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Driving forces for import of waste for energy recovery in Sweden

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Between 1996 and 2002, the Swedish import of so-called yellow waste for energy recovery increased. The import mainly consisted of separated wood waste and mixes of used wood and paper and/or plastics that was combusted in district heat production plants (DHPPs). Some mixed waste was imported to waste incineration plants for energy recovery (10% of the import of yellow waste for energy recovery in 2002). The import came primarily from Germany, the Netherlands, Norway, Denmark and Finland. We identified six underlying driving forces for this recent increase of imported waste which are outlined and their interactive issues discussed.

- The energy system infrastructure, which enables high energy recovery in Sweden.
- The energy taxation, where high Swedish taxes on fossil fuels make relatively expensive solid biofuels the main alternative for base load production of district heat.
- The quality of the waste-derived fuels, which has been higher in the exporting countries than in Sweden.
- The bans on landfilling within Europe and the shortage of waste treatment capacity.
- Taxes on waste management in Europe.
- Gate fee differences between exporting countries and Sweden.

In the future, the overall strength of these driving forces will probably be weakened. A Swedish tax on waste incineration is being investigated. In other European countries, the ambition to reach the Kyoto targets and increase the renewable electricity production could improve the competitiveness of waste-derived fuels in comparison with fossil fuels. Swedish DHPPs using waste-derived fuels will experience higher costs after the Waste Incineration Directive is fully implemented. The uncertainty about European waste generation and treatment capacity, however, might have a large influence on the future gate fees and thus also on the yellow waste import into Sweden.

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Introduction

Background

Import and export of waste within the European Union, namely between member states and countries outside the EU, is regulated through the Waste Shipments Regulation (Reg. (EEC) 259/93). The waste transported for recovery and disposal is divided into three different categories: green, yellow and red, primarily on the basis of its hazardous properties (Table 1).

For green waste, there is no obligation to report the quantities transported. Ericsson & Nilsson (2004) estimated the import for energy recovery in Sweden in 2000 to be 760 000 t. For import of yellow and red waste, the Swedish Environmental Protection Agency (Swedish EPA) has to give prior approval. Figure 1 illustrates the total import of yellow and red waste and that used for energy recovery. The import for energy recovery is dominated by yellow waste, accounting for 97–99%, especially from 1999 onwards.

Figure 2 illustrates the country/area-wide quantities of yellow waste imported for energy recovery and their use in Sweden between 1999 and 2002. Overall, this import increased from 200 000 t in 1999 to 430 000 t in 2002. It mainly consisted of separated wood waste and mixes of used wood and paper and/or plastics that was combusted in district heat production plants (DHPPs). The import to waste incineration plants was typically mixes of household waste, which was too inhomogeneous and had levels of heavy metals and corrosive compounds that were too high to be combusted in DHPPs (Appelberg 2004). A fraction of the import (typically source-separated wood waste) ended up at industries.

The import of yellow waste is controversial. The Swedish Government has expressed a degree of scepticism regarding increasing import (Ministry of the Environment 2003). The Swedish Environmental Protection Agency (EPA) would regard import as a problem if it were to impede the ambitions of the Swedish environmental policy (Swedish EPA 2002). In addition, the domestic biofuel producers fear that rising import would lower the biofuel prices and reduce their opportunity to supply the biofuel to the home market (Ahnland 2001, Davner 2001). Some environmental non-governmental organizations are also opposing the import, since they believe waste incineration is an unsound treatment option with respect to environmental and health issues (Alfredsson 2003, Greenpeace 2004).

Considering the trend of increased import of yellow waste and the many opinions, it is essential to understand the driving forces and how they could develop in future. This would improve the opportunities to take into account the effects of imported wastes when new policies and targets are set up within Swedish waste management planning.

There has been scant analysis of impact of the Swedish import of yellow waste for energy recovery. Agterberg (1997), Vinterbäck & Hillring (2000), Vesterinen & Alakangas (2001) addressed the import of green waste as part of analysing the trade of biofuels to and from Sweden. Ericsson & Nilsson (2004) addressed the import of yellow waste, but their main focus was on import of green waste.

Table 1: Examples of waste fuels sorted after trade categories (adapted after Ericsson & Nilsson 2004).

