Food waste disposers: energy, environmental and operational consequences of household residential use

DANVA Report # 85

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Study and hearing

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Summary and conclusion

This report originated from a request by DANVA's (Danish Water and Wastewater Association) members and Danish municipalities for better background information for deciding whether to permit or prohibit the installation of residential food waste disposers. Food waste disposers are installed in many locations throughout the world because they are a convenient and hygienic way for people in residential units to quickly dispose of organic food waste and to reduce the amount of organic waste in landfill and ultimately to exploit the energy in the organic food waste at sewage treatment plants with digestion tanks.

The report looks at what installing food waste disposers in residences would mean in terms of operating sewer systems, sewage treatment plants and waste management systems, as well as what it would mean in terms of utilizing the energy stored in food waste. Finally, the report examines the environmental consequences of sending waste to a waste incineration plant, biogas plant or to a digestion tank at a sewage treatment plant.

The report is based on reports collected from northern Europe and from the USA. In addition, we looked at information regarding the consequences of food waste disposers on sewer line operations that was collected directly from water utility companies. In Denmark, there is relatively little experience with installed food waste disposers.

In terms of sewer system operations, the final conclusion was that food waste that is run through food waste disposers can result in increased formation of hydrogen sulphide in sewer systems with a long retention time. There was no evidence that food waste disposers lead to increased sedimentation, fat accumulation or rat problems.

Sewage treatment plants are especially affected by an increased load of organic material because adding nutrient salts and toxic agents in particular will have a marginal effect.

If the organic portion of the waste is removed from the garbage collection, this amount of garbage is reduced by approx. 20-30%. Moreover, the garbage can be collected less frequently if food waste disposers are installed in all or the majority of residences in a given area.

The energy in food waste is used most efficiently at an incineration plant, next at a centralized biogasification plant and least efficiently at a sewage treatment plant's digestion tank. However, biogasification provides the largest reduction in greenhouse gas emissions. There may be situations with new house construction where it may be most advantageous to remove the organic food waste with food waste disposers.

The reason why less energy is extracted from food waste that is sent to a sewage treatment plant through the sewer system is that in a sewage treatment plant (with a clarification tank) approximately 40% of COD is lost in the process tank and in the outfall (and cannot be digested).

The energy-related and environmental benefits related to how food waste is best utilized depends on which energy sources are used to produce electrical power and heating and as a fuel in the transport sector.

1 Purpose

The overall goal of the report is to evaluate the advantages and disadvantages for a community by allowing the use of food waste disposers in residential homes and to highlight the consequences in terms of energy, CO_2, the environment, operations and waste management.

DANVA's members are interested in getting clarification regarding the consequences of adding pulverized organic food waste from residences for sewer systems and sewage treatment plants, including biogas production at sewage treatment plants.

The report will provide municipalities and water utility companies with a better basis for deciding on applications to install food waste disposers and will provide a better foundation for creating a strategy for handling organic food waste.

The project was carried out by COWI A/S. Financing was arranged together with DANVA, Aalborg Forsyning, Kloak A/S, Århus Vand A/S, VandCenter Syd as.

A follow-up group consisting of:

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Per Henrik Nielsen, Vandcenter Syd as (Water center South Inc.)

Paul Kristian Thomsen, Århus Vand A/S (Arhus Water Inc.)

participated in the project by contributing data, discussion of the contents, creating 3 working methods and commenting on the draft report.

The specific objectives of the report are:

- An evaluation of the consequences for operating sewer systems, sewage treatment plants, waste collection and waste treatment;

- An energy and environmental assessment of the methods for using residential organic food waste in waste incineration, biogasification or in a digestion tank at a sewage treatment plant.

2 Introduction and background

Utilizing the energy stored in our waste to replace fossil fuels as much as possible is a desirable goal. Household organic waste in Denmark is primarily used to generate energy at waste incineration plants. However, some communities use this waste for biogas production or composting.

Demand for food waste disposers is increasing, particularly in large, new constructions, but also in existing multi-unit buildings and in connection with kitchen renovations in existing homes. Therefore, there is a need to determine the best way to utilize food waste as an energy source: at a waste incineration plant, during biogasification or in a digestion tank at a sewage treatment plant.

In general, using food waste disposers can improve working conditions for sanitation workers because the heavy, organic waste is removed from regular garbage collection. This also reduces the risk of the spread of bacteria, endotoxins, etc. Likewise, food waste disposers also improve hygiene in private homes (especially multistory residences), where the organic waste is quickly removed from the kitchen or waste room/sink.

In many places in Europe, the attitude toward food waste disposers is based more on emotions and general opinions than on research-based facts. Attitudes such as "drains are for waste water and garbage belongs in the garbage bin", "putting food waste down the drain is not source-sorting" and "the number of rats will explode", can be found on the home pages of various municipalities and water companies.

Behind the proposed European decision to ban the installation of food waste disposers is also a general approach toward waste treatment (landfills, composting, waste incineration) and sewer systems (frequent discharges, no digestion tank, etc.). For example, there will be resistance to the installation of food waste disposers in areas that are investing in composting organic waste, where there are no digestion tanks at sewage treatment plants or where the sewage treatment plant is already at maximum capacity (in terms of the amount of organic material).

Countries such as USA, Ireland, Norway and Sweden have lots of experience with food waste disposers, both in terms of their widespread use and their effect on waste water systems. Stockholm Vatten (SV) recently authorized the installation of food waste disposers in residences in SV's area of operation without requiring a prior application and assessment. In addition, the annual fee on food waste disposers was removed, which previously had been SEK 312(US$ 50)/year (excl. VAT). The main argument in Stockholm for revising their position regarding food waste disposers in homes was the desire to increase biogas production at sewage treatment plants. The operators of the waste water system in Stockholm had previously not supported the introduction of food waste disposers.

2.1 Regulating biowaste

The Landfill Directive (1999/31/EF of 26 April 1999) includes requirements that EU member states create a national strategy to ensure a reduction in deposited biowaste. The strategy should ensure the following:

- By 2006, the amount of biodegradable garbage being taken to the landfill should be reduced to 75% of the total amount that was produced in 1995.
- By 2008, the amount should be reduced to 50% of the total amount produced in 1995
- By 2016, the amount should be reduced to 35 % of the total amount produced in 1995

However, Denmark has had a ban on depositing combustible materials (including biowaste) at landfills since 1997. Most organic kitchen waste from private residences is disposed of together with the regular garbage for waste incineration. Some municipalities in Denmark have source-sorting, where organic kitchen waste is treated by composting or biogasification.

At the EU level, a biowaste directive has been the subject of discussion for several years, which would force member states to create a separate system for collecting and treating biowaste from private households. The Environmental Committee of the European Parliament has been working to implement this directive, but they were blocked by the European Commission. However, it appears that according to the EU's waste framework directive (2008/98/EF of 19 November 2008), member states must take measures for the separate collection and treatment of biowaste when "relevant" according to the directive. At the same time, the directive allows for deviations from the waste hierarchy based on the results of an assessment using a life-cycle analysis.

According to the Danish Environmental Protection Agency's waste strategy Part 2, (Miljøstyrelsen 2009), a life-cycle assessment is to be completed as well as environmental and socioeconomic analyses of organic waste, where the environment, economy and resource pressures are considered. The goal is to create a basis of evidence for future decisions regarding regulating different types of biological waste. Therefore, it is currently not known how the regulations will determine the framework for treating organic waste, but previous studies have shown that there are no significant environmental advantages to handling organic waste separately. On the other hand, there has been more focus on phosphorus as a resource, which should be safeguarded and recirculated to a greater extent than at present and from waste as well.

Currently in Denmark, a permit is needed from the municipal government to install a kitchen food waste disposer in a residence.

2.2 Methodology

In this report we examined studies of waste water systems where kitchen food waste disposers were installed, especially in our neighboring countries, but also in the USA, where food waste disposers have been allowed for more than 50 years.

In Denmark, there is only one region with any experience involving sewage systems accepting waste from a food waste disposer. Food waste disposers were installed in apartment buildings in Ishøj in 1997. Food waste disposers have also been installed in other locations, but there is no compiled record of where they were installed and what the consequences were for the sewage system.

The impact in terms of operating sewer systems and sewage treatment plants is based on studies that examined the impact on sewer systems and sewage treatment plants in Norway, Sweden, Ireland, New York and the single Danish experience. The experiences in terms of sewer system operations in Norway, Sweden and New York consist of monitoring the outlet pipes with a closed circuit TV camera before and after installing the food waste disposers.

Because the issue of rats eating processed food waste is often used as one of many reasons to prohibit food waste disposers from being installed, we contacted Ann-Charlotte Heiberg, of the Skadedyrslaboratorium (Danish Pest Control Laboratory) for review of this topic.

Together with three donor water companies and DANVA, the following sewage treatment plants have been chosen in order to assess the effect on the sewage load as well as the energy and environmental consequences of a participation level of 10% and 50% of residents in the surrounding area using a food waste disposer:

Table 2.1 Overview of sewage treatment plants selected for impact assessment

Sewage treatment plant	Capacity	Load	
		2009	2020
	PE (population equivalent)	PE	PE
Aalborg			
Aalborg West	265,000	127,000	140,000
Aalborg East	75,000	45,000	60,000
Odense			
Ejby Mølle	385,000	236,000	244,000
Nordvest	65,000	51,000	53,000
Bogense	7,000	4,907	5,100
Århus			
Marselisborg	200,000	158,000	181,000
Viby	83,000	41,000	64,000
Åby	84,000	71,000	87,000
Egå	120,000	75,000	114,000

Simplified diagrams for the plants are in Appendix 2.

The energy and environmental consequences are assessed by estimating the amount of material discharged, the extra amount of biogas produced, the extra amount of sludge and the extra emissions from biogas engines and burning the sludge with 10% and 50% of the households using a food waste disposer.

Energy and environmental considerations of treatment via food waste disposers and sewage treatment plants were compared with corresponding considerations in terms of the organic waste remaining in the sewage system and either being burned at a waste incineration plant or being treated at a biogas plant. The environmental assessment uses the life-cycle method, which includes resource consumption and environmental emissions for the entire system, including the production of collection equipment, the collection process and emissions from energy consumption and production when processing the waste.

2.3 Impartiality

We have been particularly aware that some of the reports and articles we based this report on are sponsored by InSinkErator, who manufactures food waste disposers. In addition, reports from CECED, which is a governmental lobbying organization for manufacturers of food waste disposers, among others, were read with a particularly critical eye. With this in mind, these reports and articles still contain a lot of very useful and well-documented material. However, discussion of possible negative consequences that were experienced may be missing. Statements such as, e.g., "no reported operational problems in sewage systems", generally means that no specific studies of the impact of food waste were performed.

We paid particular attention to reports of operational problems in sewage systems that came directly from water utility companies with a long history of experience with kitchen food waste disposers being installed, e.g. Sweden, Australia and USA.

3 Food waste disposers

3.1 Manufacturers

Kitchen food waste disposers for residential homes are produced first and foremost in USA and in China, see Appendix 8. There are no manufacturers in Europe. The market in the western world is dominated by InSinkErator (Emerson Electric Co.), who has offices in countries where many food waste disposers are sold: Australia, Brazil, Canada, China, Spain, Italy, Japan, New Zealand, Russia, England and USA. In 1993, the company produced 50 million food waste disposers, and in 2001, they produced 75% of food waste disposers sold internationally. In 2008, approximately 100,000 food waste disposers were sold in Europe.

There are currently 15-20 producers in China, who also sell to Australia and New Zealand in addition to China.

3.2 Function

A food waste disposer is connected directly to the drain in the kitchen sink before the water seal. The unit grinds the food remnants with a rotating disc, which breaks the food down into 3-5 mm, but some larger pieces, e.g. 40-50 mm (potatoes, onion) can appear.

Experience shows that up to 80% of food waste can be ground up in the unit. The unit typically does not handle large bones, corn cobs, shells or large pieces of fat or dough.

The food waste disposer makes less noise than a blender or vacuum cleaner, i.e. less than 70 db (Stockholm 2008). Energy consumption is assessed at 3-4 kWh/residence/year (Karlberg and Norm, 1999) and 5-6 kWh/residence/year (Stockholm, 2008).

Water consumption is estimated at 3-6 l/residence/day (Stockholm 2008/Karlberg and Norm 1999) and 3-4.5 l/residence/day (CECED 2003). In other words, the increase in amount of water diverted after installing the food waste disposer is less than 2%.

Fig. 1 Food waste disposer and installation underneath the kitchen sink (Stockholm 2008)

Food waste disposers are installed because they are a fast and efficient way to dispose of food waste for consumers, and they help reduce complaints of flies, rats and birds around the house. They also reduce the amount of organic waste in the landfill (organic waste in landfills is prohibited in Denmark).

In addition, food waste disposers can be installed to reduce waste transportation because garbage can be collected at longer intervals when there is no organic material in the garbage. However, this would require the majority of homes getting a food waste disposer installed in order not to reduce the service level for residents.

3.3 Level of participation

The level of participation, or the percentage of residences with a food waste disposer, depends on the following factors:

National ban on the installation of food waste disposers

Lack of information for local governments to allow the units

Financial support for installing food waste disposers

Decisions regarding installing food waste disposers in connection with larger, new constructions or renovating residential areas.

Kitchen food waste disposers are particularly widespread outside of Europe, where installation has been permitted in some areas for over 70 years. In the USA, it is estimated that over 50% of all households have a food waste disposer (Strive 2008). A food waste disposer is often required in many places. Food waste disposers were banned in New York until 10 years ago, but after studies of the effects on sewage systems and sewage treatment plants, a decision was made to allow them to be installed in residences. The sewage systems there are not specially designed to include pulverized food waste.

Canada has a participation level of 10%, Australia 12% and New Zealand 30% (Strive, 2008). Therefore, there should be extensive experience regarding the impact of these units on waste water systems in these countries. However, there is very little reporting in terms of problems with sewage systems, and queries made directly to the water companies in Australia (Diane Wiesner, Australian Water Association) and California (sfwater) did not result in any links to report of problems.

In the EU, it is estimated that 1% of homes have a food waste disposer. In Europe, the units have been introduced in Ireland, England and Italy, however the overall participation levels are in the order of 5%. In these countries, food waste disposers were introduced to reduce the amount of organic waste at landfills (to uphold EU regulations).

In Sweden (Stockholm 2008) and Norway (Nedland 2006) attempts were made to install food waste disposers in entire residential areas (Staffanstorp, Surahammar, Bardu and Austbygde). In Surahammar, approximately 50% of the town's 4000 residents have installed a food waste disposer since they were introduced in 1997, and by 1998 almost 30% of residents had installed a kitchen food waste disposer.

In Norway, approximately 35,000 food waste disposers were installed in residences between 1999 and 2006. However, in 2007 a nationwide ban was issued on installing food waste disposers, whereby individual communities would have to apply for an exemption if they still want to allow food waste disposers to be installed (Nedland 2006). The reason for the ban was that it was not profitable from a socioeconomic perspective, and the units were thought to increase the load at the wastewater treatment plants. Another argument was that it is easier to dispose of composed food waste than waste water sludge. A combination of food waste and waste water can result in a smaller portion of the food waste ultimately being utilized. Studies in Norway are based on very high levels of participation from people using food waste disposers.

In Sweden, the city of Stockholm has permitted the installation of food waste disposers, however particularly vulnerable parts of the sewage system are being evaluated as to whether problems can arise (Stockholm, 2008). The goal in Stockholm is to increase production of biogas for use in the transport sector and avoid building new biogas plants (see section 6.4)

After permitting food waste disposers, the level of participation in Stockholm (Stockholm 2008) is expected to increase by 0.5-1% per year, which will result in a level of participation of 5-10% over 10 years.

In the EU, the percentage of homes with a food waste disposer, in European countries with no ban on the devices, is not expected to exceed 15% in the next 25-30 years (CECED, 2003).

The following table shows an overview of regulations regarding installation of food waste disposers inside and outside of Europe. In several places, kitchen food waste disposers were installed before they were regulated. Places like New York, for example, had a ban on the units which was lifted. However, Norway has introduced a ban after approximately 35,000 food waste disposers were installed nationally.

