to the waste from the owner of the plant, an additional 39 municipalities deliver waste to the plant. The plant also accepts commercial and industrial waste. The plant is mainly producing electricity with an expected delivery of 14 GWh to the grid each year. In 2015 the plant also started to deliver heat to a nearby greenhouse and the aim is to deliver 40 GWh heat annually.

Figure 6 Energy from waste plant in Pontex-les-Forges.

The main reason for the development of a small scale plant was to replace an existing plant that was too expensive to upgrade to reach the requirements regarding emissions to air. The new plant is larger than the old one and the capacity was designed to be able to handle the residual waste for the next 30 years, with an increase in the residual waste with 2% each year. Public acceptance was also considered to be better for a small plant in France and at that time there were about 100 small scale EfW plants in operation in France.

SKÖVDE VÄRMEVERK, SWEDEN

Skövde is a small municipality with 53,000 inhabitants in central-Southern Sweden. The city's district heating scheme was fuelled by biomass and fossil fuels until 2005. In 2005 a plant with a capacity of 60,000 tonnes of waste per annum started production, see Figure 7. When the plant became operational, the use of fossil fuels both for district heating and for process heat to a nearby Volvo factory was drastically reduced. A further benefit was the reduction in transport of residual waste outside of the area. The plant treats approximately 50% MSW, 47% C&I waste and 3% hazardous waste. The plant contributes 45% of total energy production by the operator, which corresponds to almost 170 GWh per year.

Figure 7 Skövde Värmeverk Combined Heat and Power Plant, Skövde, Sweden. Photographer: Thomas Harrysson

One of the main driving forces behind the development of this facility is a carbon dioxide tax which was introduced in Sweden in 1991. This tax has since been increased a number of times. Further drivers were a landfill tax, introduced in 2000, and finally a landfill ban for combustible wastes came in to force in 2002. The residual waste was transported to the EfW plant in Linköping (180 km away). In 2003 the decision makers in the municipality decided that the public energy company Skövde Värmeverk AB should build a small scale EfW plant, mainly because waste was the most economic fuel alternative for the district heating production. Skövde has one of the lowest fees for district heating in Sweden.

Today the plant treats MSW from the municipality of Skövde as well as three surrounding municipalities through service concessions. The facility also treats approximately 12,000 tonnes of waste per year which is won via other public procurement contracts. Most of the residual waste is from municipalities with separate collection of organic waste. In the last few years Skövde has also imported waste from Norway and Malta.

COMPARISON OF THE PLANTS

Below some of the general and technical data for the three case studies are shown.

Table 1 General comaprison between the three case studies.

General information	Exeter	Pontenex	Skövde
Number of inhabitants in the city/municipality	1,100,000[1]	58 000	53 000
Start of operation	2014	1997	2005
Capacity (tonnes/year)	60 000	43 000	60 000
Ownership	Private. Reverts back to public ownership at end of contract	Association of municipalities	Public company
Waste data	**Exeter**	**Pontenex**	**Skövde**
Which types of waste are treated	99% MSW, 1% C&I	MSW, C&I	50% MSW, 47 % C&I, 3% Hazardous
Lower heating value (MJ/kg a.r.)	9.8-10.7	8.5	12

[1] This is the population of Devon County Council – not just Exeter. There is another plant in the county – 245,000 tonnes, in Plymouth, so this plant does not serve all of this population.