Trade category	Examples
Green waste	Firewood Wood chips, bark Logging residues Wood pellets, briquettes, powder Tall oil Chemically untreated used wood Sorted fractions of plastics, paper, rubber
Yellow waste	Chemically treated used wood Mixed fractions of used wood, paper, rubber, plastics Municipal solid waste
Red waste	Wastes containing, consisting of or contaminated with polychlorinated biphenyl (PCB) or polychlorinated dibenzo-dioxin Peroxides other than hydrogen peroxide

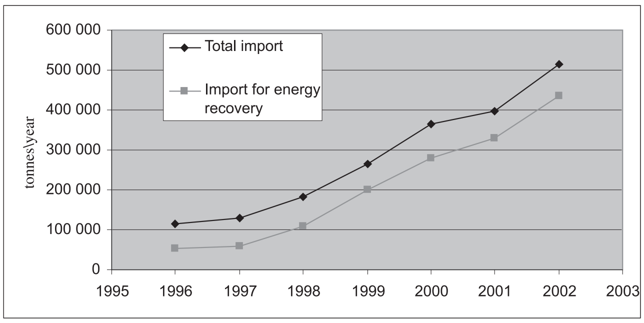

Fig. 1: Total import and import for energy recovery of yellow and red waste in Sweden, 1996–2002. The figure is based on data from Swedish EPA (2002) and Appelberg (2004). According to Swedish EPA (2002), the data for 1996 and 1997 are uncertain and might be underestimated.

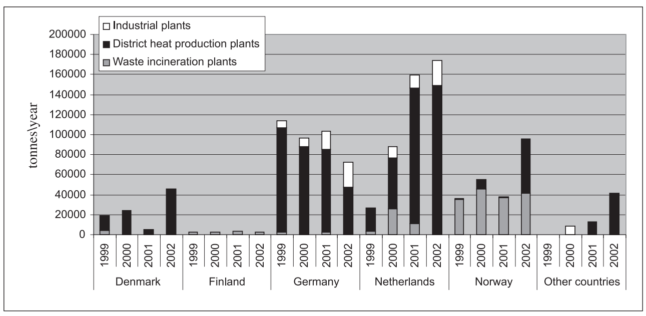

Fig. 2: Import of yellow waste for energy recovery during 1999–2002. The figure is based on data from Swedish EPA (Appelberg 2004).

For other European countries, work has been performed that addresses shipments of yellow waste for energy recovery. Dijkgraaf *et al.* (2001) presented a comprehensive economic modelling of a common waste incineration market in Europe. Nielsen (2003) discussed the possible effects on the amounts of waste incinerated and treatment prices in Denmark due to a liberalized waste incineration market in the region of Öresund (which covers the southern part of Sweden and the eastern part of Denmark). Veksebo Miljørådgivning (2003) studied the same region as Nielsen (2003) and mapped out gate fees for incineration plants, DHPPs, sorting stations and industrial facilities managing combustible green and yellow waste in both Sweden and Denmark. Rasmussen & Reimann (2004) examined the social benefit of letting a cement company in Denmark import waste from Norway and Germany, for combustion in its cement kilns.

Aim and scope

The aim of this article is to examine and identify the main driving forces behind the recent import of yellow waste for energy recovery in Sweden. Furthermore, we discuss the future development of these driving forces. Compared to earlier studies, we look at import from a larger number of countries. This will provide a stronger basis for identifying relevant driving forces behind the import. Furthermore, we explain the driving forces by examining both the waste management system and the energy system in the studied countries. This has only been done in a limited way before. Part of the results has previously been presented in a research report (RVF 2002).

Method

To capture the driving forces of the recent import, we identify and compare relevant aspects of the waste management system and the energy system in Sweden as well as in five of the exporting countries: Denmark, Finland, Germany, Norway and the Netherlands. During 1999–2002, the import from these countries accounted for 90–100% of the total import of yellow waste for energy recovery. The work has been conducted in the following steps.

1. A literature survey to get an orientation of the subject and the waste management and energy systems in the six countries.
2. Contacts with incineration plants, DHPPs and fuel companies in Sweden that have been or are importing yellow waste for energy recovery.
3. Contacts with national waste and energy organizations in the exporting countries.
4. Subsequent data analysis accompanied by gathering of additional relevant literature and data.