Table 3.1 Regulation of food waste disposers internationally

Country	Ban at national level	Discouraged at national level	Locally regulated by municipality or county	Use encouraged	Installation required	Widespread use
Europe						
Sweden			●			
Norway		●	●	●[1]		
Finland			●			
Germany		●	●			
The Netherlands	●					
Belgium	●					
Luxembourg	●					
England		●	●	●[2]		5%
Ireland			●			
France		●	●			
Italy			●	●[3]		
Austria	●					
Outside Europe						
USA				●	●	50% in 2002
Canada			●			10%
Australia			●			12%
Japan			●			
New Zealand			●			30%

[1] Byerne Bardu, Froya and Hitra support the installation of food waste disposers financially

[2] Herfordshire county and Worcestershire county refund £ 80 (2005) to a household that installed a food waste disposer

[3] Capri supported installation with $180 in 1998

3.4 Food disposer waste (GDW)

3.4.1 Amount of waste

Every day, approximately 1.7 million tones of garbage is collected from private homes in Denmark. This corresponds to approximately 300 kg annually per Dane. Of this amount, approximately 30-35% corresponds to 500,000 - 600,000 tons of organic waste per year (Petersen and Domela, 2003) that is suitable for biological processing. The amount varies depending on which fractions are considered suitable. For example, paper towels and other types of paper are considered organic and therefore suited for biological treatment.

In 2008, 38,000 tones of organic garbage was collected from private residences and treated (Miljøstyrelsens / Danish Environmental Protection Agency waste statistics 2007 and 2008). The remainder was disposed of with the rest of the garbage and burned at approximately 30 incineration plants throughout Denmark. The majority of the organic food waste collected was composted, while 15,000 tons was degassed at either Grindsted or Biovækst in Audebo.

3.4.2 Composition of organic household waste

Organic kitchen waste that is designed for food waste disposers consists of:

- Vegetable food scraps containing coffee grounds, potato peels, vegetables and fruit.
- Animal food scraps containing leftover meat, cheese, fat and sandwich meats

The chemical composition of organic household waste can be seen in Table 7.1. This typically includes approx. 30 to 35% dry matter with the bottom heating value being between 3.7 and 5.2 MJ/kg for wet waste.

Table 3.2 Character of source-sorted organic household waste (source: Nordic Council of Ministers, 2007)

Dry matter	30 - 35	%
Ignition loss (wet matter)	90	% of dry matter
Lower heating value	18.1 - 19.3	MJ/kg Dry matter
Methane potential	450	liter CH_4/kg wet matter
	500	liter CH_4/kg wet matter
C	48.6	% of dry matter
Tot-N	3.3	% of dry matter
Tot-P	0.45	% of dry matter
Total Solids	0.91	% of dry matter

3.4.3 Amount of disposer waste

As seen in the following table, it is estimated that approximately 60 kg of organic household waste per person annually can be passed through food waste disposers and the sewer system.

Table 3.3 Residences and waste production

Size of residence	2.14	person/residence	statistics bank
Potential per person	90	kg biowaste/year	MST 2003
Amount collected	67%		Stockholm report
	60.3	kg/person/year	estimated
	129	kg/residence/year	estimated

This means that the amount of processed disposer waste can be calculated as in the following table:

*Table 3.4 Amount and composition of disposer waste (*Nordic Council of Ministers, 2007)

	kg/person/year	kg/residence/year	Unit
Dry matter (DM)	18.1	38.7	kg DM
Ignition loss (wet matter)	16.3	34.8	kg wet matter (WM)
COD	25	52.6	kg COD
BOD	8.7	18.6	kg BOD
C	8.8	18.8	kg C
Tot-N	0.60	1.3	kg N
Tot-P	0.08	0.2	kg P
K	0.16	0.4	kg K
Methane potential	9.05	19.35	m^3 CH_4

The following table compares the annual output from food waste disposers compared with the annual amount of material fed into the waste water per person (if no food waste disposer is installed):

Table 3.5 Comparison of food disposer waste and standard particle contents in waste water

	Food disposer waste	Fed into waste water	Percentage food disposer waste
	kg/person/year	kg/person/year	
BOD	8.7	21.9	40%
Tot-N	0.6	4.38	14%
Tot-P	0.08	0.99	8%

With a level of participation of 10%, the organic load (BOD) from residences on a sewage treatment plant will increase by 4%, and with 50% of homes participating, the load will increase by 20%.

4 Food disposer waste and sewage systems

The impact on the sewage system is often estimated based on local "common sense". Others have performed experiments in the laboratory e.g. as part of Ph.D. research. Additionally, studies have been conducted in USA, Norway and Sweden regarding sewage systems after a considerable number of food waste disposers are installed.

For example, in Surahammar approximately 50 % of the town's 4,000 residents have installed food waste disposers since they were introduced in 1997, and by 1998 almost 30% of residents had installed a kitchen food waste disposer. For over 10 years, the effect on the pipes and sewage treatment plants has been tracked (Evans 2010). Correspondingly, food waste disposers have a wide distribution in Staffanstorp and both locations have not reported problems that can be attributed to the pulverized food waste. These experiences have had a important effect on the Swedish decision to permit food waste disposers.

The following provides an overview of operating experiences and studies from Northern Europe and areas outside of Europe.

We have taken a closer look at the issue of rats because increased rat problems are often used as an excuse to prohibit food waste disposers.

4.1 Hydraulic load

As seen in section 3.2, the amount of dry matter increases an average of less than 2% per residence, and therefore the hydraulic effect of a very high level of participation is difficult to register. This was also confirmed by studies in Ishøj and Surahammar.

Comment [K1]: Translation issue…dry matter and hydraulic effect are two different issues.

4.2 Sedimentation and blockage

The regulations regarding household waste in Ishøj municipality allow for the installation of food waste disposers as one part of a source-sorting system for household waste. Food waste disposers have been installed in the municipality since 1997, especially in public institutions, e.g. nursing homes. Installing food waste disposers has not resulted in any problems with increased sedimentation, rats, odors or grease (conversations with Svende Fischer, Ishøj Vand). Here, the experience has shown that pipes downstream from the food waste disposers have fewer fat deposits compared with pipes where food waste disposers are not installed.

Studies in Sweden (Staffanstorp and Surahammar, Nielson 1990/Evans 2010/Karlberg and Norim 1999) and in Norway (Austbygde and Fossnes, Nedland 2006) did not show any operational problems in the piping network, including pump stations and pressure lines after installing food waste disposers. The sewer systems in all locations were monitored by closed circuit TV before and after installing food waste disposers.

In Fossnes, an increase in sedimentation was detected in old pipe lines, which were in poor conditions with very little downward slope. The same experience involving pipes with little downward slope was recorded in Japan (NILIM 2006). Kegebein (Karlsruhe 2001) demonstrated that at a flow speed of 0.1 m/s, food disposer waste did not form a sediment, which is somewhat slower than the speed that is normally required for self-cleaning. In Holland, de Koning (1996) concluded that even in areas with very little downward slope, food disposer waste did not form deposits and neither did fat.

New York, which up until 10 years ago had a ban against food waste disposers, completed a study of the sewer system and concluded that connecting food waste disposers did not lead to increased operating costs for the waste water system. The food waste disposers were installed in residential areas as a pilot project, and sewer systems were then inspected via TV cameras to record sedimentation, blockages, etc. No change was recorded in terms of operational problems that already existed and neither were any new problems detected. However, it was noted that food waste processed through a food waste disposer has a specific density, which is generally lower than the contents in the waste water an much less than sand. The general ban on residential disposers was then lifted. No operational problems have been reported since then.

The San Francisco Public Utility Commission reported (in an email from 27 January 2011) that there was no regulation in terms of food waste disposers and that privately installed food waste disposers had not created any problems in the sewer systems or at sewage treatment plants. Food waste disposers have been installed in San Francisco for over 70 years with a participation level above 50%. Installing the units in diners, restaurants, etc. can create problems with fat.

Comment [K2]: According to SFPU?

4.3 Fat

Fat appears to be a problem in Danish drain pipes, where in some areas it can block the pipes. Fat is a problem especially in diners and grill restaurants, etc. Emptying fat into the kitchen sink does not depend on whether a food waste disposer has been installed or not. The experience in Ishøj showed that the pulverized kitchen waste "binds" the fat so that it does not form blockages in the sewer.

In Sweden and Norway, most water utility companies report problems with fat leading to blockages, fat accumulating in pumping stations, etc. regardless of whether a food waste disposer has been installed or not (Svensk Vatten-Swedish Water, 2010). In Sweden, the problems with fat are worst in concrete pipelines, and in Norway the problem is worst with PVC pipes. It has not been determined whether installing food waste disposers in private households will worsen the problem. Fat deposits have not been observed after 10 years of operation at Staffanstorp and Surahammar, Sweden (Evans 2010).

In Germany, DWA [1] reported that problems with fat were not a priority issue (Svensk Vatten-Swedish Water 2010), however fat in sewer systems is a large problem in the USA (FOG = Fat, oil, grease). In the USA, the amount of fat from residential homes is considerable and is related to a relatively high level of fat consumption.

In Ireland, fat is thought to only be a problem if food waste disposers are installed in diners, restaurants, etc. (Strive 2008).

[1] Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V.

4.4 Hydrogen sulfide formation and odors

Swedish and Norwegian studies did not report any problems with the formation of hydrogen sulphide in piping systems. Kärrman (2001) indicates that places in the sewer system with existing hydrogen sulfide problems could be made worse if a high percentage of residences are using food waste disposers. For example, this could be the case in long pressure lines.

The Swedish and Norwegian studies also did not report hydrogen sulfide or odor problems from pumping stations. This could be the result of the fact that the pipe systems in these countries often have a better downward slope and that truncated pipe systems, including long pressure lines, are not widespread. The transport times in Denmark are now often longer, at a rate in line with centralized waste water treatment.

Sweden is currently performing a study of the long-term impact on sewer systems downstream from areas where food waste disposers have been installed for a long period of time, e.g. Surahammar and Staffanstorp. The pipes will be monitored by TV. The results will be published in the autumn (communication with Annelie Heström, Luleå Tekniska University).

In Denmark, a method, WATS, is being developed for a specific pipe system to assess hydrogen sulfide formation and the affect of the addition of organic matter, e.g. from food waste disposers (communication with Jes Vollersten, Aalborg Universitet).

All things being equal, the addition of biodegradable matter from processed food waste into a piping system can worsen a situation where the formation of hydrogen sulphide has been reported as a problem. Where the percentage of residences using food waste disposers exceeds 10%, hydrogen sulfide problems can develop in piping systems with long retention times, which therefore must be assessed using the above-mentioned method, WATS.

4.5 Rats

The studies that have been completed on rats in sewer systems have primarily been conducted in combined sewer systems. Rats also occur in separate waste water lines, but no studies have been conducted on this.

Studies have shown that rats live in large parts of the sewer system, but that they do not appear throughout the entire pipe system (Colvin *et al*. 1998, Channon *et al*. 2004, Heiberg & Leirs 2011). Typically, rats will hide in areas with little water flow and relatively small piping dimensions. This means that rats typically appear in the top of the pipe system and in the smaller lines and service lines. Rats also appear in those parts of the pipe network where the dimensions are larger and the amount of water passing through is higher, but not in as many numbers as further up. The reason is unknown, but it is thought that rats in these areas have a greater risk of drowning. So if the entire pipeline system is taken into consideration, some areas will have more rats than others (Colvin *et al*. 1998, Heiberg & Leirs 2011). As indicated, there are no studies of sewer rats in separate systems, but by virtue of the design of the pipeline systems, it is plausible that the situation is comparable with the lower part of the combined sewer system, where there can be more water in the main line and therefore the appearance depends exclusively on the smaller service lines.

The service lines cannot handle an unlimited number of rats. The number of rats is determined by the quality of the habitat. What determines the presence of rats in sewer systems is, as is constant throughout the world, that the rats have access to water, food and hiding and nesting places. In sewer systems, water is not a limited resource and only to the extent that there is too much water will this have a negative effect on the presence and number of rats.

4.5.1 Food

As a general rule, food appears in the sewer system in relatively constant amounts and quality. Rats live well off of our excrement and whatever is flushed out with the waste water. Many studies have tried to examine the biology of the sewer rat, including recording the bodyweight of sewer rats. The average sewer rat weighs between 250-300 g. (Heiberg unpublished data) and is comparable with the weight of surface rats. In general, sewer rats are in good condition with a well-groomed coat, which is an indicator that the rat's habitat in the sewer system is good. In light of this, it is appears that finely ground kitchen waste will have little impact on the sewer rats' general health and will not result in a significant increase in their population.

English studies claim that rats "catch" food clumps in the waste water and that pulverized corn, rice, potatoes, etc. in a kitchen food waste disposer will reduce the amount of food for the rats in the pipes (Evans 2010).

4.5.2 Nesting sites

Nesting sites are supposedly the determining factor in terms of the appearance of sewer rats and their numbers. In areas with a shortage of nesting sites, the female rat will have a harder time raising a litter due to disturbances. In general, it is assumed that there are only as many rats as the space allows. Therefore, changes or increases in the amount of food available will not cause the population to exceed what the area can handle (carrying capacity). However, there may be areas where there is room for population growth, but the food supply is limited - and in these places, additional feed can lead to increased population growth, but again - not beyond the area's capacity.

4.5.3 Attracting rats

The possibility that a change in the amount of available food may attract rats to certain areas where there may not have been rats before cannot be ruled out. But if the area is already populated with a colony of rats, the changes in the food will not result in these rats increasing in number as a result of new rats moving in/immigration. Immigrant rats are seldom allowed in a rat colony that is already established. It has been shown that although there are no physical barriers for the sewer rats, the rats maintain their group/family territories in the sewer system, and rats are seldom able to cross these boundaries (Heiberg & Leirs 2011).

4.6 Overflow structures

Connecting food waste disposers to combined sewer systems upstream of a overflow structure will increase the amount of organic mater in the waste water. The following table for systems included in this study shows that participation levels below 10% will not result in a significant increase in the pollution load (see Table 5.2 also). With a higher number of food waste disposers being used, an increase in the amount of organic matter must be factored in when determining an acceptable discharge frequency.

Table 4.1 Increase in load from overflow structures

Material	Material supplied from food disposer waste	Extra load	
		10%	50%
	kg/person/year	connection	connection
COD	25	2-5 %	12-25%
BOD	8.7	2-5 %	14-25%
Tot-N	0.6	0.8- 1.7 %	4-8%
Tot-P	0.08	0.6 - 1.3 %	3-6%

An evaluation of Irish overflow structures (Strive, 2008) concludes that for overflow structures with more than 6 discharges/year there can be a significant effect on the recipient.

In Norway, estimates of increasing amounts of material in the overflow and outfall from mechanical sewage treatment plants were part of the reason for banning food waste disposers. No special consideration was given in terms of climate change.

5 Food disposer waste and sewage treatment plants

5.1 Waste water treatment in Denmark

The construction of sewage treatment plants in Denmark generally includes fine screens (3-6 mm screen gauge), sand traps, and in some cases clarification tanks, process tanks and final clarification tanks. Digestion tanks are used widely at larger sewage treatment plants and most plants have sludge dehydration systems. The sludge is then sent for incineration, composting or used in agriculture.

Based on the experiences and information of DANVA, Krüger and Punktkilde's report 2008, it is estimated that 70-80% of Denmark's population is connected to a sewage treatment plant with a digestion tank. In particular, towns with more than 20-40,000 residents are connected to a plant with a digestion tank. From the plants selected, 92% of the load is connected to a plant with a digestion tank.

Table 5.1 Sewage treatment plants size distribution in 2008 [By- og Landskabsstyrelsen (Danish Urban and Rural Development Commission), 2008]

Plant capacity	Number of sewage treatment plants	Load in % of load for all plants
≥ 30 PE	1,055	100
≥ 500 PE	587	99
≥ 2,000 PE	423	98
≥ 5,000 PE	272	94
≥ 15,000 PE	143	84
≥ 50,000 PE	67	69
≥ 100,000 PE	38	54

5.2 Experiences in Sweden and Norway

The study at the Haga sewage treatment plant, Surahammar, showed a slight increase in the material screened, but no significant increase in the Tot-N, Tot-P and BOD, no increase in energy consumption for aeration with food waste disposers installed in 50% of residences (Ceced 2003 and Evans 2010). These very surprising results can be explained by the easily biodegradable organic matter breaking down in the sewer system on the way to the sewage treatment plant. The amount of phosphorus did not increase which means that the amount of chemicals used did not increase. The report is based on data collected over a period of 2.5 years at the sewage treatment plant. The study is sponsored by a manufacturer.