Mass fraction of carbon considered as renewable	50 %	National average 65%	MSW 69% C&I 62%
Energy fraction considered as renewable [2]	50 %	50 %	

Technical data	Exeter	Pontenex	Skövde
Technology	Oscillating furnace	Oscillating furnace	Grate
Thermal capacity of the plant (MW_{th})	19.6	7	21.5 (18 originally)
Electrical capacity of the plant (MW_{el})	4.2	2.5	2
Other heat generation	No	No	Flue gas condensation 3.5 MW
Steam data (°C/bar)	390/40 (e)	355/34 (e)	215/16 (e)

[2] The energy content of waste considered to be renewable has recently changed in the UK (see DUKES 2015, Chapter 6, paragraph 6.114 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450298/DUKES_2015_Chapter_6.pdf

Operational hours/year	7796	7752	8030
Availability (operational hours/planned operational hours)	89 %	95.7 %	99 %

Note: in the table above the population served by the plant is not known precisely. The figure provided is the population of Devon County, not just Exeter. Devon is also served by another EfW plant with a capacity of 245 000 tonnes per year.

Regarding the population indicated for Pontenex, that is for the Association of municipalities owning the plant. Pontenex in itself is between 4-5000 inhabitants.

Drivers and barriers

In many cases drivers and barriers are a combination of different factors affecting each other. As an example, regulations can work in different ways. They can work as a strict framework on what is allowed and what is not, but can just as easily be something that either gives an economic incentive or disincentive for EfW. In the following part some of the drivers and barriers are discussed.

POLICY AND LEGISLATION

One of the main drivers for the establishment of EfW facilities has been the need to divert waste from landfill in order to treat waste higher up in the waste hierarchy. In Europe, the main policy drivers impacting EfW originate from EU Directives, such as the Landfill Directive (1999/31/EC), the Industrial Emission Directive (2010/75/EU)(IED) and the Renewable Energy Directive (2009/28/EC) (RED), all of which have encouraged the development of EfW infrastructure.

In response to these Directives, EU Member States have adopted a wide range of fiscal and regulatory measures in order to encourage EfW development, including imposing taxes and disincentives to landfill. These measures have made all other waste treatment operations more competitive. In some cases there has also been incentives and subsidies to specifically increase the uptake of EfW. The EU Landfill (LF) Directive contains targets on the diversion of organic waste from landfills, where the main target is that a maximum of 35 % of the organic waste are allowed to be landfilled in the year of 2016 (or in some cases 2020). The Member States have implemented the LF Directive in different ways. 20 countries in Europe have chosen to introduce a landfill tax on all or certain waste fractions going to landfill (Fisher et al, 2012). Eight countries have also introduced a landfill ban for organic and combustible waste (Fisher et al, 2012) including Sweden.

All the plants taking part in the case studies referred to the policies and regulations concerning landfill diversion as one of the most important factors for building the EfW plant. All three countries have also implemented a landfill tax, although at different levels (see Table 2).

Table 2 Landfill taxes in France, Sweden, and United Kingdom

Country	Landfill tax (€/tonne) in 2015
France (Douane, 2015)	€14-40 depending on a number of conditions
Sweden (SFS 1999:673)	≈ € 53 (500 SEK)
United Kingdom	≈ € 112 (£82.6)

In the UK in particular the increased cost of landfilling due to the annual landfill tax escalator has made other waste treatment options more competitive. The landfill tax was introduced in the UK in 1996, and increased by £8 (€10.8)/t per year until 2014. The rate is now fixed, but will rise with inflation and will not be less than £80 (€108)/t until at least 2020. This does not mean that small scale plants have any advantage over the large scale plants, however all plants become more cost viable as an alternative to landfill. For some time in the UK, the uncertainty on the level of future landfill tax increases has encouraged investment in alternative technologies such as EfW and anaerobic digestion.

These policy drivers, in addition to the Landfill Allowance Trading Scheme, were attributed as being the main drivers for the development of the Exeter Energy Recovery Facility.

Policy and legislation have a significant effect on the development of EfW. The example of the WFD was mentioned in the background and both the LF Directive and the RED have encouraged the uptake of EfW as one part of the efforts to divert waste from landfill and to generate more renewable energy. EfW in also explicitly mentioned in the newly published Energy union package (COM (2015) 80) as a potential to consider.