Outline

Major driving forces of the recent import from an energy perspective are identified in the section 'Driving forces from an energy perspective' and from a waste management perspective in the section 'Driving forces from a waste management perspective'. The future development of the import is discussed in the section entitled 'Future development'. The final section includes the major conclusions of the work. As a framework for the discussion, we use the driving forces behind the recent import identified in the following paragraphs.

Driving forces behind the recent import

Driving forces from an energy perspective

The following key drivers have been identified for the import from an energy perspective:

- the energy system infrastructure;
- the energy taxation; and
- the quality of the waste-derived fuels.

The energy system infrastructure

The *energy system infrastructure* is very important as it determines how much of the energy content in the waste can be recovered. If it allows the energy to be recovered as useful heat, for example, through district heating, the thermodynamic losses would be small and a large part of the energy content recovered. However, if it only allows electricity to be produced, the thermodynamic losses are likely to be much higher and the amount of recovered energy is sharply reduced.

In Sweden, Denmark and Finland, district heating is a well-established technology, which provides heat to a large share of the residential heat market. In the other three countries, the market share of district heating is much less, which reduces the opportunities to reach high energy recovery from waste (Euroheat & Power 2003, IEA 2004b). Table 2 illustrates the energy recovery as heat and electricity at waste incineration in the six countries. Import to Sweden can thus mean a large increase of energy recovery, even when considering the longer transport of the waste. As an example, using ECOTransIT (2004), a transport from Hamburg to Göteborg could be estimated to consume 0.024 MWh $tonne^{-1}$ waste through sea transport and 0.20 MWh $tonne^{-1}$ waste through truck transport.

Another important aspect of the energy system infrastructure is the relatively large share of energy production facilities prepared for combustion of solid biofuels and peat in Sweden (IEA 2004a, b). The moisture content and fuel particle size of waste are different from those of coal, which is a more common solid fuel in Germany, the Netherlands, and Denmark (IEA 2004a, b). In these respects, waste-derived

Table 2: Comparison of energy recovery (heat and electricity) and revenues from energy sales at waste incineration plants. The source is ISWA (2002) if nothing else is stated.

	Heat			Electricity			Total
		Revenue heat			Revenue electricity		
	MWh tonne^{-1} incinerated	€ MWh^{-1}	€ tonne^{-1} incinerated	MWh tonne^{-1} incinerated	€ MWh^{-1}	€ tonne^{-1} incinerated	€ tonne^{-1} incinerated
Sweden	2.8[1]	19[2]	54	0.1[1]	28[3]	3	57
Finland	2.6[4]	17[5]	44	0	–	–	44
Norway	1.8	17[6]	30	0	–	–	30
Denmark, heat only	2.4[7]	22[8]	53	–	–	–	53
Denmark, CHP	2.0[7]	22[8]	43	0.4[7]	28[3]	10	54
Germany	0.6	13[9]	8	0.3	23[10]	6	14
Netherlands	0.2[11]	0[12]	0	0.5[11]	30[13]	14	14

(1) RVF (2000); (2) Estimation based on the revenues at three large incineration plants; (3) Average spot market price 2002 (Nordpool 2004); (4) One mass-burn incineration plant only, producing district heat (Alakangas *et al.* 2000); (5) Eunomia (2002); (6) Estimation based on SFT (2004); (7) Bögelund *et al.* (2002); (8) Miljøstyrelsen (2002); (9) Estimation based on Baum *et al.* (2002); (10) Average spot market price 2002 (EEX 2004); (11) AOO (2003b); (12) Gerlagh (2004); (13) Average spot market price 2002 (APX 2004).

fuels are more similar to biofuel and peat, which makes it comparatively easy for plant owners in the Swedish district heating sector and industry to use the imported waste-derived fuels.

Energy taxation

The value of the district heat is higher in Sweden compared to Germany and the Netherlands. One important reason for this is the difference in *energy taxation*. Sweden has high energy and CO_2 taxes on fossil fuels (STEM 2003), which make these fuels unattractive for district heat production. Instead, the main alternative fuel for base load district heat production is biofuel (Sahlin *et al.* 2004). Solid biofuels as well as waste are exempted from energy tax, CO_2 tax and sulphur tax. Since biofuels have a higher price than coal, which would be used if there were no taxes, the value of the district heat produced from waste/waste-derived fuels is increased.