The studies in Staffanstorp showed an increased amount of organic material with a biological treatment level of 55% after presedimentation (Nielson 1990). The amount of excess sludge increased by 25%. The study here achieved the opposite results from the Surahammar study in terms of the retention of the primary sedimentation. Food disposer waste had no effect on the phosphorus emissions.

At the Austbygde sewage treatment plant, an increased amount of fat was found in the screening structure and more liquid sludge in the clarification tank (Nedland 2006). No increase in the amount of organic material was found in the sand trap. At this plant, the amount of organic material discharged increased, whereas the amount of phosphorus discharged dropped. The latter is explained by a change in the amount of phosphorus in detergents.

5.3 Affect on selected sewage treatment plants

5.3.1 Selected sewage treatment plants

Table 5.3 shows an overview of the main elements in the 9 sewage treatment plants selected. There are differences in whether they include a clarification tank or whether they have a digestion tank as well as how they dispose of sludge. Refer to Appendix 2 as well.

5.3.2 Hydraulic capacity

Because the amount of water used for food waste disposers is estimated at 3-6 l/residence/day (see section 32), this results in an increase in the dry weather flow of under 2% and the hydraulic effect is therefore not considered to be significant.

5.3.3 Material load

The material loads with 10% and 50% of residences having a food waste disposer connected have been calculated respectively for each sewage treatment plant in Appendix 3 and are summarized in Table 5.2.

The report shows how many tons of extra material is supplied to sewage treatment plants, how much the load will increase by 2020, and how much capacity will be used in 2020 as well.

Table 5.2 Increase in the load and use of capacity at sewage treatment plants in 2020

Material	Material supplied from food disposer waste	Extra load		Combined load for sewage treatment plant	
		10%	50%	10%	50%
	kg/person/year	connection	connection	connection	connection
PE				55-101%	65-113%
COD	25	2-5 %	12-25%		
BOD	8.7	2-5 %	14-25%		
Tot-N	0.6	0.8- 1.7 %	4-8%		
Tot-P	0.08	0.6- 1.3 %	3-6%		

It appears from the table that a level of participation of 10% will not result in a noticeable increase in the load of organic matter and nutrient salts at the sewage treatment plants.

A participation level of 50% involves an extra load on the sewage treatment plants in the order of 20% for organic matter and 5% for nutrient salts.

At the same time, it was noted that for one of the nine selected plants (Åby), a participation level of 10% will maximize the capacity at the sewage treatment plant by 2020 (based on the load of organic matter).

With a participation level of 50%, the Åby sewage treatment plant in Århus will be significantly overloaded with organic matter.

Table 5.3 Overview of sewage treatment plants evaluated in this report

Sewage treatment plant	Capacity	Load		Clarifi-cation	Digestion tank	Gas		Sludge deposit			
		2009	2020			Boiler	Engine	Dryer	Incinerator	Compost	Agricultural use
	PE	PE	PE								
Aalborg											
Aalborg West	265,000	124,843	140,000	X	X	X*	X	Aalborg East			
Aalborg East	75,000	44,067	60,000		X	X**		X	X***		
Odense											
Ejby Mølle	385,000	236,300	243,896	X	X		X			X	
Nordvest	65,000	50,594	52,273		Ejby Mølle		Ejby Mølle			Ejby Mølle	
Bogense	7,000	4,907	5,070								X
Århus											
Marselisborg	200,000	147,000	181,000	X	X	X	X			X	X
Viby	83,000	35,000	64,000	X*****	X	X	X				X
Åby	84,000	67,000	87,000		X	X					X
Egå	120,000	65,000	114,000								X

X* Only as back-up if gas engine fails
X** Biogas is used in the boiler to heat the oil line in the sludge drying plant.
X*** At present, further sedimentation involves incineration for energy use and using the ash.
X**** Load figures for 2025
X***** The clarification tank was not used for clarification in 2009.

Comment [K3]: Does this still need translated or does this mean sludge is pumped from one facility to another?

5.4 Digesting food disposer waste at sewage treatment plants

The assumptions and results of adding pulverized waste (from a residence) have been examined for the three types of sewage treatment plants in Appendix 4. The following assumptions have been made:

5.4.1 Screens and sand traps

An increase is not expected in the amount of screened material or the organic content of sand, cf. Swedish and Norwegian studies. There is also no expected impact in terms of fat.

5.4.2 Clarification

The clarification tank is assumed to have the following average removal efficiency:

- COD 44%
- BOD 44%
- Tot-N 11%
- Tot-P 27%

5.4.3 Process tank

The process tanks receive biodegradable carbon and a load of Tot-N and Tot-P depending on the level of participation of residents, cf. above. In the process tanks, the amount of carbon in the waste water is reduced, which means that part of the potential energy in the kitchen waste is lost.

5.4.4 Discharge of material from sewage treatment plant

The following average discharge of material has been calculated for all sewage treatment plants:

- COD 40 mg/l
- BOD 4 mg/l
- Tot-N 6 mg/l
- Tot-P 1 mg/l

Processed kitchen waste largely originates from foodstuffs and therefore does not contain significant amounts of heavy metals and other environmental toxins.

5.4.5 Digestion tank and gas production

The increasing amount of carbon will result in a gas production corresponding to 550 l gas/kg ignition loss, since the ignition loss in the sludge is estimated at 1.45 kg COD/kg. The methane content in the gas is put at 65%.

5.4.6 Sludge production and quality

Sludge production is put at 0.4 kg dry matter/kg COD in the inlet if there is a digestion tank and 0.55 kg dry matter/kg COD in the inlet if there is no digestion tank.

The dry matter content in the dehydrated sludge is estimated at 30%.

5.4.7 Energy consumption

Sewage treatment plants with clarification tanks are estimated to use 36 kWh/PE and plants without clarification are estimated at 50 kWh/PE.

Plants with clarification tanks have an estimated energy consumption for biological treatment and sludge dehydration of 1.15 kWh/kg BOD in the inlet. Correspondingly, the estimated energy consumption for plants with no clarification tank is 1.60 kWH/kg BOD.

5.4.8 Summary of assumptions

The following presents a summary of the above assumptions:

Subject	Unit	Value
Clarification	% of material removed	COD 44% BOD 44% Tot-N 11% Tot-P 27%
Discharge	mg/l	COD 40 mg/l BOD 4 mg/l Tot-N 6 mg/l Tot-P 1 mg/l
Gas production		
Ignition loss	kg COD/kg ignition loss	1.45
Gas production	1 gas/kg ignition loss	550
Methane content	%	65
Sludge production		
With digestion tank	kg dry matter/kg COD	0.4
Without digestion tank	kg dry matter/kg COD	0.55
Dry matter in dehydrated sludge	%	30
Energy consumption		
With clarification	kWh/PE	36
	kWh/kg BOD in inlet	1.15
Without clarification	kWh/PE	50
	kWh/kg BOD in inlet	1.60

5.5 Affect of energy consumption and energy production

Three of the selected sewage treatment plants have clarification and digestion tanks, four have no clarification tank but a digestion tank, and the last two do not have a digestion tank.

Appendix 6 lists the energy consumption and the energy production for each of the 9 sewage treatment plants with a participation level of 10% and 50%. Sewage treatment plants with clarification tanks clearly have the highest energy surplus. Plants without clarification tanks have less of a surplus, and plants without a digestion tank consume extra energy.

According to the Danish Center for Energy Savings (Center for Energibesparelser), Danes use 1500 kWh per year per residence. According to Appendix 6, it appears that approximately 70 people should be connected to a sewage treatment plant with a clarification tank in order to cover one person's annual electricity consumption. If the plant does not have a clarification tank, approximately 700 people should be connected to the plant.

According to Appendix 5, approximately 40% of COD is lost in the process tank and in the outfall of a plant with a clarification tank, and the energy in this portion of the COD is also lost. In plants without clarification tanks, up to 65% of COD is lost in the process tank and outfall.

6 Food disposer waste and waste management

6.1 Handling organic household waste in Denmark

6.1.1 Burning biowaste

The vast majority of communities in Denmark do not have any source-sorting for biowaste in private residences. Biowaste is therefore disposed of with the rest of the regular garbage collection, which is then burned at the waste incineration plant to produce electricity and/or district heating. The waste is collected in paper bags or plastic containers and is taken to one of approximately 30 waste incineration plants in Denmark.

A typical Danish waste incineration plant has a net electrical efficiency of 15-20% of the waste's lower heating value, and a heating efficiency of approximately 60-80% of the lower heating value. This means that burning biowaste results in a net electricity production of approx. 200-250 kWh/ton and a district heating production of approx. 750-1000 kWh/ton.

6.1.2 Sorting biowaste

Some municipalities in northwest Sjælland and around the towns of Vejle and Billund, private residences sort their biowaste for separate biological processing. Processing involves either composting, which creates usable compost or biogasification, which produces a usable fertilizer and energy-rich biogas that can be used for electricity and/or heat production. Biowaste is collected either in separate collection trucks or in trucks with 2 compartments for different waste so that there is no need to make an extra trip to collect biowaste.

6.1.3 Financing

The expenses that the municipality has in connection with garbage collection should be cost-neutral, which means that the municipality calculates the garbage collection rates so that they cover the costs for collection and processing the waste generated. The vast majority of communities have a fixed rate per residence and a possible differentiation if it is a multi-unit building vs. a single family home. In addition, there may also be some differentiation in terms of the type and size of container (also called volume-based garbage collection rates), where some municipalities offer various containers with different volumes at different rates. This provides an incentive for citizens to stop accumulating waste and to encourage the sorting of paper and glass, for example.

A few communities use weight-based garbage collection rates, which means that each round of garbage is weighed and a bill is sent to the resident. This also presents a strong incentive to increase the amount of source-sorting and to reduce the amount of waste in garbage bags or containers. However, this system is not used in very many sites due to problems with weighing, and it is not thought to become very widespread in the future.

6.2 The effect of food waste disposers on the waste management system

When a food waste disposer is installed, a considerable amount of the organic waste is removed from the regular garbage, which typically would have been sent to the waste incinerator. This means that the remaining waste is drier and has a higher heating value and therefore produces more energy per ton of waste collected. However, the incineration plants do not gain any additional capacity because it is often the input effect (the waste's heating value) that limits capacity. When waste with a low heating value is removed, only a small portion of the input effect is removed from the incineration process.

By using food waste disposers, a considerable amount of waste is removed from the regular garbage in terms of weight, and this reduces the amount of residual garbage that needs to be collected from the individual residence. At the same time, it is typically the organic waste which can result in odor problems, flies and rats and when this is significantly reduced, the opportunity opens up of reducing the frequency of garbage collection, so that the leftover garbage is collected every 14 days instead of every week. Århus already has garbage collection on a two-week schedule for single family homes, and the introduction of food waste disposers in the community will reduce any odor problems that may develop over the summer. A 14-day garbage collection cycle is often used in areas with biowaste sorting, e.g. the biowaste is collected every 14 days, however the collection frequency can be increased to weekly during the summer.

6.3 Description of the selected waste systems

6.3.1 Aalborg

Garbage is collected in Aalborg on a weekly basis in the urban areas and every 14 days in rural areas. The collected garbage is taken to the Reno-Nords incineration plant at Troensevej, east of Aalborg. Garbage is collected from detached houses and single-family residences in paper bags, while large, 4-wheeled containers are used in apartment buildings. Rural properties chiefly use 2-wheeled containers.

The incineration plant consumes and produces the following amount of energy per ton of waste collected.

Table 6.1 Consumption and production of energy at Reno-Nord incineration plant

Reno-Nord incineration plant	Consumption/production	Unit
Electricity consumption	109	kWh/ton
Heating oil	32	MJ/ton
Electricity production	600	kWh/ton
Heat production	1970	kWh/ton

Source: Green accounting partnership Reno-Nord 2009

The heat produced in Aalborg supplements the district heating system which also uses heat from the Nordjylland plant and from Aalborg Portland. The Nordjylland plant uses coal as a fuel, and it is assumed that the heat generated from waste incineration replaces the district heating generated from the Nordjyllands plant.

6.3.2 Odense

As a general rule, garbage is collected in the Odense municipality every 14 days with the option for weekly collection during the summer months, and there is no source-sorting of biowaste. People can choose from a variety of sizes for plastic containers to hold their leftover garbage. It is estimated that most residences have 190 liter containers which typically cover the needs of 2 adults and one child (www.odenserenovation.dk).

The garbage collected is taken to the Odense Kraftvarmeværk (Combined Heat & Power Plant) (DONG), which is a combined heating and power plant by the harbor in Odense. The incineration plant in Odense consumes and produces the following amount of energy per ton of waste collected.

Table 6.2 Consumption and production of energy at Odense Kraftvarme incineration plant

Odense Combined Heat and Power Plant	Consumption/production	Unit
Electricity consumption	78	kWh/ton
Heating oil	64	MJ/ton
Electricity production	646	kWh/ton
Heat production	1944	kWh/ton

Source: Green accounting Odense Kraftvarmeværk 2008

The heat produced at Odense Kraftvarmeværk is supplied to Fjernvarme Fyn, which receives heating from Fynsværket, which is coal-based. Therefore, it is assumed that the heat generated from burning the waste will replace the district heating created from coal.

6.3.3 Århus

Garbage collection in Århus occurs every 14 days and is taken to AffaldVarme, Århus' incineration plant in Lisbjerg, approximately 10 km north of Århus.

The incineration plant consumes and produces the following amount of energy per ton of waste collected.

Table 6.3Consumption and production of energy at Århus incineration plant

AffaldVarme Århus' incineration plant	Consumption/production 2008	Unit
Electricity consumption	77	kWh/ton
Heating oil	19	MJ/ton
Biofuel	118	MJ/ton
Electricity production	533	kWh/ton
Heat production	2090	kWh/ton

Source: Green accounting AffaldVarme Århus - Incineration plant 2009 (2008 data was used because there was a crash in 2008)

The heat produced from the incineration plant in Lisbjerg supplements the district heating from the Studstrup plant, which is coal-based. Therefore, it is assumed that the heat generated from burning the waste will replace the district heating created from coal.

6.3.4 Electricity and heating efficiency

It is assumed that the garbage in all three surrounding areas has an average minimum heating value of 10.5 GJ/ton. The level of efficiency in terms of electricity production and heat production can be calculated from the amount of electricity and heat produced. It appears that the incineration plant in Århus has the lowest level of electrical efficiency and the highest level of heating efficiency, while the plant in Odense has the highest electricity production.

Table 6.4. Estimated electrical and heating efficiency at waste incineration plants

	Aalborg	Odense	Århus
Electrical efficiency	21%	22%	18%
Heating efficiency	68%	67%	72%

6.4 Structural conditions - Waste and energy

Denmark has well-functioning waste incineration plants that produce both heat and electricity, which are utilized as much as possible. The heat can be devoted to district heating for most of the year. At the same time, the Danish energy system is highly dependent on coal as a fuel source. Coal is often considered a marginal fuel source because it is the source that is to be phased out due to the fact that it is the most polluting in comparison to wind, biomass and natural gas.

If there is energy that is based on sustainable energy sources, such as biomass, wind and sun, the results will be different and depending to a large degree on the direct emissions from treating the waste, such as emissions through the exhaust gas and the waste water.

Overseas, these structural conditions may be different, and in the USA a large portion of the waste is discarded, and the energy potential in the waste is only rarely exploited. At individual landfill facilities, the gas from the landfill is collected for energy production, but the waste is often not utilized. With these structural conditions, the goal is to redirect the waste away from landfills and steer them toward other reuse or treatment methods. Composting and biogas production, even at low levels of utilization, can be more sustainable than discarding the waste in the landfill.

Sweden also has waste incineration plants that utilize the energy in the waste to produce electricity and heat, but the energy system there is considerably different compared to the Danish one. In Sweden, the energy sector is highly dependent on wind power and nuclear power, and both sources emit no or almost no CO_2 per kWh delivered. Therefore it is environmentally advantageous to produce biogas that is used for transportation purposes and can supplant diesel fuel that emits large amounts of CO_2.

The structural conditions within the waste sector and the energy sector are decisive in terms of what is environmentally advantageous, and the results can therefore not be transferred directly from one region/country to another.

7 Energy and environmental reports

7.1 Methods

The energy and environmental reports compare the existing treatment of organic household waste (biowaste) with treatment consisting of food waste disposers and transporting the waste through a sewage system. A life-cycle analysis is used to ensure that all activities are taken into consideration, including emissions that occur during heat and electricity production, as well as emissions from the materials used. Likewise, emissions and supplanted emissions during energy production and fertilizer use are included.