In most cases regulations or policies are not specifically targeting small or large scale EfW, but there has been an effect, although the specific effect has differed in different countries. As mentioned in the background the number of EfW plants in Japan has decreased significantly the last 20 years or so and this is due to a change in policy and legislation in Japan where small batch-fired boilers are to be avoided to minimise the environmental impact (Vehlow et. al, 2015). That trend has also been observed in France where there in 1993 were over 300 EfW plants in operation, while today it is only 120. This decrease is due to the costs of investment to fulfil the stricter emission limit values that was introduced in the Waste Incineration Directive (2000/76/EC) and later on in the IED.

Another important driver can be taxes on energy or fossil carbon emissions. These were instrumental in the development of the Skövde Värmeverk CHP plant. Energy taxation in Sweden has had a significant effect on what fuels are used in the district heating systems since heat from fossil fuels has been heavily taxed (Holmgren, 2006). In Skövde it was never an option to build a plant based on fossil fuels when the old plant should be replaced, due to those taxes. The fossil part of the waste was not taxed, although such a carbon tax was introduced on waste incineration 2006. Depending on the electrical efficiency of the plant the tax was in the range of €7.5-50/tonne of waste. It was later (2010) abolished since it was not having the desired effect of diverting plastic material from the combustible fraction of municipal solid waste.

Another aspect of policy and legislation is the effort for the plant to keep up to date with the changes in the legislation. In larger plants there might be dedicated people working with those specific questions, while in a small scale plant, this have to be integrated in the personnel's ordinary work. Skövde explicitly mentioned this as a disadvantage and a challenge when being small scale.

ECONOMICS

The capital costs of an EfW facility do not tend to increase linearly with plant capacity (Ellyin, 2012). There are economies of scale that mean that per tonne of waste costs decrease with size of EfW plant. For example, more efficient use of land, reduced unit costs, higher energy efficiency of some elements of the plant, and the fact that some costs such as access roads, weighbridges, development costs and engineering design do not necessarily increase in line with plant capacity. Some of the operational costs are also higher for a smaller plant, such as the costs for periodic measurements of emissions stipulated by the IED in Europe (and emissions legislation in other countries around the world) and the need for quality assurance and control of the instruments used in emission monitoring are examples that are not linear with size of plant, but rather on number of instruments and/or number of production lines in the plant. This was echoed by Devon County Council, who said that not being able to benefit from the economies of scale of a larger facility was a disadvantage when developing a small scale EfW.

In addition to financial penalties such as landfill and carbon taxes, there are also financial incentives that make small scale facilities more attractive. Most gasification and pyrolysis technologies are based on modular designs and are often smaller than conventional combustion facilities. Examples of small scale gasification facilities include the Energos EfW plants in Norway, Germany and the UK, with capacities ranging from 30,000 – 80,000 tonnes per annum (Energos, 2015). Whilst these modular technologies may not benefit from the economic advantages of scaling up to larger facilities, they may be eligible for financial subsidies. In the UK for example, the growth in recent investment in this technology has been due primarily to the treatment of waste in UK Government's Renewables Order (RO). The RO supports renewable energy generated by Advanced Conversion Technologies (ACT) with two Renewable Obligation Certificates (ROCs) per MWh, whereas conventional EfW is not supported. ROCs are tradable certificates that are issued to operators of accredited renewable generating facilities for each MWh of renewable energy produced. This provides a market incentive through an increase revenue stream, enhancing the economic viability of ACT. The RO is ending in 2017 and being replaced by a 'Contract for Difference' (CfD) scheme, which will be the main UK financial mechanism for large scale renewable electricity. The CFD will also support electricity generated by EfW where ACT is used or systems that include combined heat and power are included, whereas standard electricity generation EfW plants will not be supported. The price paid for electricity generated by ACT will be higher than conventional combustion (DECC, 2015) and this has proven to be attractive to ACT developers to date (Riley, 2015).

Due to the lower economies of scale, one of the main economic impacts on small scale EfW is operating costs. In most cases, operating costs are understood to be higher per tonne for smaller scale facilities. This is evidenced in Figure 8 in which plots of average gate fees against operational capacity of EfW and MBT facilities in England are shown (Local Partnerships, 2014).

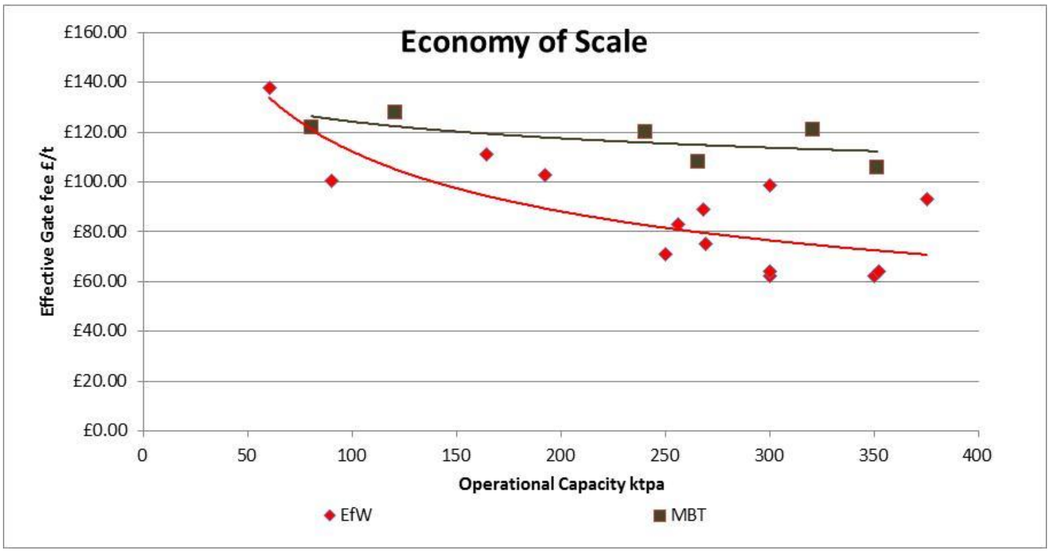

Figure 8 Gate fee vs operational capacity in the UK. (Local Partnerships, 2014).

The costs can be offset by subsidies in different ways. That has also been the case in Pontenex, where the investment was subsidized by 30% through EU (Life) and other support mechanisms. Later modifications to the plant has also been supported economically by Ademe and Life. In addition the Pontenex plant has also received a feed-in tariff guaranteeing the value of the electricity. The other two plants (Skövde and Exeter) have not received these subsidies. A comparison between investment costs, gate-fees and prices for electricity and heat between the plants are shown in Table 3.

Table 3 Comparison between the plants concerning economic data. Please not that the data for the investment is in the year when the plant was taken into operation.

Economics	Exeter	Pontenex	Skövde
Investment cost in the year of delivery	£41.2 M (€51 M)	€16 M (would be approx. € 40M in 2014)	320 MSEK (€34.5 M)
Financing	Capital financed by Pennon group	Subsidies from EU, regional council and Ademe, Bank loan, gate fees	Partly by bank loan with the municipality as guarantee and partly by operative lease
Gate fee MSW (€/tonne)	>141	81-100	41-60
Gate fee C&I (€/tonne)	>141	101-120	41-60
Average price electricity (€/MWh)	61.7	40 (feed-in tariff)	33.5 (average spot price)
Average price for heat (€/MWh)	-	31	55 (price to end consumer, including costs for distribution)

There is a significant difference in the gate-fee between the plants, some of which could be explained by for examples the subsidies received for the Pontenex plant but also depending on the possibilities for revenues from heat production which is shown in the next section.

ENERGY DEMAND

In general there is a demand for electricity especially from renewable energy sources. However what is considered renewable from Energy-from-Waste plants and their priority in the grid differs between countries and this impacts the availability of incentives. Of the three plants participating in the case studies, only Pontenex has received any incentives for electricity production (through feed-in tariff).

The largest difference between countries when it comes to energy demand come when looking at the heat market. In Sweden, one of the drivers for small scale EfW plants has been the need for an economic fuel for district heating production and the fact that the heat source needs to be within reasonably close proximity to the heat network. In the case of the Skövde facility, in choosing which technology to develop it was important to have high availability of the technology and to have a technology that was shown to be reliable. There were already two existing plants established in other parts of Sweden that had proven reliable. The size was determined by the need to be able to run on full load (without the need of chillers) during summer, when heat demand is low. An additional economic driver in the Swedish case was also the high tax on carbon dioxide, which made it unrealistic to invest in district heating production from fossil fuels. So in the case of Skövde, the EfW plant competed with similar small scale biomass fired plants, which have similar disadvantages when it comes to economy of scale.

In Pontenex they have just developed heat deliveries to a nearby greenhouse. This will make a considerable addition to the efficiency of the plant and the status for the plant will be changed to recovery (R1- according to European Waste Framework Directive). The heat delivery will also contribute positively to the economics of the plant.

The Exeter plant is currently looking into the possibilities to export heat through a district heating network which then mainly would supply public buildings with heat.

In countries where there is less demand for heat, or no established district heating infrastructure, small scale facilities may not be as attractive as the loss of economy of scale cannot be offset by the sale of heat. The difference in energy exported (electricity+ heat) is clearly shown in Table 4. The value of the heat is also demonstrated earlier in the comparison between the plants (see Table 1) where the Swedish plant has chosen low steam data which put priority to heat production and high availability compared to the production of electricity.

Table 4 Comparison between the plants concering generated and exported energy.

Energy production and use	Exeter	Pontenex	Skövde
Electricity produced (GWh)	31.3	14	9.8
Heat produced (GWh)	0	71.6	189
Electricity exported (GWh)	26.8	6.9	4
Heat exported (GWh)	0	40*	168

*Starting deliveries to a nearby greenhouse, the number given is the intended size of deliveries.

GEOGRAPHY

Geography is a common factor influencing the decision to develop a small scale EfW facility. As an example, in remote locations transport of waste can be difficult and expensive; this might make a small scale plant more viable. This is evidenced in the development of small scale EfW facilities on islands such as the Isle of Man, Shetland Isles and The Faroe Islands, all of whom have small scale EfW plants (Waste Atlas, 2015). A further driver will be the likely lack of landfill capacity on smaller islands. There might also be a desire to be self-sufficient in managing waste by developing a local solution for waste treatment and thereby avoiding transports of waste to other areas, and the opportunity for district heating may also be a driver. Conversely, communities on islands or other remote locations may oppose EfW, even at a small scale, due to perceived negative impact on environment and tourism (Zevgolis, 2002).

SECURITY OF SUPPLY

When considering the supply of combustible waste for a EfW facility, a small scale facility might be an advantage, making it possible to secure the necessary amounts of waste to fulfil a large part of the capacity in advance. This can be a crucial factor when obtaining financing for the plant, since a large part of the revenues of the plant is from the gate-fee on incoming waste. Larger plants generally have a larger area of uptake and are, in some cases, dependant on commercial and industrial waste as well as MSW from public procurement. Depending on the treatment capacity present in a region or nation there might be a tight competition for the waste. This in turn might both lead to lower gate fees and insecurity of supply, both of which represent larger risks for the party financing the plant. In Sweden, Netherlands and Germany this competition has also been somewhat offset with the import of waste from countries like Norway, UK and Ireland. However the competition can also come from neighbouring countries: the Swedish import from Norway has created a need for Norwegian plants to in their turn import waste from mainly UK.

PUBLIC ACCEPTANCE AND PLANNING

Public opposition of EfW differs significantly from country to country. There are many more years of experience of EfW in Scandinavia and therefore the public is familiar and more accepting of this technology. In the UK, the harmful impact of the mass burn incinerators built in the 1950s and 1960s have resulted in negative perceptions of EfW persisting to current times. In countries where there is a good track record of government policy supporting EfW as part of an integrated waste management system, public opposition is generally low. The public ownership of plants through specific non-profit companies has also aided the public acceptance of EfW facilities and the guarantee of protection of public health. In Sweden, public opposition to EfW facilities is in general low, although when establishing an EfW plant in a city that has no previous experience of EfW the opposition is generally larger than if expanding an existing plant. In the mid-1980s there was a moratorium on expanding EfW capacity. This was due to reports about high dioxin emissions. This was lifted after a year after an agreement between the industry and the authorities. The agreement involved the investment in better air pollution control equipment and the emissions dropped rapidly.

In the UK, gaining public acceptance for EfW facilities has often been challenging, with many facilities delayed by ongoing and determined public opposition. This has been particularly true in some cases of large scale EfW facilities in the UK in the last decade. Waste, and the treatment of waste, remains a highly a politically motivated area in the UK, with some local authorities adopting a 'no-burner' strategy for the treatment of residual waste. This has often resulted in the construction of alternative facilities, such as Mechanical Biological Treatment (MBT) facilities being constructed instead. However, these facilities will still produce a residual waste which requires further treatment of disposal. Therefore the option of a small-scale EfW solution may be more attractive in the UK from a public perception point of view.

The fact that the Exeter Energy Recovery Facility was designed at a smaller scale was an advantage, especially when creating a connection with the public and the waste that they generate (Barratt, 2015). The small scale was a benefit when selling the concept to stakeholders at a planning stage, and in subsequent public engagement. It was also judged to have been easier to obtain the relevant planning permits for a small scale plant than it would have been for a larger scale. There has been only a very small amount of local opposition experienced during the planning, construction and operation of the facility to date. Devon County Council consider this to be a good reflection of both the extensive communications work that was undertaken throughout the project, and the suitability of the solution for the local area. The smooth process was also attributed to the fact that the facility was constructed on an existing industrial area, and was the site of a previous Exeter incinerator which closed in the 1990s.

Small scale facilities are not always advantageous, however, when it comes to public procurement. The need to use public procurement procedures to develop a facility can be a barrier for small scale facilities. Small scale plants in general have higher costs per tonne, and may have to compete with sending waste to a larger facility, even if transport distances are considerably longer. This was the case with the Exeter facility, for which the authority had a considerable challenge demonstrating value for money, and it is thought that it would have been unaffordable if it had been smaller.

TECHNICAL ISSUES

Other than capacity, there are other key differences between small scale and larger plants. A recently published article that reviewed technologies and performances of thermal treatment systems concluded that the smaller size energy from waste plants were generally having low to moderate steam data and thus limited to 20-24% net electrical efficiency (Lombardi, 2015). This was also independent of the chosen technology (traditional incineration or gasification or pyrolysis). The larger plants have shown that a net electrical efficiency of 30-31% is possible when generating electricity only. A energy efficiency report by CEWEP report a lower average electricity production (as well as overall energy recovery) from the smaller plants compared to the larger ones (CEWEP, 2012). The same study also shows geographical differences, where plants in northern Europe have a higher energy recovery rate than the ones in southern Europe. The latter is related to the more frequent use of district heating to provide heating for both commercial and residential buildings in northern Europe.

Devon County Council considered other forms of waste treatment when developing their facility, with pyrolysis and gasification and mechanical biological treatment all being evaluated. Whilst most types of thermal treatment are proven at small scale, other options were rejected on issues included the limited track record and reliability of the technology, and the requirement of the pre-treatment of waste for some technologies. Now that the Exeter facility is operational, the main technical challenge from the waste disposal authority's perspective is managing the waste inputs on day-to-day basis, because the facility's bunker only has capacity for around 3 days' deliveries. This reduces the operational flexibility of the facility on a day-to-day basis. A larger bunker size would have been preferable, but this was constrained by the physical size of the site.

Conclusions

There are clear policy drivers which are influencing EfW development in general, but the decision to develop facilities on a small scale are more relevant to local politics and situation. The factors behind the development of different small scale facilities will differ, as evidenced in the three examples of the UK, France and Sweden.

It is recognised that the costs, both operational and capital, are higher for small scale EfW facilities, but that, despite this, there are often other drivers which take precedence over economics alone. Whilst it may be challenging in some cases to demonstrate value for money, other benefits will support a case for small scale EfW.

In the future, financial incentives, and energy and resource drivers may further drive the development of smaller scale EfW facilities using Advanced Conversion Technologies. These technologies enable flexibility in the way in which outputs from EfW are used, and are likely to be at a smaller scale. For example, the conversion of syngas for use as a fuel in dedicated gas engines, for conversion in to liquid fuels, or use as ammonia or methanol, which can be used in transport fuels and as a chemical feedstock. Energy and resource drivers will also add to this, in additional to waste management and landfill diversion targets.

Geography can be a driving factor for small scale EfW, but in many cases there are additional drivers.

Security of supply is a factor to consider. A larger plant might have the economics of scale, but uncertainties in the supply will affect the economic risk assessment and might thus make it harder to initially finance the investment.

The advantages offered by small scale EfW, such as the treatment of waste close to the point of generation, the generation of jobs in the local community, and lower transport distances, all serve to increase the public acceptance of such facilities. With their smaller footprint, smaller scale EfW facilities can be more easily integrated in to existing industrial areas.

Technical issues are not deemed to be a specific barrier. Technologies deployed at small scale are established, and include conventional combustion facilities such as moving grate and oscillating kilns, and Advanced Conversion Technologies.

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Appendix I - Questionnaire small scale Energy-from-Waste

This questionnaire is s to be used **as a basis** for a survey among operators of small scale waste-to-energy plants (< 100 000 tonnes of waste/year). It is not to be sent to respondents but rather as a guiding tool for performing an oral interview with operators.

General data

What is the location of the plant? (country and city/region)

When was the operation of the plant started? (year)

Who owns the plant (e.g. municipality, municipal company, private company) and share of each ownership (%)?

Received waste and other fuels

From which municipalities/area is waste received?

What is total yearly amount of waste received (tonnes)?

What types of waste are received (e.g. municipal waste, commercial waste, industrial waste, hazardous waste) and share of each (%)?

What other fuels are used in the plant (tonnes, m^3 or MWh per year for each fuel)?

What are the agreements concerning waste reception (i.e. is municipal waste directed to the plant or is the operator acting on a free market)?

Is the waste received at the plant due to any source-separation scheme (i.e. is the waste a residual combustible waste fraction)? If yes, describe the source-separation system(s) and estimate the shares of the respective waste streams (% of the total amount of waste received with origin in the respective source-separation scheme)

Is the waste received at the plant sorted at a central facility (MRF/MBT or other sorting facility) or at the plant before energy recovery? If yes, describe the separation process (i.e. the share and character of the fraction for energy recovery)

For the **received waste** what is the average…(on basis as received)

…net calorific value (MJ/kg)

…moisture content (% by weight)?

…ash content (% by weight)?

…mass fraction of renewable carbon (renewable carbon/total carbon) (% by weight)?

…energy fraction considered as renewable (% of energy content)?

Technical specifications

Total capacity of the plant (MW)?

Thermal capacity of the plant (MWth)?

Electrical capacity of the plant (MWe)?

Other factors (e.g. flue gas condensation or other economizer not included in thermal effect above, expressed in MW)?

Which treatment process is applied (e.g. combustion, pyrolysis, gasification)?

What type of boiler(s) are there at the plant (grate/fluidised bed and number of each)? How many lines are there?

What kind of flue gas cleaning system is applied (e.g. electrostatic precipitator, baghouse filter, wet scrubber, SNCR, SCR, NID reactor or a combination of several of those)?

Steam/hot water data for the plant (bar and ℃)?

Supplier of…

…boiler (company)?

…turbine (company)?

…flue gas treatment system (company)?

Energy production and use

Heat production (including process steam) at the plant (GWh/year)?

Electricity production at the plant (GWh/year)?

From the plant what is the exported…

…heat (GWh)?

…steam (GWh)?

…electricity (GWh)?

To whom is the heat delivered (e.g. district heating network, industrial customers)?

Internal consumption of…

…heat (GWh)?

…electricity (GWh)?

How many hours is the plant in operation per year (hours)?

The availability of the plant (number of hours of operation / (8760 – number of hours of planned shutdown) expressed in %)?

Energy efficiency of the plant (utilised energy/supplied energy expressed in %)?

Thermal efficiency of the respective boilers (generated energy/supplied energy expressed in %)?

Is the process in the plant considered to be a recovery operation (R1) according to the waste framework directive 2008/98/EC, Annex II (yes/no)?

Residual products

What types of residual products does the process generate (e.g. fly ash, bottom ash etc)?

What is the yearly amount of residual products (tonnes per type of rest-product)?

How are the residual products treated/managed (e.g. landfilling, recovery of mine, road construction)?

Drivers/obstacles

Which were the main reasons for the establishment of the plant (e.g. to reduce waste to landfilling, energy)?

Why was the plant established as a small scale plant (e.g. due to remote location, only limited funding, public perception)?

What legislation (if any) contributed to/were barriers to the establishment of the plant?

Which policies (if any) contributed to/were barriers to the establishment of the plant?

Which were the main economic incentives contributing to the establishment of the plant?

If the plant is connected to a district heating network…

…was there an existing network already when the plant was established?

…was the network installed as the plant was established?

…did the operator have to finance it, completely or partly?

…if yes, is this part of the capital cost for the establishment and what was the cost?

Was the plant constructed in an existing industrial area or on virgin land?

Was there any local resistance to the establishment of the plant (i.e. protests from neighbours)?

Economy

For all cost/price estimates below, please include a date for the estimates

How was the development of the plant financed (e.g. gate fees, sales of energy, underwritten by local community, bank/venture capitalists, discount rate required by financers etc)? Describe the financial forms applied and the approximate shares.

What was the investment costs for the…

…land/site (Euros)?

…buildings and construction work (Euros)?

…equipment/installations (Euros)?

What was the total investment cost for the plant (the sum of the separate costs in question 43) and at what year was the investment made (Euros and year)?

What is the cost (including capital cost of the plant, land costs, operating costs and production costs) for the plant per tonne received waste (Euros/tonne)?

What is the yearly cost for operation and maintenance of the plant (Euros)?

What is the approximate gate fee for municipal waste (Euros)?

<40 €/ton   41-60€/ton   61-80 €/ton   81-100€/ton   101-120€/ton   121-140€/ton   >141 €/ton

What is the approximate gate fee for industrial/commercial waste (Euros)?

<40 €/ton   41-60€/ton   61-80 €/ton   81-100€/ton   101-120€/ton   121-140€/ton   >141 €/ton

What is the approximate average price for delivered …

…heat (€/MWh)?

…steam (€/MWh)?

…electricity (€/MWh)?

Is the operation of the plant subsidised in any way? If yes, please describe and also include the way the base for subsidies (e.g. capital grant, feed in tariff, subsidy per MWh)

Personal reflections

What is (according to your opinion) the advantages/disadvantages of establishment and operation of a small scale energy from waste plant?

What was or is (according to your opinion) the most difficult thing about developing and operating a small scale energy from waste plant?

Is there anything you would do differently if you would re-develop the plant?

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Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/