In Germany and the Netherlands, the main alternative is district heat production from combined heat and power (CHP) plants fuelled with natural gas or coal. The energy and CO_2 taxes on coal (but also on natural gas) are lower than in Sweden (Euroheat & Power 2003), which in combination with the fact that the CHP plants are erected for the main purpose of producing electricity (which makes the heat a by-product) might explain why the value of the district heat from waste/waste-derived fuels is lower. According to Gerlagh (2004), the revenues from sold district heat in the Netherlands are much smaller than the revenues from electricity. In the discussions on electricity production subsidies, the revenues from heat are often neglected (Gerlagh 2004).

In Table 2 revenues of the energy recovered from waste incineration are compared on a national level. The table should be evaluated with care since the data are assimilated from diverse sources and from different years. However, the table shows that the high energy recovery and the relatively high value of district heat in Sweden make the average energy revenues much higher in Sweden than in Germany and the Netherlands.

Quality of the waste-derived fuels

Beside the economic situation, interviews with importers to DHPPs (Dahlgren 2001, Hammar 2001, Ryk 2001, Werkelin 2001) have also indicated that the quality of the waste-derived fuels has been higher in Germany and the Netherlands. It was not until the Swedish landfill tax was introduced in 2000 that the quality difference began to diminish.

Driving forces from a waste management perspective

From a waste management perspective, we identified the following as key drivers for the import:

- bans on landfilling and shortage of waste treatment capacity;
- taxes on waste management; and
- gate fee differences.

In the Netherlands, the *landfill ban* was imposed in 1996, much earlier than other countries (see Table 3). This has led to a *shortage of alternative treatment capacity*. In 2003, this shortage amounted to almost 1 million tonnes (AOO 2004). One way of coping with the ban has been separation of combustible waste fractions, which could be combusted either in domestic coal-fuelled power plants/cement kilns or exported. In 2003, the export of combustible waste amounted 2.5 million tonnes (AOO 2004).

Table 3: Implementation of bans.

	Landfill ban on combustible waste	Landfill ban on organic waste
Sweden	2002	2005
Denmark	1997	–
Finland	–	–
Germany	–	1 June 2005
Netherlands	1996	1996*
Norway	–	2001**

* Agricultural waste, park and garden waste and source-separated organic household waste (AOO 1996).
** Defined as easily degradable organic waste from the food industry, food waste from restaurants and private households, and parts of the park and garden waste. The ban will probably be extended to all degradable waste from July 16, 2009 (SFT 2004).

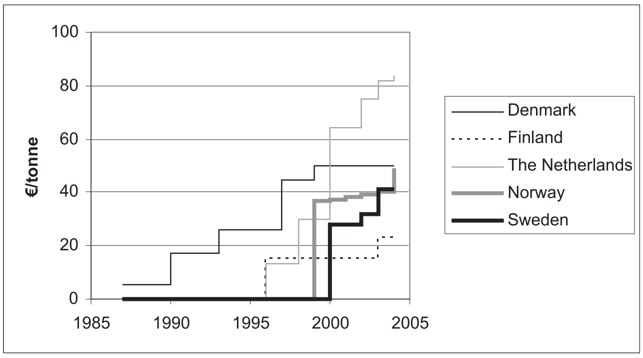

Fig. 3: Comparison of landfill taxes in Denmark, Finland, Norway, the Netherlands and Sweden during 1987–2004. The sources are Videncenter (2004) (for Denmark), Saether (2004) (for Norway), Lindenhovius (2004) (for the Netherlands), Marttila (2004) (for Finland), and RVF (2003) (for Sweden). Since the second half of 2003, the Norwegian landfill tax is differentiated in two classes depending of the environmental standard of the landfill. In this figure, we have used the lower tax. In 2004, the higher tax amounts to around 64 €/tonne.

In Germany, some landfill owners, who will close their landfills before the ban takes effect, have drastically reduced the gate fees, resulting in very low gate fees for landfilling in some parts of Germany (GACE 2002, Reimann 2002). In other parts of Germany, where the gate fees for incineration and landfilling are high, it is possible that the upcoming ban has stimulated separation of mixed waste, resulting in combustible fractions that could be either combusted in domestic coal-fuelled power plants/cement kilns or exported. The low landfill gate fees, in combination with the options of separating combustible fractions, have led to a current overcapacity of waste incineration in Germany (GACE 2002).

The next important driving force is the *tax applied both on landfilling and incineration*. A landfill tax makes domestic landfilling more expensive. Furthermore, it makes the landfilling of residues from incineration more expensive. The landfill tax in Sweden was introduced later than the corresponding taxes in Denmark and the Netherlands (Figure 3). While the level of taxes in Sweden, Denmark and Norway now is quite similar, there is still a large difference in taxation of combustible waste between Sweden and the Netherlands.

Looking at the incineration taxes, they have been introduced in Denmark, Norway and the Netherlands (although the tax level in the Netherlands so far has been 0 € $tonne^{-1}$). The tax level in Denmark increased from 5 to 44 € $tonne^{-1}$ between 1987 and 2003. From its introduction in 1999, the Norwegian incineration tax has been divided into a base tax and an extra tax depending on the level of energy recovery. The resulting tax was in the interval 10–44 € $tonne^{-1}$ (100 and 0% energy recovery, respectively) during 1999–2003. The tax will be reconstructed into a system where different emission fees are used for the emissions regulated through the Waste Incineration Directive.

The last driving force is the *gate fee difference* for waste treatment. The gate fees largely depend on the driving forces we have presented earlier. For example, a high energy recovery and a high value of energy increases the revenues, which make it possible to lower the gate fees. Taxes on landfilling and incineration normally mean that the plant owner will have to increase the gate fee to compensate for the tax.

However, the gate fees also depend on the management and the market orientation of the plant owners. Since the beginning of the 1990s, there has been a trend of municipalities selling out their energy utilities, including waste incineration plants, to large energy companies. Other plants have been transformed into companies with a market orientation, where the focus shifted from local to regional waste treatment. Earlier, the fees (for energy and waste treatment) would cover the costs of the municipality. Now, many district heating plants, including incinerators, have changed their strategies into maximizing the profits. It is therefore natural for the companies to examine options to reduce costs or increase revenues. The large energy companies are accustomed to international import of fuels (oil, natural gas and coal) and it is not a big step to also import waste-derived fuels. Here the gate fee level can be used flexibly and competitively.

Comparing the gate fees in Figure 4, it is clear that the Swedish levels are competitive. However, for export to Sweden, the transport costs have to be taken into account (see Table 4). From an economic point of view, it would be possible to expand imports of mixed waste. This goes especially for the Netherlands, where the gate fee to incineration is high; there is a ban on landfilling and there is a shortage of treatment capacity. However, as pointed out by Dijkgraaf *et al.* (2001), the long transport distances from the Netherlands to Sweden might mean unacceptable degradation of the waste, followed by hygiene problems. It is worth noting that export of mixed waste for waste incineration is currently banned in

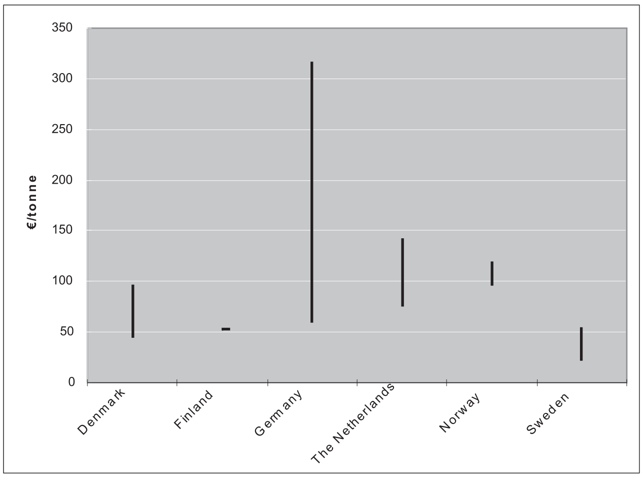

Fig. 4: Typical gate fees to incineration including tax excluding VAT. The figure is based on information from the following sources: Bögelund *et al.* (2002) (Denmark), AEA (2001) (Finland), AOO (2003a) and Reimann (2002) (Germany and the Netherlands), SFT (2004) (Norway), RVF (2003) (Sweden) and Eunomia (2002) (all countries but Norway).

the Netherlands; but the Dutch government is currently examining whether this ban should be lifted from 2006 onward (VROM 2003).