The environmental assessment is conducted using EASEWASTE, which is a recognized tool for life-cycle analyses (LCA) of waste. The tool uses the Danish-developed LCA method UMIP [1]. It receives supplemental data from GaBi4[2], which is an LCA tool.

The results from EASEWASTE show a host of environmental effects including,

- Greenhouse gas emissions (CO_2-equivalents),
- Acidification (SO_2-equivalents),
- Nutrient sale load (NO_3^-equivalents).

These environmental effects are selected because they are the most complete indicators of the environmental effects from treating organic household waste, because it contains a very low amount of environmentally toxic and human toxic materials.

Estimates of environmental effects of cleaning waste water show that nutrient salt emissions and ecotoxic materials are the two clear dominating effects (DANVA/COWI 2009)

In addition, the savings potential for phosphorus, which is a limited resource, was also considered, The resource pressure on this resource can be reduced when the organic materials are recirculated.

7.1.1 The functional unit

In order to compare the results from the energy and environmental reports, a service is given a definition that will meet all disposal options, and this service is called *the functional unit.*

[1] The UMIP, Udvikling af Miljøvenlige IndustriProdukter (development of environmentally-friendly industrial products), a method for reporting environmental impacts.

[2] Database of the environmental impact of the material

The energy and environmental estimates are completed for 1 ton of source-sorted, organic household waste that is suitable for processing in a food waste disposer. The results are then scaled so that they correspond to the annual production of source-sorted, organic waste for one household.

It is estimated that approximately 130 kg of biowaste[1] annually, per residence is collected with the average size of the household being 2.14 people[2], but the amount varies depending on the size of the residence and the level of information.

The functional unit is therefore:

disposal of organic waste for one year from an average household, corresponding to approximately 130 kg/year.

7.1.2 Limitations of the reports

In addition, the limitations must be defined precisely and cover all relevant activities in the scenarios being evaluated from the time when the waste is placed in the food waste disposer or in the garbage bin until it is finally deposited or used.

The reports include the activities:

- Material (production of food waste disposers and garbage containers)
- Collection (garbage collection)
- Waste treatment (waste incineration and biogasification)
- Transport in sewer system and waste water treatment
- Sludge disposal (incineration, composting or agricultural use)
- Transportation (of sludge, ash, cinders, etc.)
- Use of degassed biowaste in agriculture

7.1.3 Composition of organic household waste

Organic kitchen waste, which is designed for food waste disposers consists of:

- Vegetable food scraps containing coffee grounds, potato peels, vegetables and fruit.
- Animal food scraps containing leftover meat, choose, fat and processed food

The chemical composition of organic household waste that is used in the energy and environmental calculations is listed in section 7.1, based on waste with a dry matter content of 30% and a minimum heating

[1] Existing figures from Rødovre municipality with a separate collection in 2010 as well as from Stockholm Vatten in 2008.

[2] Statistics bank

value on a dry basis of 18 MJ/kg dry matter. This means that the lower heating value for wet waste is 3.5 MJ/kg. At the same time, the methane potential is 122 liters CH4 per kg of wet, organic waste.

Table 7.1 Character of source-sorted, organic household waste used in environmental and energy calculations (evaluated by the Nordic Council of Ministers, 2007)

Parameter	Value	Unit
Dry matter	30	%
Ignition loss (wet matter)	90	% of dry matter
Minimum heating value	18	MJ/kg dry matter
Methane potential	450	liter CH4/kg wet matter
	500	liter CH4/kg wet matter
C	48.6	% of dry matter
Tot-N	3.3	% of dry matter
Tot-P	0.45	% of dry matter
Total Solids	0.91	% of dry matter

The amounts of organic household waste are shown in the table below.

Table 7.2 The amounts of organic household waste

	kg/person/year	kg/residence/year	Unit
Amount	60	130	kg biowaste
Dry matter	18.1	38.7	kg DM
Ignition loss (wet matter)	16.3	34.8	kg wet matter (WM)
COD	25	52.6	kg COD
BOD	8.7	18.6	kg BOD

7.2 Energy report for food disposer waste in waste water system

This section describes the energy balance for three waste water cleaning systems:

- sewage treatment plant without digestion tank
- sewage treatment plant with digestion tank and only clarification
- sewage treatment plant with digestion tank and both clarification and final clarification

The energy balance includes the residential energy consumption, the energy consumed in producing the food waste disposer, the energy consumed at the sewage treatment plant, the energy production and sludge disposal.

It is assumed here that the loss of methane gas in the pipeline network is marginal, and has no impact on the vast majority of residential areas. It has been previously estimated that 1-2.5% of the methane potential disappears per hour (Stockholm Vatten 2008, page 18-19). For areas with a very long transportation time from the residence to the sewage treatment plant there may be a significant loss of methane which can be highlighted using the WATS method (see section 4.4).

In addition, the amounts from screening and from fat, drains or sand traps are not expected to be affected by the processed, organic household waste being sent to the sewage treatment plant. Similarly, use of precipitate chemicals and polymers is not expected to be affected by the relatively modest increased inflow due to the organic waste.

7.2.1 Food waste disposer

The stored (accumulated) energy consumption for the food waste disposer is assessed at 500 MJ/ton (Diggelman and Ham, 2003), corresponding to 60 MJ for 130 kg, which is defined for a functional unit. This consumption covers material extraction and the production of the food waste disposer. The environmental load is therefore estimated in light of this stored energy that is assumed to be based on coal consumption.

A corresponding value is estimated at 50 MJ/100 kg by Strutz et al. (Strutz et al., 1998).

The physical make-up of the food waste disposer is described by Insinkerator (see Appendix 7), and the estimated environmental load, that is due to extracting these materials is in the same order of magnitude as the environmental impact of 60 MJ of coal, but it is slightly below 20-30% for most of the environmental effects. This is likely due to the fact that private energy consumption for the production and assembling the food waste disposer is not included in the estimates.

7.2.2 Electricity consumption during operations

Electricity consumption to run food waste disposers is estimated at 5-6 kWh per residence (Stockholm Vatten 2008).

The extra water consumption, which is necessary to grind down the waste is estimated at 3-6 liters per day, per residence, corresponding to 1100-2200 liters of water per year. The energy consumption for the production and distribution of this amount of water is marginal and estimated at 0.2-0.3 kWh/year.

7.2.3 Waste water cleaning

Energy consumption for water purification depends a lot on the individual sewage treatment plant, but it is typically between 1.2 and 1.6 kWh/kg BOD. If this rate of consumption is converted for the amount of organic household waste that would be expected to be processed with a food waste disposer, the electricity consumption would be 22-28 kWh/residence/year.

7.2.4 Biogas production

Biogas production at the sewage treatment plant depends on the amount of organic material that is fed into the digestion tank. Again, this depends on the processes at the given plant.

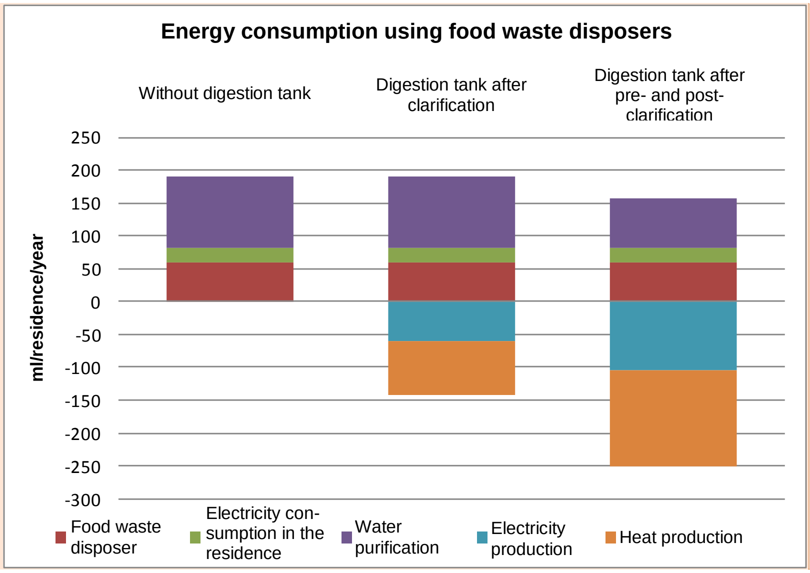
Approximately 550 liters of biogas is expected to be produced with 65% methane per kg of ignition loss (wet matter) (existing figures from COWI) during mesophilic digestion with a retention time of approximately 20 days. This level of production corresponds to a methane production of 357 liters of CH_4/kg wet matter and a digestion level of 79% of the anticipated methane potential.

The expected amounts of organic material sent to the digestion tank and the expected methane production are listed in Table 7.3. The largest amount of methane production is achieved when organic material is added from both the clarification tank and the final clarification tanks.

Table 7.3 Anticipated methane production at sewage treatment plant

	Added ignition loss per residence	Anticipated methane-exchange per residence	Energy in biogas
Without digestion tank	0 kg wet matter	0 Nm^3 CH_4	0 MJ
Digestion tank, clarification only	12.7 kg wet matter	4.5 Nm^3 CH_4	163 MJ
Digestion tank with pre- and post-clarification	22.1 kg wet matter	7.9 Nm^3 CH_4	284 MJ

The gas engines that use the biogas produced for heat and electricity have 37% efficiency for electricity production and 51% efficiency for heat production, which is either utilized at the sewage treatment plant or sold to the district heating network. The energy surplus for the sewage treatment plant, including digestion, amounts to up to approximately 170 MJ/residence/year. Conversely, if there is no digestion, the rate of consumption amounts to up to approximately 200 MJ/residence/year.



Comment [K4]: Needs translated

Figure 7.1 Energy consumption with food waste disposer use

The amount of electricity and heating produced is therefore the same as those shown in Table 7.6.

7.2.5 Sludge disposal

Sludge in this assessment is assumed to be disposed of by either composting it and then using it for agricultural purposes or incinerating the sludge. In 2010, COWI completed an assessment of sludge disposal, from which the results are used. Energy consumption and production is listed in Table 7.4 for sludge with 30% dry matter.

Table7.4 energy consumption during sludge disposal with 30% wet matter)

Energy consumption kWh/ton sludge with 30%	Incineration	Composting	
Energy consumption	148	50	kWh/ton
District heating production	446	-	kWh/ton
Total	-298	50	kWh/ton

Source: Results from environmental report for Odense Municipality, COWI 2010

Table 7.5 Sludge amounts from organic waste via food waste disposers to sewage treatment plant.

Sludge amounts from biowaste per residence per year	Without digestion tank	Digestion tank, clarification only	Digestion tank with pre- and post-clarification
Sludge amount with 30% (ton)	0.095	0.073	0.070

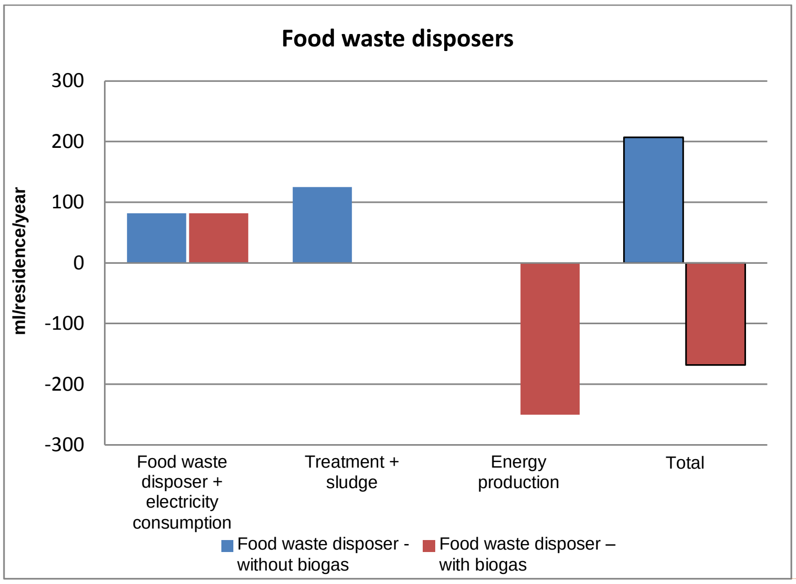


Figure 7.2 Combined energy balance with food waste disposer and treatment of biowaste

Table 7.6 Energy balance with biowaste via food waste disposer to sewage treatment plant

Energy balance Food waste disposer kg/person/year	Without digestion tank	Digestion tank, clarification only	Digestion tank with pre- and post-clarification
Food waste disposer	60	60	60
Electricity consumption in the residence	22	22	22
Waste water cleaning	108	108	75.6
Sludge disposal			
a) composting, or	17	13	13
b) sludge incineration	-102	-79	-76
Electricity production	0	-60	-105
Heat production	0	-83	-145
Total[1]	88 – 207	-31 – 61	-168 – -80

[1] Lowest number is for sludge incineration, highest is for composting

Comment [K5]: Needs translated

7.3 Energy report for organic household waste in the waste treatment system

This section describes the energy balances for collecting and treating organic waste from private residences. A total of three incineration solutions were evaluated which reflect the plants in Aalborg, Odense and Århus. In addition, a potential system that includes source-sorting and treatment at a common biogas plant was evaluated.

7.3.1 Collection equipment

Collecting waste in the kitchen assumes that approximately 0.7 kg LDPE per residence annually is used in the form of plastic bags. This amount of plastic can be saved if a food waste disposer is installed, even if the waste is collected together with the other garbage.

LDPE consumption for plastic bags is approximately 0.7 kg per residence per year as above. Collecting biowaste separately for either composting or biogasification typically involves using a 120-140 liter plastic container for outdoor collection of biowaste. Alternatively, a 2-part container can be used. A typical 120 liter waste container weighs approximately 10 kg and has an average lifespan of 10 years. This means that approximately 1 kg HDPE is used for the functional unit in the case of a biogasification solution.

Table 7.7 Energy balance for biowaste collection materials

Energy balance, Per functional unit	Consumption	Energy consumption	CO_2 emissions
Use of plastic bags	0.7 kg LDPE	53 MJ	1.4 kg
Use of plastic containers (for separate collection of biowaste)	1.0 kg HDPE	76 MJ	1.85 kg

7.3.2 Collection and transportation

Collection and transportation for garbage collection and biowaste varies depending on the the population density. On average, roughly 3-4 liters of diesel are used per ton of garbage collected. This corresponds to 0.43 liters per residence for the organic portion of garbage collection. This level of consumption corresponds to about 16 MJ for the functional unit.

7.3.3 Incineration

Incinerating waste results in the production of heat and/or electricity. The heat contributes to the local district heating system, which replaces individual gas furnaces or burning gas or coal at combined heat and power plants or district heating plants.

Table 7.8 Energy balance for incinerating organic garbage

Energy balance	Per ton of organic waste	Per residence per year for organic garbage	
Electricity consumption [1)]	392	51	MJ
Other energy consumption [1)]	32	4	MJ
Electricity production 20% [1)]	-722	-94	MJ
Heating production 65% [1)]	-2371	-308	MJ
Total	-2668	-347	MJ

[1)] Evaluated based on green accounting from Reno-Nord 2009

In addition, energy is also used to process and dispose of sludge and residues from cleaning exhaust gases. However, the amount of sludge and residual products from burning organic waste is very limited, and transportation of this material is estimated to have very minimal significance.

Based on Table 7.9, there appears to be little difference in terms of the surplus energy between the three incineration plants. The incineration plant in Århus has the largest energy surplus at approximately 374 kWh per residence annually. This is because the plant has the highest combined energy efficiency and the lowest energy consumption.

Table 7.9 Energy balance for burning organic garbage at the three incineration plants in Aalborg, Odense and Århus (see Section 6.3)

Incineration per residence per year for organic garbage	Aalborg	Odense	Århus	Unit
Electricity consumption	14	10.1	9.4	kWh
Other energy consumption	4.2	8.3	2.3	MJ
Electricity production 20%	-26	-28	-23	kWh
Heat production 65%	-308	-304	-327	MJ
Total	-347	-360	-374	MJ

The combined energy surplus for collecting and burning biowaste is given in Figure 7.3.

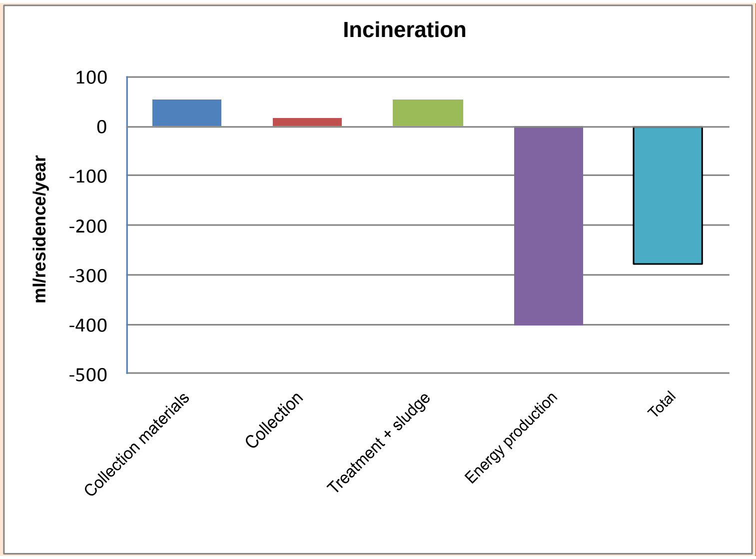


Figure 7.1 Combined energy balance for collecting and processing biowaste for incineration

Comment [K6]: Needs translated

7.3.4 Biological gasification

None of the three surrounding areas have source-sorting of biowaste from private residences and separate biological treatment of biological gasification. Aalborg University has studied collecting food waste separately and taking it to a sewage treatment plant for digestion along with waste water sludge (Poulsen 2009). A national plan involving separate collection and treatment of residential biowaste continues to be a topic of discussion. This is why the energy balance with this solution is included in the current assessment.

Source-sorted organic waste from households has typically needed to be pre-treated before being sent to a biogas plant. The pre-treatment involves sorting out impurities and improperly sorted items as well as opening the bags and removing them. The biowaste is often collected in plastic bags that should be removed, but in certain areas the waste is collected in paper bags, both inside the residence and outside in larger garbage bags. In the case of Grindsted, there is no pre-treatment.

Pre-treatment typically involves electricity consumption in the order of 10 to 20 kWh/ton for the amount of material received (Nordic Council of Ministers, 2007). Pre-treatment does have an advantage in that it divides the wettest items for biogasification, while the drier items are sent to incineration.

The biogas process is expected to be able to produce approximately 85 l CH_4/kg of waste, corresponding to approximately 11 Nm3 ch_4 per residence per year, corresponding to an energy content of approximately 400 MJ/year. The same degree of efficiency for electricity and heating is assumed when using biogas from sewage treatment plants (see Table 7.10), i.e. 37% for electricity and 51% for heat production.

The degassed waste is typically earmarked for local agricultural use, with fuel consumed for transportation and delivery. This level of consumption is typically approx. 50 MJ/ton with a distance of 20 km on average (Nordic Council of Ministers, 2007).

The energy surplus for biological treatment amounts to approximately 265 MJ/residence/year. This surplus can be significantly increased by optimizing the gas engine's energy efficiency, which could be raised to 80-90%.

Table 7.10 Energy balance for degassing source-sorted, organic garbage

	Per ton of organic waste	Per residence per year for organic garbage	Unit
Electricity consumption including pre-treatment	216	28	MJ
Other energy consumption for treatment	35	4.6	MJ
Electricity production 37 %	-1214	-158	MJ
Heat production 51 %	-1673	-217	MJ
Transporting degassed biomass	50	7	MJ
Total	-2586	-336	MJ

The overall energy surplus for biosorting, collection and separate biological treatment is 190 MJ/residence per year (Figure 7.). It appears that the production of the collection equipment is a significant part of the energy consumption, approximately 130 MJ for producing plastic containers for separate collection of biowaste. This rate of consumption can be reduced if the garbage containers are kept longer than the expected 10 years.

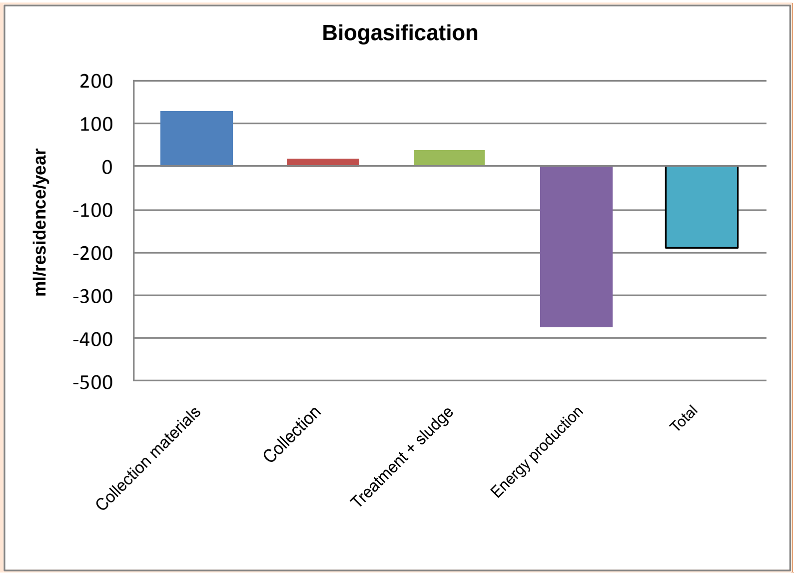
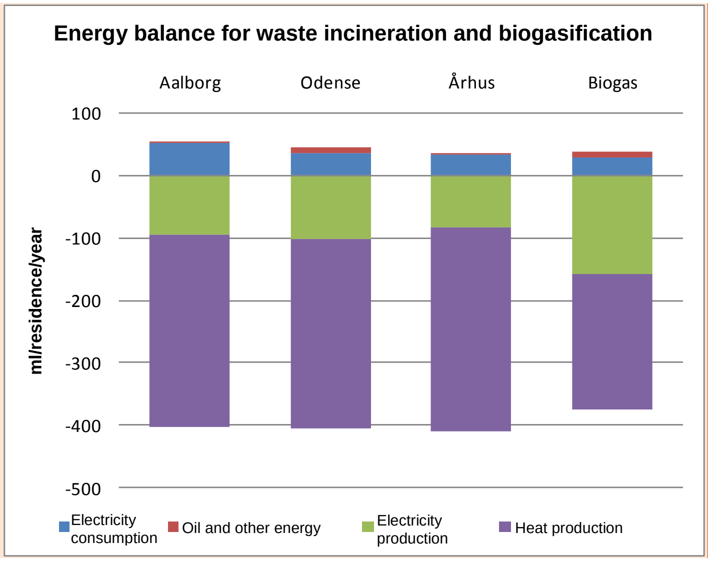


Figure 7.2 Overall energy balance for biogasification, including collection materials, collection and separate biowaste treatment

Comment [K7]: Needs translated

The figure below provides an overview of the different incineration plants and biogas solutions. It appears that there is a significant amount of energy gain in terms of electricity and heat productions and that biogas involves greater production of electricity in comparison to waste incineration.



Comment [K8]: Needs translated

Figure 7.3 Energy consumption for waste incineration and biogasification of organic waste

7.4 Environmental report

An environmental report has been created that assesses the emissions for greenhouse gases, acidic gases and nutrient salts for 3 for sewage treatment plant systems, 3 incineration plants and for a biogas plant receiving source-sorted organic household waste. This assumes that all of the selected systems exist and have sufficient capacity to receive the kitchen waste. In other words, expanding sewage treatment plants and new construction of a plant for biogasification is not included in the report.

The assessment is performed in EASEWASTE with conditions that are listed in section 0 and section 7.2.

7.4.1 Environmental assessment of food waste disposers

The environmental assessment for removing and treating biowaste via food waste disposers and sewage treatment plants depends a lot on the concrete processes that occur in the sewage treatment plant. Special conditions around the amount of organic waste for digestion and the subsequent biogas production are critical for the environmental accounting.

The selected sewage treatment plants are divided into three types (see Appendix 2):

- sewage treatment plant without digestion tank
- sewage treatment plant with digestion tank and only post-clarification of waste water
- sewage treatment plant with digestion tank and both pre- and post-clarification of waste water

The impact on the environment from the production of food waste disposers is evaluated based on a carbon consumption of 60 MJ, since coal is one of most polluting energy sources. Therefore, the environmental impact from the production of food waste disposers may be exaggerated, but because the precise composition of the waste disposer units is not known, this is just an approximation that doesn't create large uncertainties.

Electricity consumption, in both residences and at the sewage treatment plant, is expected to be marginal based on coal condensation power, which means that each kWh of electricity produced or used is based on carbon power.

Using biogas in the gas engine involves the following emissions per m3 biogas:

Table 7.11 Emissions from incinerating biogas at sewage treatment plant[10].

Emissions from incinerating biogas at sewage treatment plants		
CH_4	7.3	g/m^3 biogas
CO	2.4	g/m^3 biogas
SO_2	1.0	g/m^3 biogas
NO_x	14.7	g/m^3 biogas

Table 7.12 Environmental results for waste disposal via food waste disposers per residence per year excluding sludge disposal

	Without digestion tank	**Digestion tank, clarification only**	**Digestion tank with pre- and post-clarification**	
Greenhouse gas effect	31	17	-7	kg CO_2-equiv.
Acidification	0.04	0.09	0.13	kg SO_2-equiv.
Nutrient salt load	0.18	0.18	0.18	kg NO_3^-equiv.

The environmental effects of disposing of sludge depend on the actual methods involved. Two options were considered in this assessment:

- composting with subsequent use on the soil
- burning sludge

The results are calculated from previous studies which consider different amounts of dry matter. Both composting and incineration have a positive effect in terms of greenhouse gases and acidic gases, but composting has the smallest effect on the environment as a whole.

Advanced technologies for sludge incineration have significantly different environmental profiles, where modern technologies can utilize a greater portion of the energy contained in the sludge. Even if there is an energy surplus by using the sludge for district heating (see Table 7.4), more CO_2 is emitted (where electricity and natural gas are used as an energy source) than the supplanted district heating that comes from a combined heating and power plant based on coal.

[10] Based on data from the Avedøre Waste Water Treatment Center

Table 7.13 Environmental results for disposing of waste water sludge from organic waste per ton of sludge at 30%

Sludge disposal Per ton with 30% dry matter	Composting	Incineration	
Greenhouse gas effect	19	45	kg CO_2-equiv.
Acidification	0.02	0.29	kg SO_2-equiv.
Nutrient salt load	-9.4	-15	kg NO_3^-equiv.

Source: Results from environmental assessment for Odense Municipality, COWI 2010

It appears in Table 7.14 that the energy consumption at the sewage treatment plant is a significant cause for the emission of greenhouse cases. Emissions from the production of food waste disposers and use in residences are also significant factors, which together with use at the sewage treatment plant, result in net emissions of approximately minus 5 kg and up to 40 kg CO_2-equivalents per residence, per year.

Table 7.14 Greenhouse gas emissions divided by activity

Greenhouse gas effect	Without digestion tank	Digestion tank, clarification only	Digestion tank with pre- and post-clarification	
Disposer	6.0	6.0	6.0	kg CO_2-equiv.
Electricity consumption in the residence	2.1	2.1	2.1	kg CO_2-equiv.
Consumption at sewage treatment plant	27.6	27.6	19.3	kg CO_2-equiv.
Biogas production	0.0	-18.6	-35.1	kg CO_2-equiv.
Transport	0.3	0.2	0.2	kg CO_2-equiv.
Composting	1.8	1.4	1.4	kg CO_2-equiv.
Incineration	4.3	3.3	3.3	kg CO_2-equiv.
Total	38 − 40	19 − 21	-6 − -4	kg CO_2-equiv.

Spreading the sludge from sewage treatment plants on the fields provides phosphorus for agricultural purposes, which can replace the phosphorus in artificial fertilizers.

Table 7.15 Airborne emissions from waste incineration

Source: green accounting from RenoNord, Odense Kraftvarmeværk and AffaldVarme Århus;
io: not reported

Airborne emissions		Aalborg		Odense		Århus	
		Total	per ton	Total	per ton	Total	per ton
Waste incinerated	ton	189,879	-	263,413	-	229,033	-
HCl	kg	1,447	0.0076	54,000	0.2050	5,015	0.0219
SO_2	kg	8,601	0.0453	103,000	0.3910	1,090	0.0048
NO_x	kg	201,418	1.0608	234,000	0.8883	243,534	1.0633
Hydrogen fluoride (HF)	kg	io	Io	326	0.0012	195	0.0009

7.4.2 Environmental assessment of waste incineration

An environmental assessment has been created for waste incineration, which includes the collection equipment (bags) and collection and incineration.

The combustion processes are based on the composition of the waste and the heating value, as well as the energy efficiencies that are calculated in section 7.2. The most critical process-specific airborne emissions are likewise evaluated based on information given in green accounting (see Table 7.15).

The environmental effects of garbage-related equipment and collection are assumed to be identical from the three regions. The incineration plants have different levels of energy consumption and energy production, as well as different levels of airborne emissions, where the environmental results are slightly different between the regions. Garbage collection equipment and the actual garbage collection process contributes very little to the overall environmental profile. Odense has the best environmental profile because it has the highest degree of electrical efficiency and a low level of electricity consumption (Table 7.16 and Table 7.17).

Table 7.16 Greenhouse gas emissions with waste incineration per residence per year

Greenhouse gas effect	Ålborg	Odense	Århus	
Equipment (bags)	1.4	1.4	1.4	kg CO_2-equiv.
Collection	1.4	1.4	1.4	kg CO_2-equiv.
Incineration	-24	-31	-26	kg CO_2-equiv.
Total	-21	-28	-23	kg CO_2-equiv.

Table 7.17 Environmental results for waste incineration per residence per year

Total	Ålborg	Odense	Århus	
Greenhouse gas effect	-21	-28	-23	kg CO_2-equiv.
Acidification	0.08	0.10	0.07	kg SO_2-equiv.
Nutrient salt load	0.17	0.11	0.16	kg NO_3^-equiv.

7.4.3 Environmental assessment of biological gasification

Waste management systems that involve source-sorting biowaste in the home often require an extra container for collection, separate collection (can occur with 2 chamber trucks) and potential pre-treating before the biological waste can actually start to be treated.

Table 7.18 Greenhouse gas emissions with separate collection and treatment for biowaste per residence annually

Greenhouse gas effect	Biogas	
Equipment (bags and containers)	3.3	kg CO_2-equiv.
Collection	1.4	kg CO_2-equiv.
Pretreatment	9.2	kg CO_2-equiv.
Biotreatment	-38	kg CO_2-equiv.
Transporting degassed waste	1.4	kg CO_2-equiv.
Use on soil	-1.8	kg CO_2-equiv.
Total	-25	kg CO_2-equiv.

There is a gain in terms of CO_2 emissions of approximately 25 kg per residence, per year (Table 7.18), which is the same level as with waste incineration. The combined environmental effects with separate collection and biogasification are on the same order of magnitude as waste incineration (Table 7.19).

Table 7.19 Combined environmental results for biogasification of biowaste per residence per year

Total	Biogas	
Greenhouse gas effect	-25	kg CO_2-equiv.
Acidification	0.02	kg SO_2-equiv.
Nutrient salt load	0.19	kg NO_3^-equiv.

Across the globe, approximately 3.2 kg of pure phosphorus (P) is used per person, and it is estimated that phosphorus as a resource will be depleted within a period of 50 to 100 years based on the current rate of consumption (Global Phosphorus Research Initiative, 2010). Consumption in the western world is somewhat above average because consumption in the poorest countries is considerably below average.

Reusing biowaste from private residences recirculates phosphorus back to agricultural land, and it is assumed that phosphorus in biowaste replaces the phosphorus in artificial fertilizer by a ratio of 1:1. This means approximately 5% of the residence's phosphorus consumption is recirculated.

7.5 Summary of energy and environmental assessment

The following figures and tables show the combined energy balances for selected solutions. The greatest energy consumption is with food waste disposers and sewage treatment plants without a digestion tank. The largest energy surplus is achieved by incinerating waste, while biogasification avoids the largest amount of CO_2 emissions. This condition is caused by a gasoline engine having a higher electrical efficiency than waste incineration, and since the supplanted electricity production has a higher level of CO_2 emissions than the corresponding amount of heat replaced, a high degree of electrical efficiency is achieved by improving the environmental profile. In addition, storing carbon on agricultural land is considered as a negative CO_2-emission.