If the gate fee for treating mixed waste is high, this works as an encouragement to find alternative solutions by separating the waste into fractions that can be treated by other methods, one of them being energy recovery in other facilities. For the separated waste, it is more relevant to compare the gate fees at DHPPs in Sweden with the gate fees for cement kilns and co-combustion at coal-fired power plants. Swedish importers can offer to take care of this waste at around 0 € $tonne^{-1}$ and also pay for the transport (Carlsson 2001, Dahlgren 2001, Hammar 2001). In Germany, the gate fees to cement kilns and co-combustion range from 0 to 130 € $tonne^{-1}$ (Reimann 2002). According to Lanser (2004), the situation for Dutch cement kilns does not differ much from the German situation. The export to Sweden is thus a competitive alternative for producers of residual-derived fuel (RDF). International trade is also a competitive alternative for Swedish district heat producers. For example, in 2001 the price of RDF-pellets from the Netherlands was in the range of 2–4 € MWh^{-1} (Michélsen 2001). This can be compared to the fuel price of domestic wood pellets in Sweden, which ranged from 15–20 € MWh^{-1}.

Future development

The energy system infrastructure

In future it is likely that the energy system infrastructures will change, leading to reduced incentives for import into Sweden. This influence comes from the following.

1. The Kyoto Protocol.
2. The 'White Paper for a Community Strategy and Action Plan, Energy for the Future: Renewable Sources of Energy', adopted by the European Commission in December 1997.
3. The EU Directive (2001/77/EC) on the promotion of electricity produced from renewable energy sources in the internal electricity market.
4. The EU Directive (2004/8/EC) on the promotion of cogeneration based on a useful heat demand in the internal energy market.

In the Kyoto Protocol, the 'old' EU-15 member states have agreed on reducing their greenhouse gas (GHG) emissions for the period 2008–2012 by 8% compared to the reference year 1990. One option to reduce emissions is to increase the use of renewable energy sources. Within the European Union the shift from fossil fuels to renewable fuels is further supported by the above-mentioned White Paper and the EU Directive on the promotion of electricity produced from renewable energy sources.

Since combustible waste to different degrees can be considered a renewable fuel, the Kyoto Protocol, the White Paper and the Directive give strong incentives to use it for reaching domestic targets, especially in countries where the resources of renewable fuels are small. This is the case in the Netherlands, where the largest renewable electricity production in 2000 came from incineration of the organic fraction of municipal solid waste (MSW; Junginger *et al.* 2004). In Germany, electricity produced in bio-fuelled combined heat and power

Table 4: Example of transport costs of mixed waste from the five countries to Stockholm (own calculations based on a transport cost equation used in Dijkgraaf et al. (2001)). Observe that the truck costs require that the trucks have a return transport.

	Truck (€ $tonne^{-1}$)	Boat (€ $tonne^{-1}$)	Total (€ $tonne^{-1}$)	Comment
Denmark	52		52	800 km truck, including bridge fee 11 € $tonne^{-1}$
Finland	27	11	38	500 km truck, 500 km boat
Germany	27	13	40	500 km truck, 1000 km boat
The Netherlands	11	15	27	150 km truck, 1600 km boat
Norway	32		32	600 km truck

plants receives a fixed high electricity price of around 80–100 € MWh^{-1} during 20 years of plant life (Elcertifikatutredningen 2001). This has increased the national demand for wood waste, which has led to higher prices and greater competition. This trend is expected to continue in the coming years, since there are many plans to expand the capacity for bio-fuelled combined heat and power plants (Scheuermann & Thrän 2004). As a consequence, it will be more difficult to export wood waste to Sweden.

Another possible route of reducing GHG-emissions is further promotion of co-combustion of waste and coal in power stations. Both in the Netherlands and in Germany large use of coal power make this an interesting option (Junginger *et al.* 2004). The use of waste in cement kilns could also increase, since the waste is replacing fossil fuels.

The recently adopted directive on the promotion of co-generation will promote higher energy efficiencies in the energy conversion of fuels. One plausible effect of this directive is that district heating will be supported in European countries where it currently has a small share of the residential heat market. District heating enables efficient co-generation of electricity and heat, but it also improves the opportunities of reaching higher energy recovery from waste incineration. The effects of this directive are rather to be seen in a long-term perspective, resulting in diminished differences in energy recovery between waste incineration plants in Sweden and in other European countries.

The energy taxation

In comparison to other European countries, Sweden has high energy and CO_2 taxes on fossil fuels. However, this tax difference might be reduced in the future. First, there is the introduction of tradable CO_2-emission permits (TEP) within the European Union. The value of the TEP is important, since it has the same effect on the energy system as a common CO_2 tax. The International Energy Agency made an overview of TEP studies, where the TEP value ranged from 6 to 36 € $tonne^{-1}$ CO_2 (IEA 2001). This can be compared to the Swedish current CO_2 tax of around 100 € $tonne^{-1}$. If the CO_2 tax were replaced by an international TEP system, it is thus likely that the costs of emitting CO_2 would be significantly lowered, which would improve the opportunities of using fossil fuels. Consequently, the value of the district heat produced from waste would be lowered in Sweden. In European countries where the CO_2 tax is low or absent, the introduction of a TEP scheme would work in the opposite way and increase the value of district heat produced from waste.

Second, the Swedish energy taxation system must be reformed, since the lower taxation of the manufacturing sector is regarded by the EU as an illegal governmental support. An inquiry was commissioned by the government (SOU 2003), which proposed that all companies would have the same low energy and CO_2 taxes as the manufacturing industry. A consequence analysis (Profu 2003a) showed that this would reduce the competitiveness of biofuels and could increase the use of coal in the energy system. The competitiveness of biofuels might be 'compensated' by the use of tradable green certificates (TGC) for production of electricity from renewables and by the TEP system, but the lower taxes would lower the value of the district heat produced from waste.

Both the reform of the energy taxation and the conditions for the national TEP system are under development and will probably be presented during 2004–2005. Both changes might lead to a development where the Swedish energy and CO_2 taxes on fossil fuels are lowered, which would lower the value of district heat produced from waste. Consequently, this would lower the incentives for import of waste for energy recovery in Sweden.

The quality of the waste-derived fuels

In Europe, there is currently an ongoing standardization project for fuels derived from waste: solid recovered fuels (SRF) (CEN 2003). This will facilitate trade of waste for energy recovery, since the standardization will enhance the quality of the fuels and give the buyers better information about the product.

However, the standardization process will probably lead to higher costs for the companies producing SRF, which may lead to higher prices. In Sweden, owners of DHPPs can buy and use the current waste-derived fuels without adjusting their combustion equipment according to the Incineration Directive (2000/76/EC) only until 28 December 2005. To cope with the Directive, they can choose to invest in more advanced combustion and flue gas cleaning equipment, or use cleaner fuels with a higher price (e.g. green waste). In either case, the profitability of using waste-derived fuel will decrease, and consequently the profitability of the import will be reduced.

The standardization, in combination with a possible large demand from other European countries that need to meet their Kyoto targets, might also raise the price to a level where export to Sweden is not competitive. The Swedish importers might then instead focus on the Swedish market, where the quality of the waste-derived fuels has been improved.

Bans on landfilling and shortage of waste treatment capacity

The Landfilling Directive (1999/31/EC) means that large amounts of European waste that are currently landfilled, must be treated by other methods. These amounts also depend on the waste generation quantities. The effects of this development on the export to Sweden are not obvious. In Sweden, the bans on landfilling will mainly be met by expanding the incineration capacity (Profu 2003b). If the Swedish waste amounts would increase less than anticipated, the current expansion might result in an overcapacity at plants. Plant owners might then be more interested, than today, in import to make use of the overcapacity. On the other hand, if waste amounts would grow faster than expected in combination with some expansion plans being withdrawn, a shortage of capacity in Sweden would probably reduce the incentives for import. In the same way, waste generation and treatment expansion leading to shortage or excess of capacity in other European countries might also increase/reduce the incentives for import to Swedish incineration plants.

Taxes on waste management

The Swedish Government has commissioned an evaluation of the Swedish waste tax law. In this work, an assessment of the consequences of a waste incineration tax is one of the main assignments. The whole evaluation should be finished by 30 June 2005.

A waste incineration tax will reduce the incentives for import to waste incineration plants. However, the level of the tax will decide whether the impact on the import is small or large. The tax must also be co-ordinated with the energy taxation and with the system for tradable green certificates (TGC) for production of electricity from renewables. Since a large share of the waste has a renewable origin, there has been an ongoing discussion of whether waste incineration should be included in the system in order to stimulate more combined heat and power production from the planned new waste incineration facilities.

Note that only a small share of the import ends up in waste incineration plants. The major part ends up in DHPPs (cf. Figure 2). The introduction of a tax must therefore consider impacts on these plants.

Gate fee differences

Looking at the different future changes in the waste management system and in the energy system, we find it probable that the gate fee differences would be reduced between Sweden and the other countries in the study. The strongest factor for this development is the possible introduction of a Swedish tax on waste incineration. The reformation of the whole energy taxation system is also important, since it might decrease the value of the produced heat. For CHP plants, however, an incorporation of waste in the TGC system could outweigh this effect, leading to smaller increments of the gate fees or even to reduced gate fees depending on the TGC value, the incineration tax and the change of the energy taxes (Profu 2004). In other countries, it is possible that the ambition to reach the Kyoto targets and increase the renewable electricity production will improve the competitiveness of source-separated waste-derived fuels in comparison with fossil fuels. Gate fees for energy recovery can thus be stimulated to decrease.

These outcomes are, however, sensitive to the uncertainty about waste generation and treatment capacity in the future. If an excess capacity of incineration is established in Sweden, plant owners might lower their gate fees as long as their variable costs are covered, in an attempt to attract foreign waste. Similarly, if landfill bans in Europe in combination with increased waste generation lead to shortage of capacity, the gate fees may increase outside Sweden, thus increasing the gate fee difference and thereby incentives for import.

Conclusions

The import of yellow waste for energy recovery in Sweden mainly comes from Denmark, Finland, Germany, the Netherlands and Norway. During 1999–2002 the amounts from these countries corresponded to over 90% of the import. Our conclusion is that the following driving forces have contributed to recent import into Sweden.

- *The energy system infrastructure*, which enables high energy recovery in Sweden through the use of district heating. The large use of solid fuels (biofuels and peat) with characteristics similar to those of waste-derived fuels also facilitates the import.
- *The energy taxation*, which increases the value of district heat from waste-derived fuels. High Swedish taxes on fossil fuels make the solid biofuels the main alternative for base load production of district heat.
- *The quality of the waste-derived fuels*, which has been higher especially in Germany and the Netherlands.
- *The bans on landfilling and the shortage of waste treatment capacity*, which in the Netherlands, Norway and Denmark have stimulated international trade.
- *Taxes on waste management*, which have increased the costs for landfilling in the Netherlands, Finland, Norway and Denmark and the costs of incineration in Norway and Denmark.
- *Gate fee differences*, resulting from the above-mentioned driving forces and the management and the market orientation of the plant owners.

In comparison with earlier work on import/export of yellow waste, we have identified a larger number of driving forces behind the import. Dijkgraaf *et al.* (2001) identified the difference in gate fees as the main driving force for the export and import. Nielsen (2003) and Veksebo Miljørådgivning (2003) both concluded that shortage of treatment capacity and the existence of a waste incineration tax were additional driving forces affecting the gate fee differences and thus the import/export.

Looking at the different future changes, it is probable that the overall strength of these driving forces will be weakened. The strongest factor for this development is the possible introduction of a tax on waste incineration in Sweden. However, the reformation of the Swedish energy taxation system is also important, since it might decrease the value of the produced heat. In other European countries, it is possible that the ambition to reach the Kyoto targets and increase the renewable electricity production will improve the competitiveness of source-separated waste-derived fuels in comparison with fossil fuels. Additionally, Swedish DHPPs using waste-derived fuels will experience higher costs after the Waste Incineration Directive is fully implemented.

The conclusions herein are sensitive to some factors. The introduction of a tax on waste incineration must include not only incineration plants, but also DHPPs. The uncertainties about waste generation and treatment capacity, both in Sweden and the exporting countries, are other important factors.

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