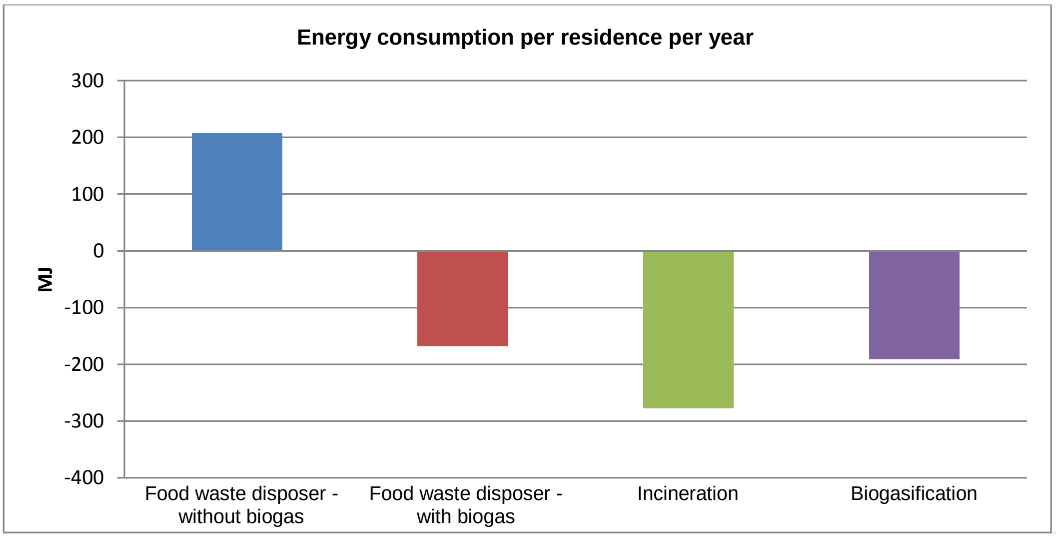


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Figure 7.4 Combined overview of energy consumption with using food waste disposers and in the waste management system

Table 7.20 Summary of energy balances

Energy balances MJ/residence/year	Food waste disposer - without biogas	Food waste disposer - with biogas	Waste incineration[3)]	Biological gasification
Collection equipment	82	82	53	129
Collection	0	0	16.5	16.5
Treatment + sludge disposal	125	0	55	39
Energy production	0	-250	-402	-375
Total	207	-168	-277	-191

[1)] composting sludge, [2)] burning sludge, [3)] Aalborg

In Table 7.21, it appears the largest amount of CO_2 emissions can be avoided through waste incineration, and biogasification is also more beneficial in terms of greenhouse gas emissions than food waste disposers and treatment at sewage treatment plant - even if biogas is digested and utilized at the sewage treatment plant.

Table 7.21 Summary of greenhouse gas emissions

Greenhouse gases Kg CO_2/residence/year	Food waste disposer - without biogas	Food waste disposer - with biogas	Waste incineration[3)]	Biological gasification
Equipment	8.1	8.1	1.4	3.3
Collection	0.0	0.0	1.4	1.4
Treatment + disposal	30	23	14	19
Energy production	0.0	-35	-38	-48
Total	38	-4	-21	-25

[1)] composting sludge, [2)] burning sludge, [3)] Aalborg

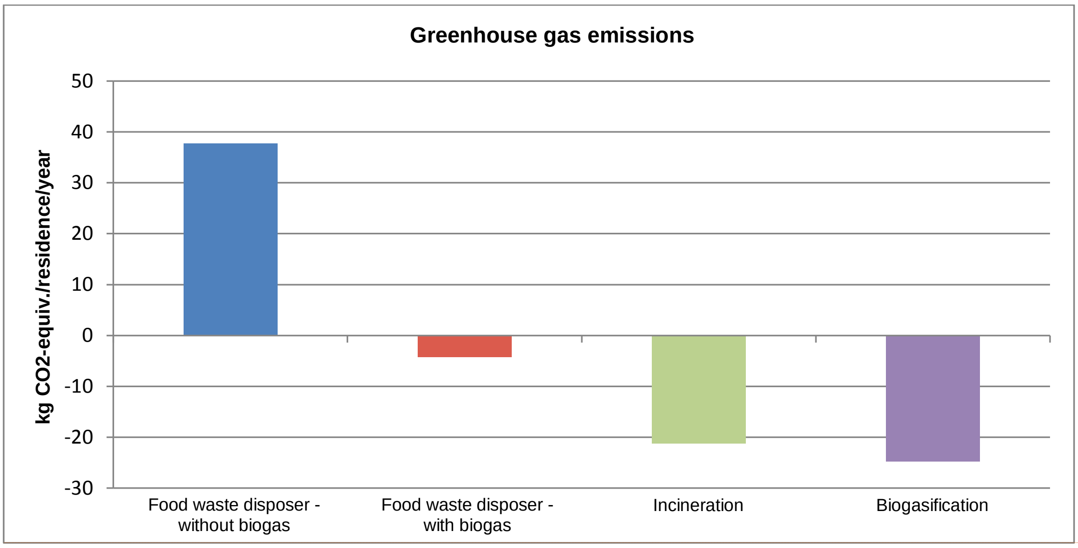

Figure 7.5 Greenhouse gas emissions for using food waste disposers with waste incineration and biological gasification

Emission of acidic gases, which contribute to acidification is greatest with food waste disposers and biogas production at sewage treatment plants because biogas engines emit significantly larger amounts of NO_X and SO_2.

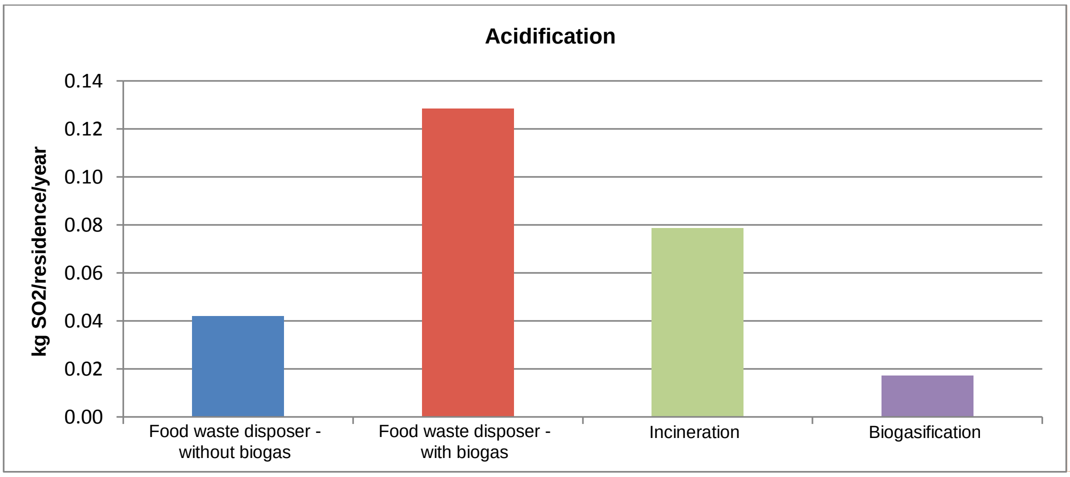

Figure 7.6 Acid gas emissions for using food waste disposers with waste incineration and biological gasification

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Comment [K11]: Needs translated

The nutrient salt load is greatest when using food waste disposers, whereby approximately 18 g of nitrogen per residence per year and approximately 2.9 g phosphorus per residence per residence per year is discharged from the waste directly into runoff water.

The nutrient salt emissions from sewage treatment plants treating residential biowaste corresponds to an average of 1% of a person's nutrient salt emissions, so in all cases there is a relatively small impact on the environment that is caused by treating organic household waste.

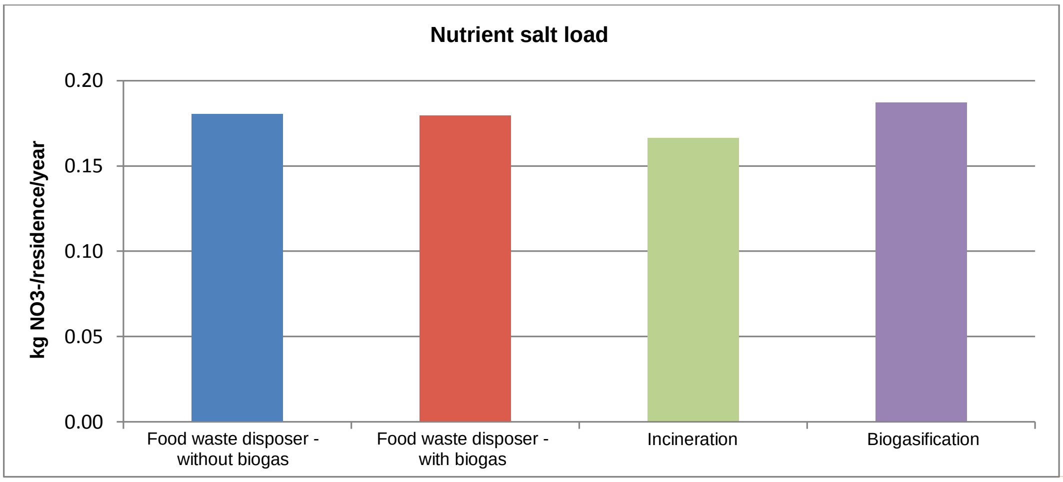

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Figure 7.7 Nutrient salt emissions for using food waste disposers with waste incineration and biogasification

7.5.1 Normalized environmental results

In order to compare the various environmental effects, they have been normalized below. Normalization shows the relative magnitude of the potential environmental effects in relation to an average person's potential environmental impact. These consequences are normally expressed in personal equivalents (PE) but are expressed below in % of a PE.

Figure 7.8 shows that the greenhouse gas effect is the most significant environmental effect, and it is the environmental effect that is affected the most by the individual scenarios. The nutrient salt load and acidification are not changed as dramatically under these scenarios as the greenhouse gas effect. The figure shows that a pure, biogas solution (source-sorting and collection via a garbage truck) has a marginally better environmental impact than waste incineration, which is better than the solutions involving food waste disposers.

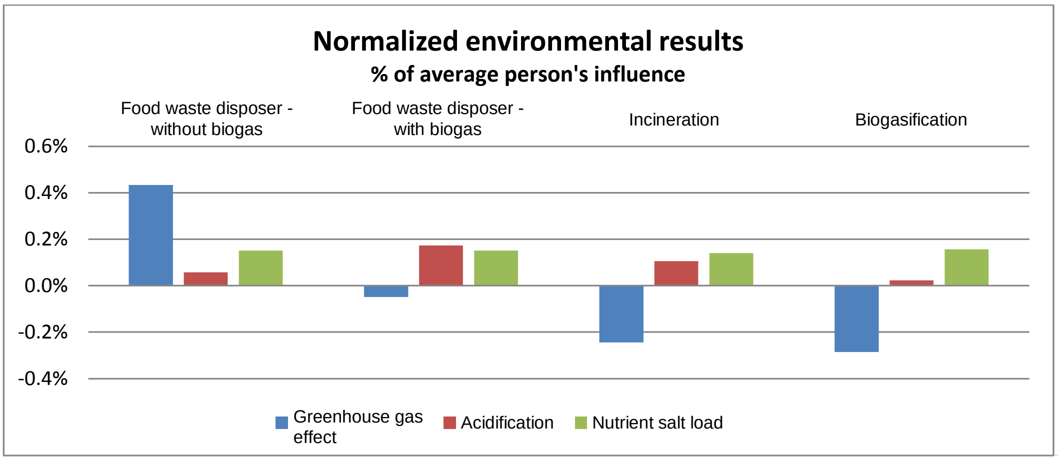

Figure 7.8 Normalized potential environmental effects with using food waste disposers with waste incineration and biological gasification

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7.6 Other studies

7.6.1 Aalborg municipality

Aalborg University has evaluated the changes in energy and environmental conditions related to waste management in Aalborg municipality (Poulsen 2009). All organic waste is currently sent for incinerations, but sending food waste to a digestion tank at a sewage treatment plant will improve both energy utilization and further reduce greenhouse gas emissions. This improvement requires that this part of the organic waste be collected separately.

7.6.2 Swedish study

The communities north of Stockholm (Käppalaförbundet 2009), completed a study of the methods for utilizing residential organic waste in the digestion tank of a sewage treatment plant, whereby the waste was: a) pulverized in a food waste disposer and taken to the sewage treatment plant via the sewer system, b) pulverized in a food waste disposer and sent to a collection tank and then sent to a sewage treatment plant (e.g. in Bo01 in Malmö) and c) sorted and sent directly to a digestion tank.

The three methods were evaluated by assigning points for environmental parameters, costs, operating problems, administration, etc. The conclusion was that source-sorting was a marginally better solution than using food waste disposers, but the difference between the solutions is so small (in relation to the uncertainty of assigning points) that no clear conclusion can be made.

8 Conclusion

The purpose of this report is to improve the amount of information available when deciding to allow the installation of residential food waste disposers.

Food waste disposers are installed in residences because they are an easy way to dispose of food waste that would otherwise create problems with odors and flies and because it makes garbage collection more hygienic. From the point of view of the community, one of the requirements is to be able to utilize the energy in this type of biological waste in the best way possible. In Denmark, most food waste is currently sent from residences to an incineration plant.

Food waste disposers have long been installed in the USA, Australia and New Zealand, and in the last 20 years, food waste disposers have also been installed in cities in Norway and Sweden.

There is a large amount of literature and reporting regarding the impact of food waste disposers on the waste water system and how the energy should be best utilized. A large part of the available material consists of theoretical calculations or studies financed by manufacturers.

Hence, there are very few studies "on the ground" that examine the consequences for sewage systems, or examine the statements from companies that confirm the attitude that "permitting food waste disposers has no impact on the sewage system functioning" that is based on a reactive attitude (no news is good news).

Based on experiences in areas where food waste disposers are allowed, permitting these units will lead to a level of participation (residences with food waste disposers) of 5-10% within 10 years.

8.1 Consequences for waste water systems

8.1.1 Sewer systems

The following conclusions were made in terms of sewer systems:

1. The extra **water consumption** is marginal and will not affect the hydraulic capacity.

2. Waste processed through a food disposer has a specific density, which is generally lower than the contents in the waste water and much lower than sand. Processing food waste will therefore not increase **sedimentation and blockages**.

3. A food waste disposer installed in a home will probably not change the amount of **fat** in the sewer system considerably. Liquid fat from cooking food should be collected under all circumstances and put in the garbage bin. In Norway and Sweden, there have been problems with grease in sewer systems regardless of whether private residences have a food waste disposer or not. In Northern Europe, it is generally agreed that problems with fat are related to fast-food diners and grill restaurants.

4 There have been no reports of problems with **hydrogen sulphide**, but there haven't been any reports "on the ground" examining this problem. If they already exist, adding processed kitchen waste can worsen the problem, particularly in pipelines with a long retention time, e.g. long pressure lines. No differences have been found between separate and combined sewer systems in terms of this problem.

5 The critical factor for the presence or lack of **rats** in a sewer system is access to nesting sites, e.g. leaky sewers. Rats already have a rich supply of food in Danish sewer systems and rats will not be able to access processed (pulverized) food waste because they won't be able to catch "food clumps" in the waste water.

6 In **combined sewer systems**, a participation level above 10% will result in a significant increase in the organic load of recipients from **overflow structures**.

7 There is a big difference between permitting food waste disposers in residences compared with **diners**, restaurants and similar establishments.

8.1.2 Sewage treatment plant

The following conclusions were made in terms of sewage treatment plants:

1 Processed food waste is not expected to affect the function (or number) of **screens and sand traps**

2 Installing food waste disposers will not affect the **hydraulic load** of the sewage treatment plant.

3 Installing food waste disposers in up to **10%** of residences in the area around a sewage treatment plant will not increase the load of organic matter and nutrient salts noticeably. In terms of the sewage treatment plants that were assessed in this report, participation at this level would not lead to sewage treatment plants being overloaded by 2020.

4 Installing food waste disposers in **50%** of residences, the extra burden in terms of organic matter is in the range of 12-25% and for nutrient salts it is in the range of 3-8%.

5 Since connecting food waste disposers to the waste water system will not result in a noticeable increase in the hydraulic load, the **discharge of organic matter and nutrient salts** would also not increase significantly if 50% of residences had a food waste disposer installed.

6 A sewage treatment plant must have a **digestion tank** for producing biogas (methane) in order to utilize the energy in the processed food waste. If the plant does not have a digestion tank, the added food waste will result in increased energy consumption due to the extra energy for the process tank.

7 Producing **biogas** from the extra food waste added depends on whether the sewage treatment plant has a clarification tank or not. In sewage treatment plants with a clarification tank, approximately 40% of COD is "lost" in the process tank and outfall (and therefore not in the sludge that is digested). Plants without clarification "lose" approximately 65% of COD.

8 **The energy** in the processed food waste is utilized best at sewage treatment plants with clarification tanks and digestion tanks. At sewage treatment plants without a digestion tank, the processed food waste will result in increased energy consumption.

9 If the food waste is sent to a sewage treatment plant, the sewage treatment plant can change its status to also be a **waste treatment plant**.

8.2 Consequences for waste management systems

1 If the **organic portion of the waste** is removed from garbage collection, the amount of garbage is reduced by approx. 20-30%. This can also result in fewer odor problems and better hygiene for workers collecting the garbage.

2 Sorting out the organic kitchen waste from the garbage increases the possibility of reducing the **frequency of garbage collection** without any particular odor problems or hygiene problems if food waste disposers are installed in all or a large portion of homes in a given area.

3 The heating value increases for the remaining garbage measured by ton of garbage, but the combined input effect on the incinerators is only minimally affected. There is no significant increase in the **capacity at waste incineration plants** from sorting out organic kitchen waste.

8.3 Energy and environmental consequences

1 The greatest **energy production** comes from using food waste at an incineration plant (65% more than at a sewage treatment plant), followed by a biogasification plant (14% more than at a sewage treatment plant), and the least energy comes from pulverized food waste being sent with waste water to a sewage treatment plant with a clarification tank and digestion tank.

2 There is a significant difference between **electricity and heat production**, which is critical in terms of the environmental assessment, because the electricity produced makes up for a large number of emissions in relation to a comparable amount of energy in the form of district heating.

3 Food waste that is sent for waste incineration currently replaces coal and therefore saves fossil fuels by supplanting **coal-based electricity and district heating.**

4 Biogasification provides the greatest savings in terms of **greenhouse gas emissions** because biogasification produces more electricity than waste incineration. Waste incineration provides the next largest reduction and sewage treatment plants have the lowest reduction.

5 **The acidification potential** is greatest in a system with food waste disposers with digestion tanks and with waste incineration.

6 The potential **nutrient salt load** is largely identical between the different scenarios.

7 By normalizing the potential **environmental effects**, it appears that the greenhouse gas effect is the effect with the largest relative impact, when the environmental effects are expressed in relation to an average person's influence over the respective environmental effects.

8 **The structural conditions** within the waste sector and the energy sector are decisive in terms of what is environmentally advantageous, and the results can therefore not be transferred directly from one region/country to another. Therefore, it is critical to evaluate the district heating system in the applicable surrounding area in order to assess the overall environmental effects because heat production from biogas or waste incineration can have a decisive effect on the environmental results.

8.4 Recommendations

If a municipality or water company wants to evaluate the options and conditions for allowing residential food waste disposers, the following recommendations apply:

1 Reviewing the sewer system is recommended to assess areas where the system is vulnerable in terms of the formation of hydrogen sulphide and overflow with over 10% of residences using a food waste disposer, based on the operational experiences and inspections of the system.

2 In areas where the addition of processed food waste can result in documented operating problems, a ban on installing food waste disposers may be justified.

3 Recording the addresses with permission to install a food waste disposer is recommended.

In special situations, assessments of the working environment, accessibility and other issues may mean that installing food waste disposers is the most optimal solution.

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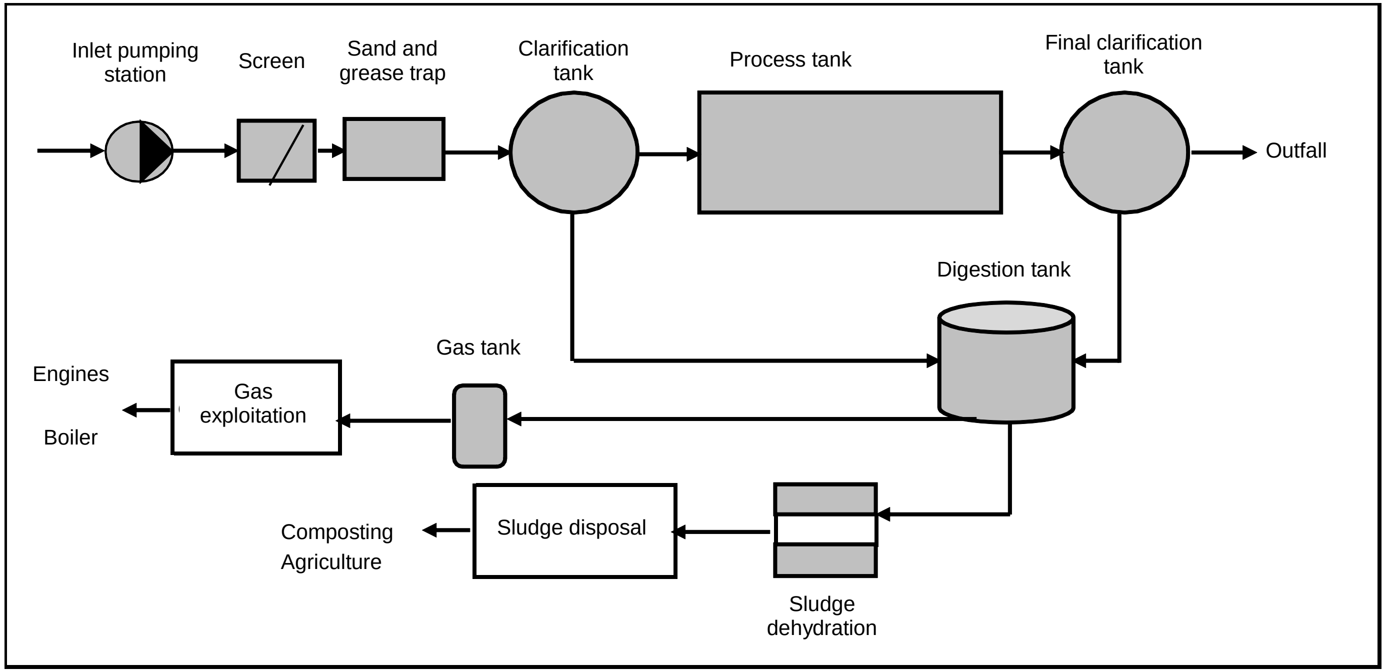
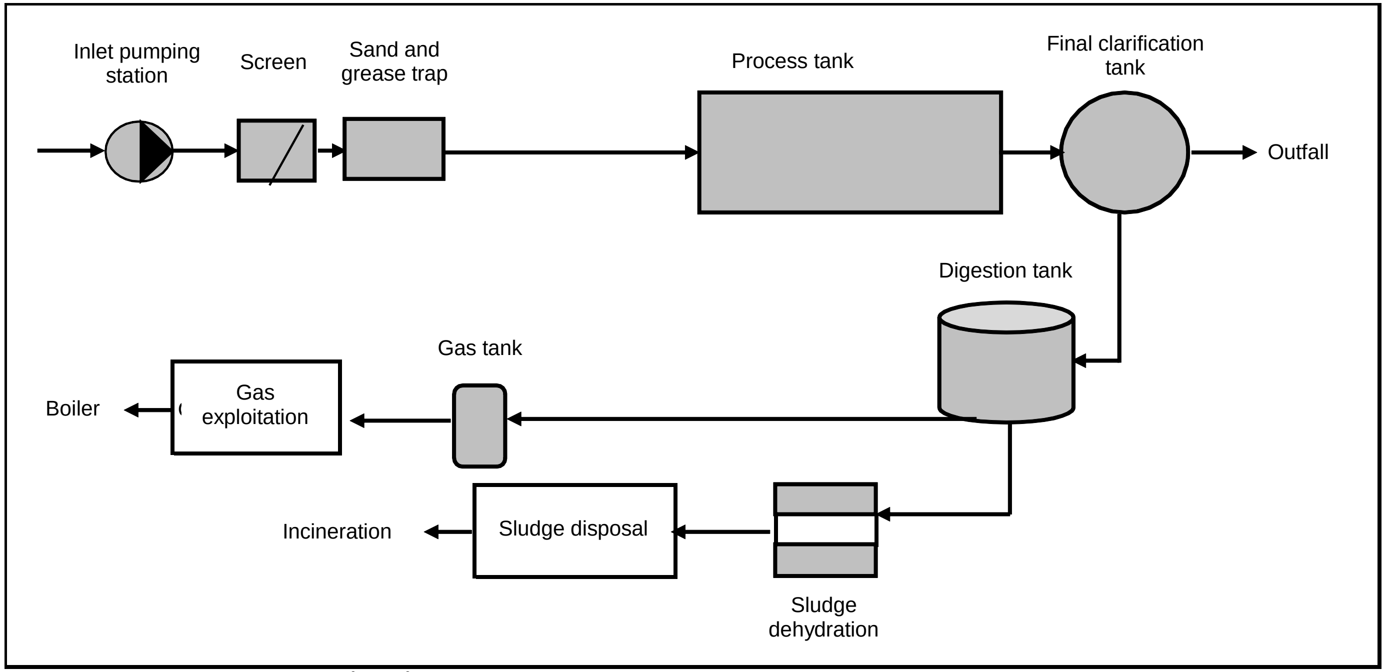
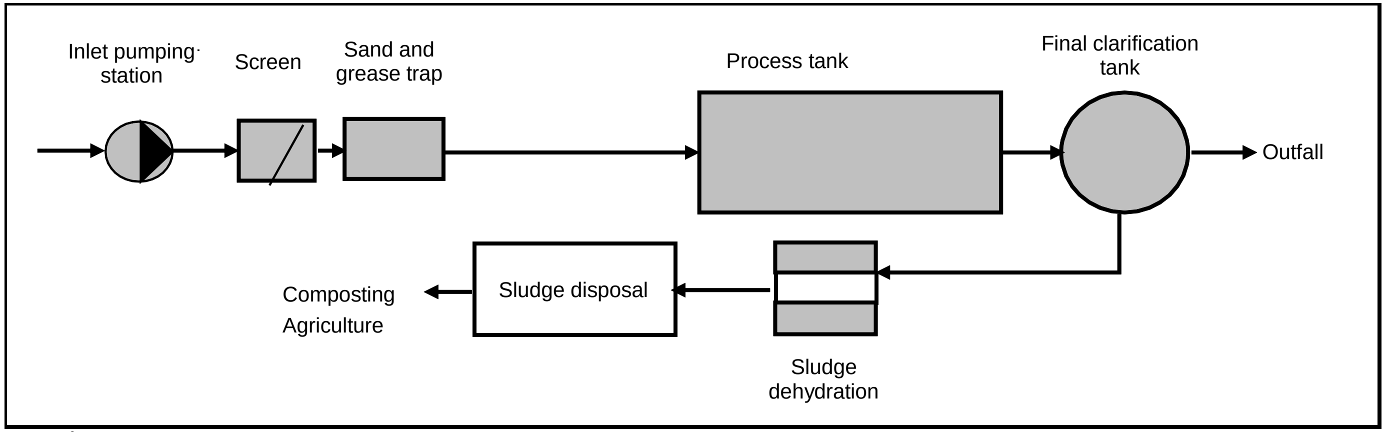
Appendix 2 Selected sewage treatment plants



Ejby Mølle, Odense	385,000 p.e.	Aalborg Vest	265,000 p.e.
Marselisborg, Århus	200,000 p.e.		



Aalborg Øst 75,000 p.e. Åby, Århus 84,000 p.e. Nordvest, Odense 65,000 p.e. (sludget to Ejby Mølle,
Viby, Århus 83,000 p.e. where it is digested)



Egå, Århus 120,000 p.e. Bogense 7,000 p.e.

Appendix 3 Affect of loads from food waste disposers

								2020					
Sewage treatment plant	**Unit**	**Capacity**	**Load***		**Persons connected**		**Matter supplied from food disposer waste**	**Contributions from food waste disposers**		**Extra load**		**Load sewage treatment plant**	
			2009	2020	2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Aalborg													
Aalborg West					137,000	154,000							
Load	PE	265,000	127,000	140,000									
COD	*tons/year*		6,910	7,617			25	385	1,925	5%	25%		
BOD	*tons/year*	5,804	2,789	3,074			8.7	134	670	4%	22%	55%	65%
Tot-N	*tons/year*		504	556			0.6	9.2	46	1.7%	8%		
Tot-P	*tons/year*		87	96			0.08	1.2	6.2	1.3%	6%		
Aalborg East					55,000	75,000							
Load	PE	75,000	45,000	60,000									
COD	*tons/year*		3,170	4,227			25	188	938	4%	22%		
BOD	*tons/year*	1,643	983	1,311			8.7	65	326	5%	25%	84%	100%
Tot-N	*tons/year*		235	313			0.6	4.5	23	1.4%	7%		
Tot-P	*tons/year*		41	55			0.08	0.6	3.0	1.1%	5%		

* 60% fractile, PE load based on COD load

Sewage treatment plant	Unit	Capacity	Load**		Persons connected		Matter supplied from food disposer waste	2020 Contributions from food waste disposers		2020 Extra load		2020 Load sewage treatment plant	
			2009	2020	2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Odense													
Ejby Mølle					121,107	125,000							
Load	PE	385,000	236,300	243,896									
COD	*tons/year*		12,259	12,653			25	313	1,563	2%	12%		
BOD	*tons/year*	8,432	5,175	5,341			8.7	109	544	2%	10%	65%	70%
Tot-N	*tons/year*		653	674			0.6	7.5	38	1.1%	6%		
Tot-P	*tons/year*		115	119			0.08	1.0	5.0	0.8%	4%		
Nordvest					47,426	49,000							
Load	PE	65,000	50,594	52,273									
COD	*tons/year*		2,693	2,782			25	123	613	4%	22%		
BOD	*tons/year*	1,424	1,108	1,145			8.7	43	213	4%	19%	83%	95%
Tot-N	*tons/year*		219	226			0.6	2.9	15	1.3%	6%		
Tot-P	*tons/year*		38	39			0.08	0.4	2.0	1.0%	5%		
Bogense					4,500	4,649							
Load	PE	7,000	4,907	5,070									
COD	*tons/year*		334	345			25	12	58	3%	17%		
BOD	*tons/year*	153	106	110			8.7	4	20	4%	18%	74%	85%
Tot-N	*tons/year*		30	31			0.6	0	1	1%	5%		
Tot-P	*tons/year*		4	4			0.08	0	0	1%	5%		

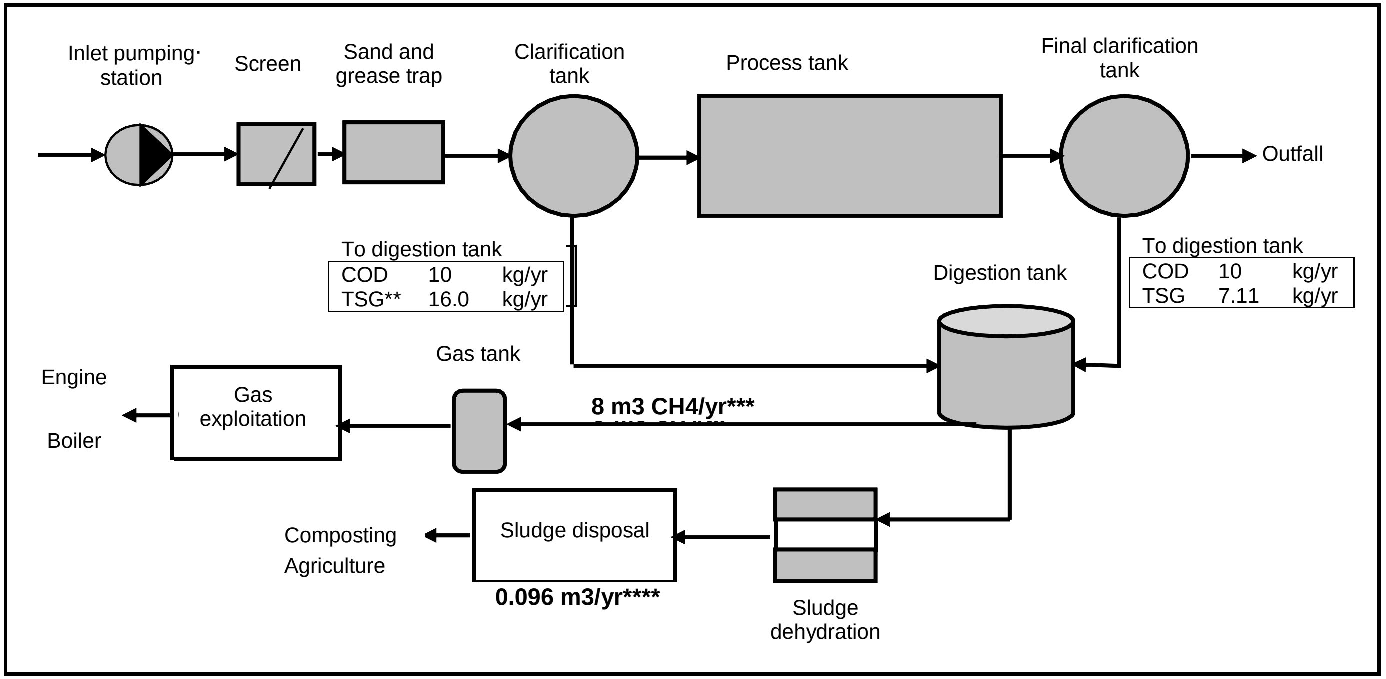
***Average*

								2020					
Sewage treatment plant	**Unit**	**Capacity**	**Load***		**Persons connected**		**Matter supplied from food disposer waste**	**Contributions from food waste disposers**		**Extra load**		**Load sewage treatment plant**	
			2009	2025	2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Århus													
Marselisborg					144,000	145,000							
Load	PE	200,000	147,000	181,000									
BOD	*tons/year*	4,380	3,226	3,972			8.7	126	631	3%	16%	94%	105%
Tot-N	*tons/year*		557	686			0.6	8.7	44	1.3%	6%		
Tot-P	*tons/year*		99	121			0.08	1.2	5.8	1.0%	5%		
Viby					30,000	37,000							
Load	PE	83,000	35,000	64,000									
BOD	*tons/year*	1,818	760	1,389			8.7	32	161	2%	12%	78%	85%
Tot-N	*tons/year*		178	326			0.6	2.2	11	0.7%	3%		
Tot-P	*tons/year*		29	53			0.08	0.3	1.5	0.6%	3%		
Åby					63,000	66,000							
Load	PE	84,000	67,000	87,000									
BOD	*tons/year*	1,840	1,468	1,906			8.7	57	287	3%	15%	107%	119%
Tot-N	*tons/year*		256	332			0.6	4.0	20	1.2%	6%		
Tot-P	*tons/year*		43	56			0.08	0.5	2.6	0.9%	5%		
Egå					78,000	95,000							
Load	PE	120,000	65,000	114,000									
BOD	*tons/year*	2,628	1,407	2,468			8.7	83	413	3%	17%	97%	110%
Tot-N	*tons/year*		319	559			0.6	5.7	29	1.0%	5%		
Tot-P	*tons/year*		51	90			0.08	0.8	3.8	0.8%	4%		

Appendix 4 Effect of processes in sewage treatment plants

Active sludge plants with clarification and digestion tanks

Inlet			Cleaning effect	To process tank			Combined cleaning effect	Outfall		
COD	53	kg/yr	0.44	COD	29	kg/yr	0.93	**COD**	**3.7**	**kg/yr**
BOD	19	kg/yr	0.44	BOD	10	kg/yr	0.98	**BOD**	**0.4**	**kg/yr**
Tot-N	1.3	kg/yr	0.11	Tot-N	1.2	kg/yr	0.86	**Tot-N**	**0.18**	**kg/yr**
Tot-P	0.2	kg/yr	0.27	Tot-P	0.15	kg/yr	0.91	**Tot-P**	**0.02**	**kg/yr**



COD*: based on a yield constant of 0.35 kg SS/kg COD to the process tank and COD content in the sludge to the digestion tank of 1 kg COD/kg SS
TSG** (Ignition loss): based on 1.45 kg COD/kg TSG
Nm3CH/year: based on 550 l gas/TSG and a methane content of 65% of the gas
m3/year****: based on 0.4 kg TS/kg COD in the inlet. Sludge dehydration at 22% of TS.

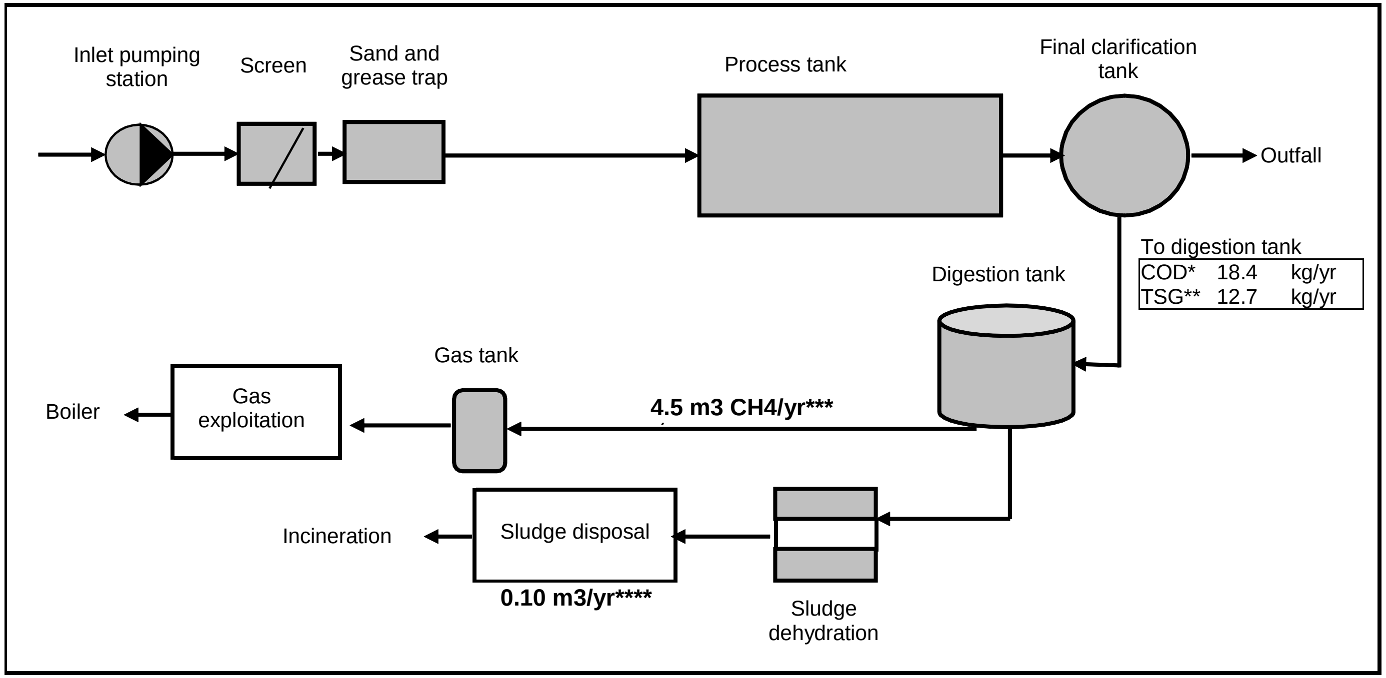
Total current usage: 36 kWh/p.e., of which goes to bio and sludge dehydration: 1.15 kWh/kg BOD
Current consumption for functional unit: **21 kWh**

Airborne emissions from biogas engine per m3 gas

CH_4	g/m3	7.3
CO	g/m3	2.4
CO_2	g/m3	1310
SO_2	g/m3	1
NO_x	g/m3	14.7

Active sludge plant with disgestion tank

Inlet			Combined cleaning effect	Outfall		
COD	53	kg/yr	0.93	**COD**	**3.7**	**kg/yr**
BOD	19	kg/yr	0.98	**BOD**	**0.37**	**kg/yr**
Tot-N	1.3	kg/yr	0.86	**Tot-N**	**0.18**	**kg/yr**
Tot-P	0.2	kg/yr	0.91	**Tot-P**	**0.02**	**kg/yr**



COD*: based on a yield constant of 0.35 kg SS/kg COD to the process tank and COD content in the sludge to the digestion tank of 1 kg COD/kg SS
TSG** (Ignition loss): based on 1.45 kg COD/kg TSG
Nm3CH/year: based on 550 l gas/TSG and a methane content of 65% of the gas
m3/year****: based on 0.4 kg TS/kg COD in the inlet. Sludge dehydration at 22% of TS.

Total current usage: 50 kWh/p.e., of which goes to bio and sludge dehydration: 1.60 kWh/kg BOD
Current consumption for functional unit: **30 kWh**

Airborne emissions from sludge treatment by functional unit

CO	1.25	g
CO2	1204	g
SO2	6.4	g
NOx	3.4	g
HCl	0.28	g
HF	0.024	g
Bly(Pb)[2)]	0.00026	g
Cadmium(CD)[2)]	0.00014	g
Mercury(Hg)[2)]	0.00014	g
PAH(sum)[3)]	0.0068	mg
Dioxin(TEQ)	0.0020	µg
Oil consumption	0.73	liter

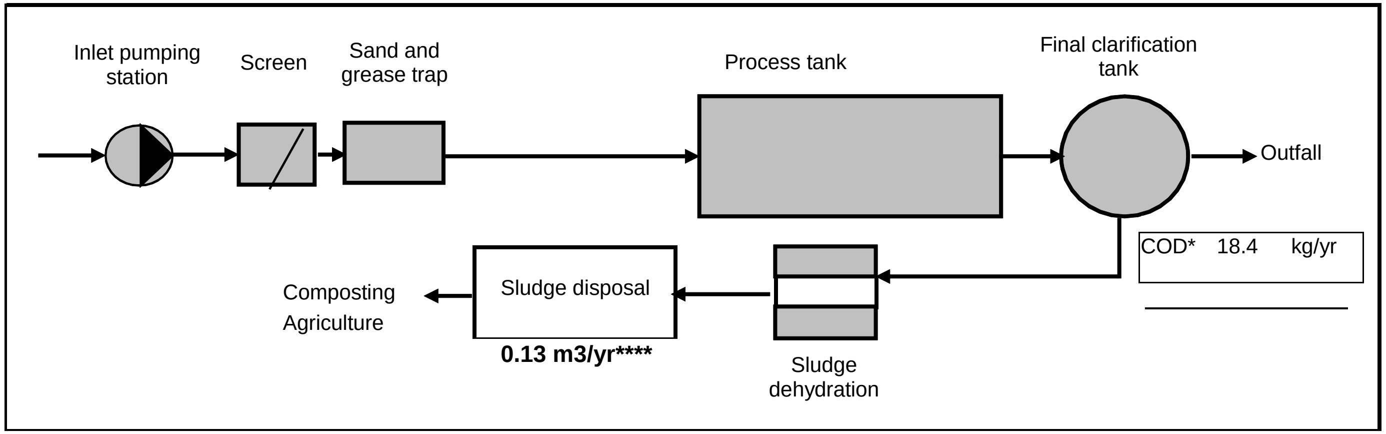
2) Sum of particle and gas phase
3) mg benzene-pyrene - equiv/Nm3

Airborne emissions from biogas engine per m3 gas

CH4	g/m3	7.3
CO	g/m3	2.4
CO2	g/m3	1310
SO2	g/m3	1
NOx	g/m3	14.7

Plant without digestion tank

Inlet			Combined cleaning effect	Outfall		
COD	53	kg/yr	0.93	**COD**	**3.7**	**kg/yr**
BOD	19	kg/yr	0.98	**BOD**	**0.37**	**kg/yr**
Tot-N	1.3	kg/yr	0.86	**Tot-N**	**0.18**	**kg/yr**
Tot-P	0.2	kg/yr	0.91	**Tot-P**	**0.02**	**kg/yr**



COD*: based on a yield constant of 0.35 kg SS/kg COD to the process tank and COD content in the sludge of 1 kg COD/kg SS
m3/year****: based on 0.55 kg TS/kg COD in the inlet. Sludge dehydration at 22% of TS.

Total current usage: 50 kWh/p.e., of which goes to bio and sludge dehydration: 1.60 kWh/kg BOD
Current consumption for functional unit: **30 kWh**

Appendix 5 Effect of energy production/consumption

						2020							
Sewage treatment plant	**Unit**	**Type of plant**	**Persons connected**		**Matter supplied from food disposer waste**	**Contributions from food waste disposers**		**Extra energy (gas) production**		**Extra energy consumption (electricity)**		**Energy results**	
			2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Aalborg													
Aalborg West		F E R	137,000	154,000									
COD	*tons/year*				25	385	1,925						
Energy	*kWh/year*							506,660	2,533,300	184,479	922,396	322,181	1,610,904
Aalborg East		F E R	55,000	75,000									
COD	*tons/year*				25	188	938						
Energy	*kWh/year*							141,750	708,750	125,000	625,000	16,750	83,750

F Clarification — FER Energy prod. 1.316 kWh/kg COD — Energy consump. 0.479 kWh/kg COD

E Final clarification — ER Energy prod. 0.756 kWh/kg COD — Energy consump. 0.667 kWh/kg COD

R Digestion tank — Average consumption for one residence 4000 kWh/year

Sewage treatment plant	Unit		Persons connected		Matter supplied from food disposer waste	2020 Contributions from food waste disposers		Extra energy (gas) production		Extra energy consumption (electricity)		Energy results	
			2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Odense													
Ejby Mølle		F E R	121,107	125,000									
COD	*tons/year*				25	313	1,563						
Energy	*kWh/year*							411,250	2,056,250	149,740	748,698	261,510	1,307,552
Nordvest		E R	47,426	49,000									
COD	*tons/year*				25	123	613						
Energy	*kWh/year*							92,610	463,050	81,667	408,333	10,943	54,717
Bogense		E	4,500	4,649									
COD	*tons/year*				25	12	58						
Energy	*kWh/year*							0	0	7,749	38,745	7,749	38,745

F	Clarification	FER	Energy prod.	1.316	kWh/kg COD	Energy consump.	0.479	kWh/kg COD	
E	Final clarification	ER	Energy prod.	0.756	kWh/kg COD	Energy consump.	0.667	kWh/kg COD	
R	Digestion tank					Average consumption for one residence		4000	kWh/year

Sewage treatment plant	Unit		Persons connected		Matter supplied from food disposer waste	2020 Contributions from food waste disposers		Extra energy (gas) production		Extra energy consumption (electricity)		Energy results	
			2009	2020	kg/person/year	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection	10% connection	50% connection
Århus													
Marselisborg		F E R	144,000	145,000									
COD	*tons/year*				25.0	363	1,813						
Energy	*kWh/year*							477,050	2,385,250	173,698	868,490	303,352	1,516,760
Viby		E R	30,000	37,000									
COD	*tons/year*				25.0	93	463						
Energy	*kWh/year*							69,930	349,650	61,667	308,333	8,263	41,317
Åby		E R	63,000	66,000									
COD	*tons/year*				25.0	165	825						
Energy	*kWh/year*							124,740	623,700	110,000	550,000	14,740	73,700
Egå		E	78,000	95,000									
COD	*tons/year*				25.0	238	1,188						
Energy	*kWh/year*							0	0	158,333	791,667	-158,333	-791,667

F Clarification — FER Energy prod. 1.316 kWh/kg COD — Energy consump. 0.479 kWh/kg COD

E Final clarification — ER Energy prod. 0.756 kWh/kg COD — Energy consump. 0.667 kWh/kg COD

R Digestion tank — Average consumption for one residence 4000 kWh/year

Appendix 6 Composition of food waste disposer

Material	Total Wt.		Total %
	pounds	kilograms	
Aluminum	1.68	0.76	7.88%
Brass	0.002	0,001	0.01%
Cardboard	1.15	0.52	5.41%
Copper	2.26	1.03	10.62%
Nylon	0.02	0.01	0.08%
Paper	0.09	0.04	0.43%
Plastic	2.61	1.18	12.27%
Polyester Cord	0.002	0,001	0.01%
Powdered Metal	0.05	0.02	0.24%
Rubber	0.60	0.27	2.84%
Steel	12.70	5.76	59.68%
Tape	0.01	0.00	0.02%
Wire	0.04	0.02	0.20%
Zinc	0.06	0.03	0.30%
Total Weight =	21.28	9.65	100%

Information from Insinkerator, Michael Keleman

Appendix 7 Food waste disposer manufacturers

- Emerson InSinkErator
- Xiamen Dingrong Electrical Components Co., Ltd., Fujian, China
- Foshan Shunde Shentop Information Technology Co., Ltd., Guangdong, China
- Gladore Electric Co., Ltd., Shanghai, China
- Tenghua Railway Material And Fitting Factory Of Xingtai City, Hebei, China
- 12 other Chinese manufacturers found: