

## Experiences with waste incineration for energy production in Denmark

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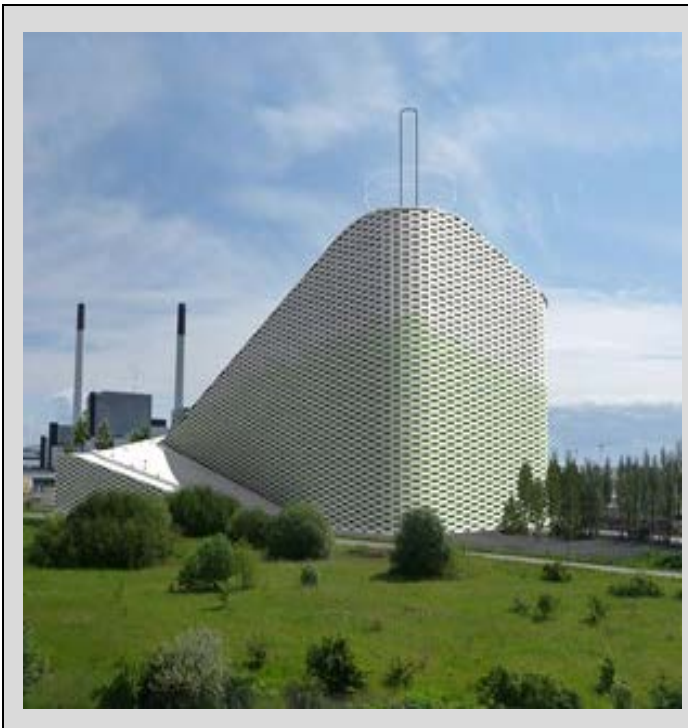
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# Experiences with waste incineration for energy production in Denmark



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June, 2014

COWI

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June 24, 2014

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## PREFACE

The Bioenergy Department in SENER have requested assistance with planning for the deployment of bioenergy (Biomass, biogas and waste incineration) in Mexico and information on Danish experiences with developing policy initiatives promoting bioenergy.

This introduction to the Danish experiences with waste incineration for energy production use is compiled as preparation for SENER's potential visit to Denmark in 2014.

This report was prepared 19 June, 2014 by COWI DTU System Analysis to Danish Energy Agency (DEA) as part of a frame contract agreement.

# 1 INTRODUCTION TO THE DANISH WASTE MANAGEMENT SYSTEM

This report aims to give a brief overview of the Danish waste management system and the waste treatment systems. The report has a special focus on waste-to-energy facilities and the organisation of these in Denmark.

The population of Denmark is app. 5.4 million and there are 98 municipalities and approximately 45 inter-municipal companies that manage waste to recycling, incineration and landfilling as well as hazardous waste.

Domestic waste is collected at the households on a weekly or biweekly basis. An increasing number of municipalities have source separation of organic waste for either composting or biogasification. Recyclables are either collected at the households, in bring banks or at amenity sites or by a combination of these three collection systems. Bulky waste and garden waste is also collected at the household or/and at the amenity sites, but collection schemes are very different from municipality to municipality as the municipalities have the overall responsibility of providing treatment and disposal capacity for all waste.

## 2 WASTE MANAGEMENT STATUS IN DENMARK

### 2.1 WASTE STATISTICS

In Denmark approximately 9.1 million tonnes of waste is produced annually. Most of the waste generated is produced in the building & construction sector and by households. Waste from household is app. 26 % of the total waste generation and equals a production of waste of app. 500 kg/pers/year.

Over the past 20 years, the majority of waste produced in Denmark has been recycled. The recycling has increased from 55 % in 1994 to 61 % in 2011. Especially waste from the construction and demolition (C&D) sector and from the industry sector have high recycling rates. The incineration rate went from 21 % in 1994 to 29 % in 2011, whereas the percentage of waste landfilled dropped considerably from 22 % to 6 % during the same period considering all the generated waste in Denmark. The low percentage of waste being landfilled is due to a mixture of bans against organic waste in landfills and taxes on landfilling (Danish Government, 2013).

TABLE 1 WASTE PRODUCTION IN DENMARK, 2011 (SOURCE: DANISH EPA, 2013)

SOURCE	TOTAL	RECYCLING		INCINERATION		LANDFILLING	
	Tonnes	Tonnes	%	Tonnes	%	Tonnes	%
Households	2,399,000	856,388	36	1,342,724	56	100,442	4
Building and construction sector	2,663,448	2,317,832	87	88,230	3	208,152	8
Industry	1,076,041	764,640	71	165,652	15	55,995	5
Service sector, including public institutions	1,857,514	1,093,414	59	626,791	34	58,227	3
Utilities and other commercial waste	1,105,757	560,358	51	381,538	35	126,635	11
<b>TOTAL</b>	<b>9,101,760</b>	<b>5,592,632</b>	<b>61</b>	<b>2,604,935</b>	<b>29</b>	<b>549,450</b>	<b>6</b>

Figure 1 shows the generation of municipal solid waste (MSW) which includes household waste and some parts of waste from the commercial sector for a range of European countries. Denmark produces app. 650 kg/person and is thereby in the high range of waste production compared to other European countries. However, there are differences in how MSW is defined and how efficient waste collection and data reporting is in the different countries.

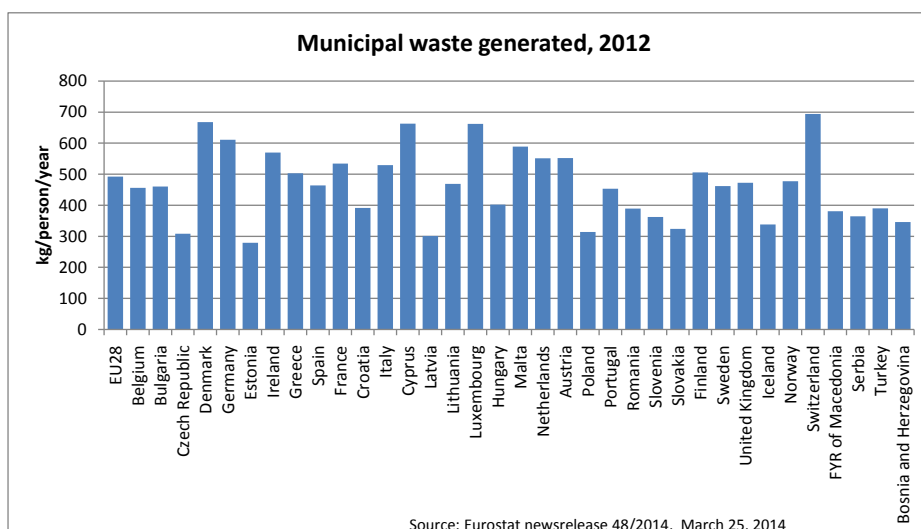


FIGURE 1 MUNICIPAL WASTE GENERATION IN EUROPE (SOURCE: EUROSTAT, 2014)

Figure 2 shows the distribution of treatment methods for MSW in the selected European countries. In Denmark app. 3 % of all MSW is sent to landfills, app. 52% is incinerated and app. 32 % is recycled. Denmark has a very high recovery rate of MSW,

and a one of the highest rates of WtE of MSW in Europe. However, this hasn't affected the recycling rate significant as the recycling rate in Denmark also is one of the highest in Europe.

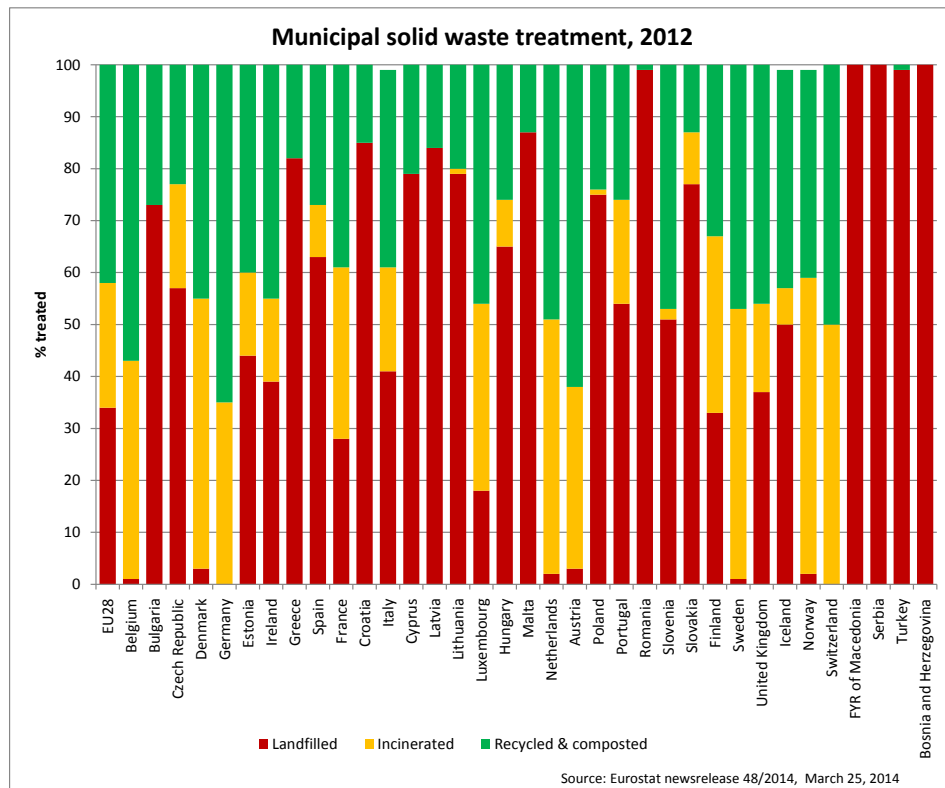


FIGURE 2 DISTRIBUTION OF TREATMENT OF MUNICIPAL WASTE IN EUROPE (SOURCE: EUROSTAT, 2014)

## 2.2 ORGANISATION OF THE WASTE-TO-ENERGY SECTOR

Around 1965 the first inter-municipal waste management companies were established for the purpose of managing the incineration of the waste that was collected in the owner municipalities.

The oil crises in the 1970s and the consequent extension of the district heating systems contributed to the development of establishment of WtE facilities. A number of originally municipal facilities now became the backbone of newly established inter-municipal partnerships.

The majority of the WtE facilities are owned and operated by municipalities or inter-municipal companies. The municipal cooperation secures the establishment of the necessary treatment capacity. Moreover, it ensures that the waste is managed according to the principles of proximity and self-sufficiency. The waste-to-energy facilities are operated by non-profit companies, based on a cost coverage principle (Renosam, 2006).





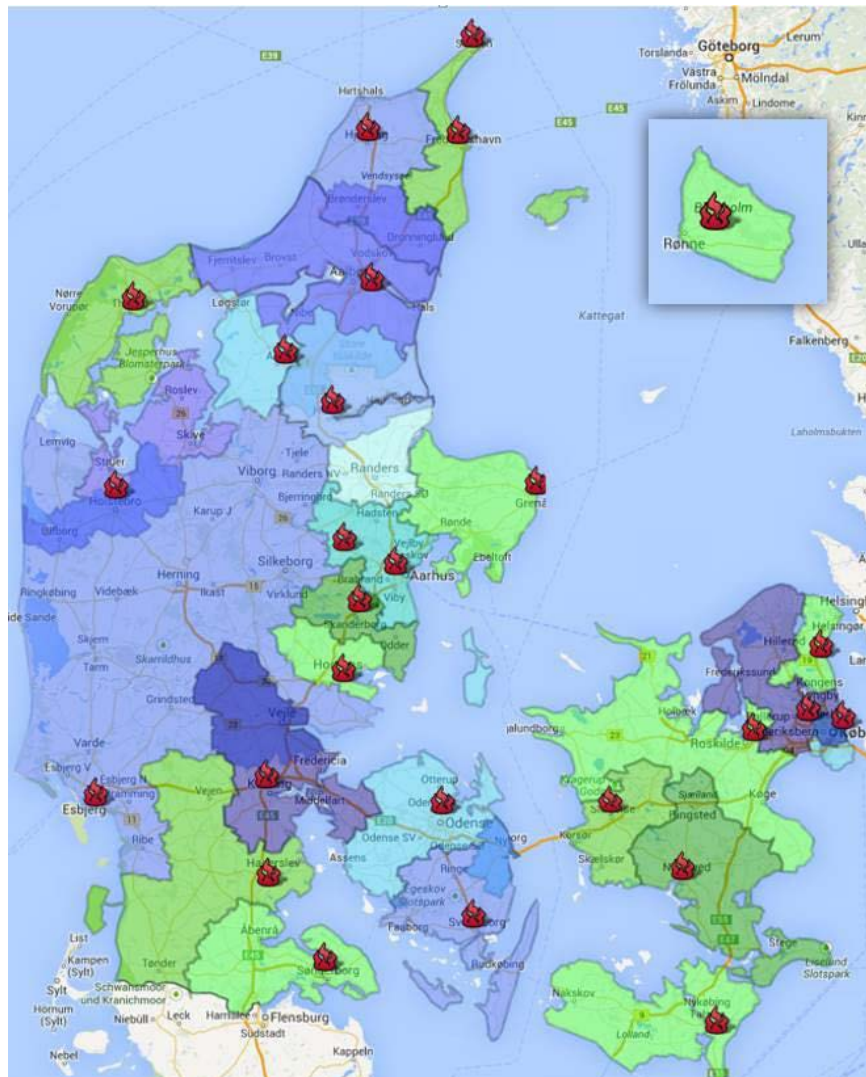
**FIGURE 3** NORDFORBRÆNDING NORTH OF COPENHAGEN, SITUATED IN RESIDENTIAL AREA

At the end of 2005 there were 27 dedicated waste-to-energy facilities in Denmark. Twenty-one of these facilities are publicly owned by one or more municipalities, while six plants are owned and operated by energy companies. These facilities have made binding agreements with the municipalities for treatment of the waste suitable for incineration generated in these municipalities. In this way, the energy companies' waste-to-energy facilities act as contractors for the municipalities involved (Renosam, 2006).

The WtE facilities are situated in various places in Denmark and are usually close to larger cities and in size matched to the base district heating demand in those cities, see Figure 4.

There are also three thermal treatment facilities whereof two treats hazardous waste and the third facility is a cement plant that treats mixed types of solid waste as a feed stock for energy.

Finally, there are three facilities that incinerate digested sewage sludge. These facilities are all located at waste water treatment plants and all are in the larger capital area of Copenhagen. These sewage sludge incineration facilities also produce heat for district heating but no electricity is produced.



**FIGURE 4 WASTE-TO-ENERGY PLANTS AND AREA OF COLLECTION (SOURCE: DANSK AFFALDSFORENING, 2014)**

The capacities of the waste incineration facilities range from app. 10,000 ton to 600,000 tonnes per year. However, most of the facilities have a capacity of 150,000 to 300,000 tonnes per year.

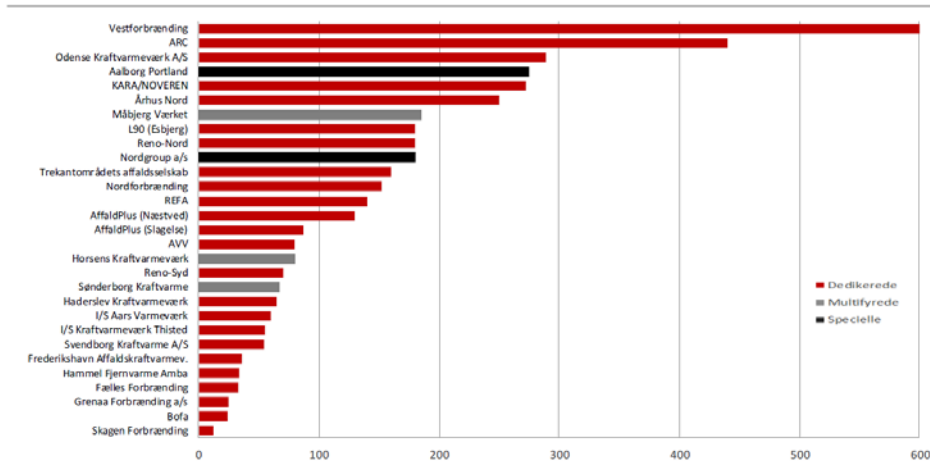


FIGURE 5 CAPACITIES OF DANISH WtE FACILITIES INCLUDING SPECIAL FACILITIES IN 1000 TON/YEAR (SOURCE: BEATE, 2013)

The energy efficiency of Danish WtE facilities are among the highest compared to other European countries (see Figure 6). Most of the WtE facilities are combined heat and power (CHP) facilities that also make use of flue gas condensation to recover as much energy as possible. In average the facilities recover app. 2.3 MWh per ton of waste incinerated. The energy efficiencies depend largely on the age of the WtE facilities and on the energy systems and prices in the countries where the WtE facilities are located. In many countries no district heating network exists nor maybe needed why focus is on producing electricity.

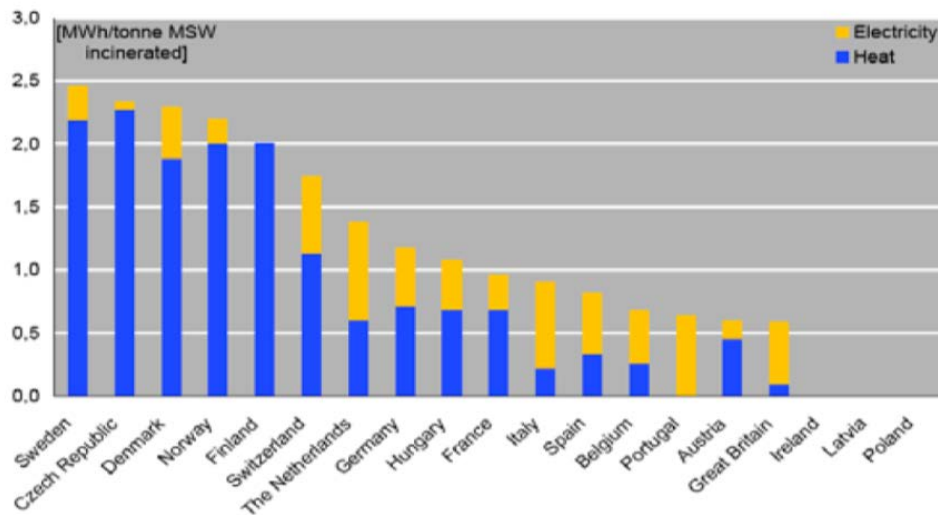


FIGURE 6 UTILISATION OF ENERGY IN WASTE INCINERATION PLANTS IN SELECTED EUROPEAN COUNTRIES 2005

Figure 7 shows the map of EU and the number of WtE facilities and the amount of waste that is incinerated in selected EU countries. From this map it is evident that Denmark compared to for example Spain and Poland has a high capacity compared to the size of the population. Other countries like Sweden, the Netherlands and Germany also have relative many facilities and large amounts of waste sent to WtE.

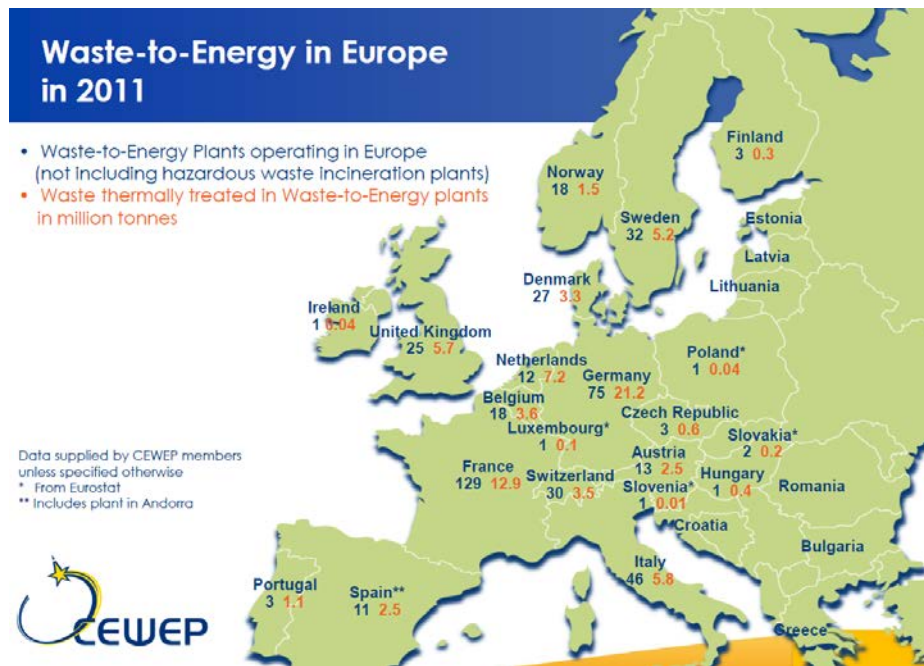


FIGURE 7 WASTE-TO-ENERGY FACILITIES AND WASTE AMOUNT INCINERATED IN EU COUNTRIES (REF: CEWEP, 2011)

### 3 HISTORICAL DEVELOPMENT OF WTE IN DENMARK

#### 3.1 DISTRICT HEATING AND WASTE INCINERATION

Incineration of municipal solid waste in Denmark started in 1903 in a densely populated municipality with little access to space for landfill. The energy was used for a district heating system established at the same time and for generation for the local grid. The plant also contained two coal-fired steam boilers. It was built opposite to the new municipal hospital with supply of central heat for the hospital and electricity for the local grid. A new technology – 'rotary kiln' instead of 'batch firing' was introduced in 1931 and followed by a few other plants including a replacement of the first plant from 1903. The waste was collected by horse-driven wagons. Following a contemporary description of the process:

*"... the body of the wagon is tipped ... so that the waste is emptied into the waste pit ... Absolutely nobody gets into physical contact with the waste. The waste is temporarily stored in ...the bay, and subsequently transported by two scraper conveyors to a vibrating feeder, which is continuously moving back and forth, taking the waste to a chute that leads to the drying grate of the furnace'. Then followed an ignition grate and a rotary kiln, ... The bottom ash was taken to a sorting plant with a magnetic separator 'so that the bottom ash is sorted into three fractions as well as an iron fraction.*

*The incineration products have an average temperature of approximately 1000°C in the flue gas chamber after the rotary kiln. The heat contained in the incineration products is recovered in a Babcock & Wilcox high-pressure boiler. The rotary kiln system generates very little fly ash – only approximately 2 per cent of the amount of waste incinerated ... In order to be able to perform a complete cleaning of the flue gas both*

*the boiler and the economiser are equipped with 'soot pockets'... and after the economiser a special flue gas cleaner capturing approximately 80 per cent of the fly ash has been established so that the flue gas, when emitted from the stack of the incineration plant, is light and free of solid matter'.*

In each of the three plants there were two units with achieved capacities up to 10 tonnes per hour. The steam pressure was different – from 16 to 30 bar – with steam temperatures between 190° and 425° C. The steam production was 0.9-1.0 kg steam per 1 kg waste.

During the German occupation 1940-1945 and after there was shortage of all kinds of imported raw materials, and waste salvaging was so well organised that there was practically no incinerable waste left for the few waste incineration plants. Until waste incineration in Denmark re-emerged in the 1960s the expertise of the Danish company Vølund (now Babcock & Wilcox Vølund) was upheld, thanks to contracts in France, Sweden and the USA.

District heating grew significantly during the 1960s – mainly driven by excess heavy fuel oil from the new-established Danish refineries. This gave a market for the heat from waste incineration plants, which was established in many medium-sized towns. The mismatch between the seasonal variation in the heat demand and the all year-round supply from waste incineration plants was gradually solved by expanding district heating grids and interconnection of smaller separate grids.

The oil shocks in 1973 and 1979 led to further development of district heating with supply from both waste incineration and combined heat and power within the framework of national heat planning together with further development of waste treatment technologies. Today district heating covers about half of the market for space heating and nearly all incinerable waste is incinerated.

### 3.2 WASTE TREATMENT IN DENMARK

The priority of waste treatment technologies today are 1) recycling, 2) waste incineration, and 3) landfill. This means that recycling must be promoted, landfill must be avoided, and waste incineration must be used for energy purposes, either district heating, district cooling or electricity generation. As the first country in the world, Denmark introduced a ban on the landfilling of incinerable waste from 1997. The EU landfill directive from 1999 contains the requirement that waste disposed of at landfills has to undergo prior treatment (at for instance incineration plants).

There are some 30 waste incineration plants in Denmark. These are mainly operated by companies owned by the municipalities, which have been formed since the 1970s. However, recycling is becoming the main focus of these companies. The capacities of these plants range from 2.5 t/h for the plant serving an island with 50,000 inhabitants, to more than 50 t/h for two plants in the Copenhagen region. Steam pressure of the most recent plants is 50 bar, and steam temperature is some 400° C. Steam production is 4.0 kg/kg waste, i.e. about four times higher than for the plants built in the 1930s.

The technology of waste incineration is continuously being improved with emphasis on environmental impacts. Most of the regulation is based on EU directives.

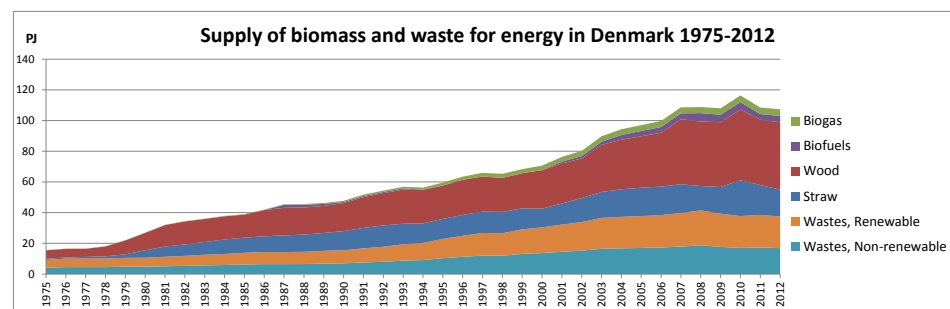
### 3.3 ELECTRICITY GENERATION AND DISTRICT COOLING

The cold climate in Denmark creates a demand for space heating most of the year, while the demand for comfort cooling is limited compared to countries with warmer climates. However, many large buildings (e.g. data centres, server rooms) and public buildings (e.g. hospitals, libraries etc.) have cooling today, and the demand is expected to increase. The existing infrastructure and the availability of cheap surplus heat from waste incineration in some areas during the summer has made thermally driven cooling or absorption cooling an interesting option, which has been tested with limited success since the late 1980s. The technology options for centralised cooling are very dependent on site and season. In the City of Copenhagen heat is produced centrally in three different ways: 1) Sea water during the winter; 2) Absorption cooling with surplus heat from the district heating system during the summer; 3) supplemented by electric compressors.

District cooling is an attractive option for using the heat from waste incineration in countries with little demand for heat, but the experience is very limited worldwide. A recent example is the new airport in Bangkok (Udomsri et al. 2011). The thermally driven cooling provides significant potential to replace electrically driven cooling: and, in addition, increase the increasing electricity yield, which is most attractive in countries with peak electricity demand during the hot season.

### 3.4 BIOMASS AND WASTE STATISTICS 1975 - 2012

Figure 1 below shows the development of energy supply from biomass and waste for energy from 1975 to 2012. According to international statistical requirement, waste is divided into renewable and non-renewable; the latter is considered as CO<sub>2</sub> neutral. Straw and wood may be used for co-firing in waste incineration plants and large combined heat and power plants, while biogas may be used in small plants or upgraded to natural gas quality for use in the gas grid. Further details on the availability and use of biomass and waste in Denmark using a modelling framework are found in Münster and Lund (2009).



**FIGURE 8 BIOMASS AND WASTE FOR ENERGY, 1975 - 2012. SOURCE: ENERGY STATISTICS 2012, DANISH ENERGY AGENCY.**

## 4 WASTE TO ENERGY TECHNOLOGIES

### 4.1 INTRODUCTION TO WTE

Waste is incinerated in special facilities designed and built specifically for the purpose of treating and reducing volume of waste from households and enterprises while producing energy. A waste-to-energy facility consists of the following main components: a reception and waste feeding system, one or more incineration units complete with bottom ash handling system, boiler, flue gas treatment system and stack.

As with all other energy generation facilities, waste-to-energy facilities are designed in accordance with the specific properties of the fuel and optimised to generate the highest possible revenue from energy sales depending on the local energy demand and energy prices. Waste is a far more complex fuel than conventional fuels.

If the facility is a CHP plant, it is equipped with a steam boiler. The steam produced is led to a steam turbine, which drives a power generator. The residual heat of the steam is recovered for the production of district heating.

The facility is dimensioned in accordance with the waste arisings as well as with the potential for selling heat for district heating. With a view to optimising heat sales, waste that does not necessarily have to be incinerated straight away (i.e. certain types of commercial waste) is sometimes put into intermediate storage from summer to winter where the heat demand is the highest. Household waste is of hygienic and odour reasons always incinerated immediately.

The flue gas generated is cleaned of dust, heavy metals, acid gases (HCl, HF and SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and dioxins and furans. This is achieved in up to five subsequent treatment steps. The emission limit values are stipulated in the environmental permit of the facilities, which in turn is based on the Waste Incineration Order issued by the Ministry of the Environment and the underlying EU Waste Incineration Directive (No. 2000/76).

When incinerating 1 tonne of waste approx. 2 MWh district heating and approx 0.67 MWh electricity are produced. Where no electricity is produced, all the energy is recovered in the form of district heating (Renosam, 2006). At an increasing number of WtE plants flue gas is condensed and heat extracted from this achieving an energy efficiency of app. 100 % of the lower heating value.

The bottom ash from Danish WtE is sorted so metals (both ferrous and non-ferrous) are recovered and sent for recycling. The remaining bottom ash is matured and used as filling materials and hereby substituting mineral resources. Approximately 90 % of bottom ash is reused in the construction sector.

The advantages of waste-to-energy are:

- 1 Efficient and well-proven technology for residual waste that cannot be recycled or used for high-quality compost

- 2 Can be located close to point of waste generation.
- 3 Generate skilled jobs in the local community.
- 4 95% reduced need for landfill volume
- 5 Bottom ash can be recycled for road construction (300/1000 kg). Flue gas treatment residue is hazardous (50 /1000 kg) which must go to special hazardous waste landfill
- 6 Plant configuration can be adapted to local conditions, e.g. waste composition, coastal/inland and island conditions.
- 7 Produces heat and/or power. Heat can also be used for district cooling & desalination of seawater
- 8 Most efficient means to meet EU Landfill Directive diversion targets complementing recycling and Mechanical-Biological Treatment

## 4.2 WtE CASES IN DENMARK

### 4.2.1 ARC

Amager Resource Centre (ARC) is a large inter-municipal company in Copenhagen. ARC is currently establishing a new WtE facility of app. 400.000 ton per year and will deliver power to 550.000 citizens and heat to 140.000 households. The overall net energy efficiency will be at app. 107 % of the lower heating value and will thereby be one of the most energy efficient WtE plants in the world. This facility will replace the existing facility which is more than 40 years old ([www.a-r-c.dk](http://www.a-r-c.dk)).

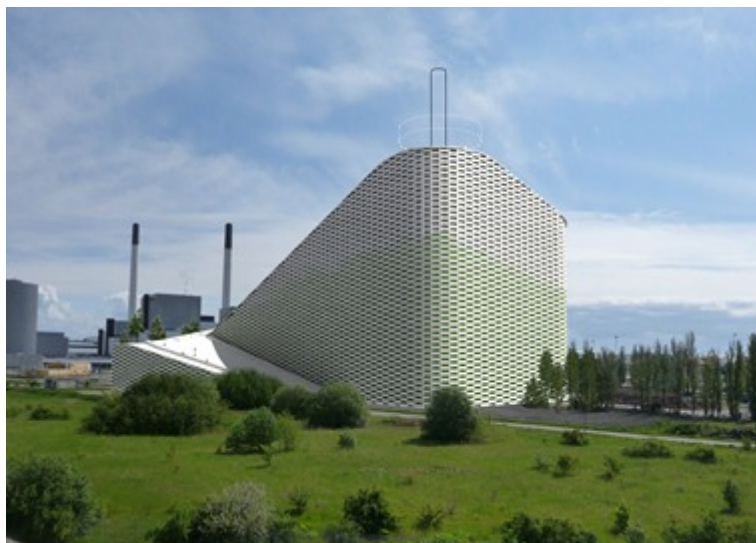


FIGURE 9 ANIMATION OF THE NEW ARC WtE FACILITY - ALSO CALLED AMAGER BAKKE (AMAGER HILL),  
SOURCE: [WWW.DISTRICTENERGY.ORG](http://WWW.DISTRICTENERGY.ORG)



The new facility will have the following technologies (source: [www.a-r-c.dk](http://www.a-r-c.dk))

- › Grate boiler combustion, to ensure high and stable operation availability
- › Front-end SCR technology - to clean NOx by over 95% efficiency
- › Wet flue gas cleaning - to minimize their environmental impacts
- › flue gas condensation and heat pumps to ensure high thermal efficiency
- › High vapour parameters - to ensure high electrical efficiency
- › A common steam turbine with no gearbox between the turbine and generator and preparation for low pressure turbine to ensure maximum power generation
- › Flexible heating coupling to ensure the maximum heat sales to utilities

#### 4.2.2 KARA/NOVEREN

The newest WtE facility in operation is the facility owned and operated by the inter-municipal waste company Kara/Noveren which is owned by 9 municipalities in the middle and north-western part of Sealand.

The new facility begun operation in October 2013. The facility will now annually process about 350,000 tons of waste from residential, commercial and industrial sectors. Simultaneously, the system could supply, respectively, 60,000 and 40,000 households with electricity and district heat.

- › Grate boiler combustion
- › SCR technology
- › Wet flue gas cleaning
- › Flue gas condensation and heat pumps to ensure high thermal efficiency



FIGURE 10 ANIMATION OF THE NEW KARANOVEREN WTE ([WWW.KARANOVEREN.DK](http://WWW.KARANOVEREN.DK))

## 5 POLICY AND REGULATION

### 5.1 INTRODUCTION TO THE POLICIES IN DENMARK

Danish waste policy comprises both prevention and management of waste. The overall authority in waste is the Danish Environmental Protection Agency under the Danish Ministry of Environment. Local and regional councils are in charge of the practical administration of waste management.

Waste management is planned in detail for a six year period. All local councils are under the obligation to survey waste amounts and to draw up waste management plans. Also, it is the responsibility of local and regional councils that sufficient incineration and landfill capacity is available. They are responsible for ensuring collection of household waste and that there is adequate capacity to treat Danish household waste as well as waste suitable for incineration and landfill which arises in the municipality. Recyclable commercial waste separated at source is subject to market conditions. The majority of the existing landfill facilities are owned by the public sector. Most incineration plants are owned by municipal companies. With regard to recycling, in many cases capacity is ensured by the municipality establishing agreements with private recycling companies. Most types of waste that are recycled are processed abroad, but there are many Danish enterprises – private and public – which separate and pre-treat the waste before it is exported. Irrespective of whether it comes from households or businesses, waste is primarily collected and transported by private companies (Danish EPA, 1999 and Danish Government, 2013).

#### **Responsibility of the Danish government**

- Work out national waste management plans (see <http://eng.mst.dk/topics/waste>)
- Prepare the legal framework for waste management (see <http://eng.mst.dk/topics/waste>)
- Prepare detailed legislation on specific wastes
- Participate in international meetings(EU, OECD and UN)

#### **Responsibility of the local councils**

- Local councils are competent authorities on waste management issues and responsible for waste generated in its municipality
- Prepare local regulation on collection, sorting and treatment of waste generated in its municipality
- Ensure capacity for recycling, incineration and disposal of waste generated in its municipality
- In charge of supervision of compliance with the regulation
- Collection of waste management levies and fees, thus providing a 100% recovery of cost for waste management services from the waste generators

## 5.2 WASTE HIERARCHY

The EU Waste Directive (Dir. 2008/98/EC of 19 November 2008) states that the waste policy of the member states should aim at reducing the use of resources and the environmental impacts and favour the practical application of the waste hierarchy as seen in Figure 11.

### The Waste Hierarchy

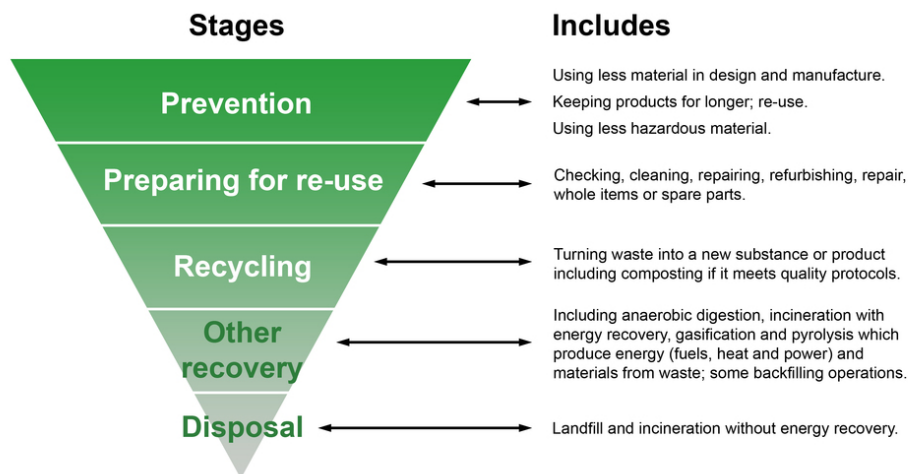


FIGURE 11 THE WASTE HIERARCHY (SOURCE: [ANDREWTMARLOW.WORDPRESS.COM](http://ANDREWTMARLOW.WORDPRESS.COM))

The most important objective of our waste management policy is to reduce waste amounts and prevention of waste has top priority. Through environmental management and development of cleaner technology it is possible to reduce the generation of waste, for example by taking waste treatment into consideration already at the design of products and by using less environmentally harmful products.

This is in line with the integrated product policy of the Danish Ministry of Environment and Energy, aiming at limiting resource consumption and environmental impact for all products "from cradle-to-grave".

Another aim is to recycle as much waste as possible. Today, some 60 % of all waste is recycled. In Denmark, the waste hierarchy is the basis for our prioritisation of waste management options. According to this hierarchy, recycling ranks higher than incineration with energy recovery and landfilling ranks lowest.

Recycling is the highest ranking waste treatment form – it ensures better exploitation of resources in waste. In Denmark incineration does not count as recycling. (source: Danish Environmental protection Agency, 1999).

## 5.3 EU WASTE DIRECTIVE

The EU's legislation on waste management is based on the Waste Directive (Dir. 2008/98/EC of 19 November 2008), which among others provides a definition of waste and the overall frameworks of which waste is to be managed.

Recognizing that not all waste can be prevented or recovered, the EU has also adopted directives on incineration and landfilling of waste.

#### 5.4 WASTE INCINERATION DIRECTIVE

The Waste Incineration Directive (No. 2000/76/EC) stipulates that waste incineration facilities shall have an environmental permit and in Articles 6, 7 and 8 and in Annexes IV and V lays down rules pertaining to operating conditions and emissions to air and water. The Directive entered into force on 28 December 2002 for new facilities, and the new and stricter requirements had to be fully complied with by existing incineration facilities not later than 28 December 2005.

#### 5.5 LANDFILL DIRECTIVE

The Landfill Directive (No. 1999/31/EC) generally states (Article 6a) that 'only waste that has been subject to treatment [may be] landfilled. This provision may not apply to inert waste for which treatment is not technically feasible, nor to any other waste for which such treatment does not contribute to the objectives of this Directive, by reducing the quantity of the waste or the hazards to human health or the environment.'

The Directive (Article 5) furthermore requires that the member states shall set up a strategy for the implementation of the reduction of biodegradable waste going to landfill. Such waste shall rather be subject to recycling, composting, biogas production or materials/energy recovery. The strategy shall ensure that the amount of biodegradable municipal waste going to landfill is reduced as follows: by 2006 to 75 per cent, by 2009 to 50 per cent and by 2016 to 35 per cent of the amount produced in 1995. Member states which in 1995 landfilled more than 80 per cent of their municipal waste may postpone the attainment of the targets by four years. Finally, the Directive makes a number of specific requirements for the design of and the acceptance of waste at landfills (Renosam, 2006).

### 6 ECONOMICS OF WASTE-TO-ENERGY

The Danish waste-to-energy facilities are subject to a cost coverage principle, which means that they can show neither a profit nor a loss. Receipts and expenses must balance within a small time span.

Waste-to-energy facilities are economically controlled by three main factors:

- Fiscal instruments (State taxes)
- Energy earnings from sale of electricity and heat
- Gate fees

## 6.1 FISCAL INSTRUMENTS

The Danish waste model is based on a combination of traditional administrative instruments (acts, orders, circulars), and various economic instruments covering taxes and charges as well as subsidy schemes and agreements.

In Denmark, we have a general state tax on waste. The waste tax is differentiated so that it is most expensive to landfill waste, cheaper to incinerate it and tax exempt to recycle it. Also, we have so-called "green" taxes on for example packaging, plastic bags, disposable tableware and nickel-cadmium batteries.

In addition, deposit and return systems have been established for a number of packaging types. For example, packages for beer and carbonated soft drinks must be covered by a deposit and return system.

The deposit and return system for beer and soft drinks means that we prevent management of some 390,000 tons of waste every year, corresponding to around 20 per cent of the total amount of domestic waste from households (Danish EPA, 1999).

Fiscal instruments		
Waste	treatment	taxes
Aim: to divert waste to recycling		
›	Landfill tax: 475 DKK/ton [64 Euro/ton]	
›	Incineration tax: app. 330 DKK/ton [44 Euro/ton] depending on power and heat production and content of fossil carbon	
›	No tax on recycling or treatment of hazardous waste	
<b>Packaging tax:</b>		
Aim: to minimise waste		
›	Taxes on beverage containers (volume based) and other packaging (weight based), based on type of material	
<b>Deposit system for beverage containers:</b>		
Aim: to ensure reuse of bottles and cans for beverages		
›	All glass and plastic bottles and cans for beer and soft drinks are part of a return system with a deposit paid and refunded in the shop.	

This tax structure has been introduced for the purpose of promoting recycling above waste incineration and landfilling. Denmark's neighbouring countries Sweden and Germany today have no such tax on incineration (Renosam, 2006).

## 6.2 ENERGY EARNINGS

If the waste-to-energy facility is a cogeneration plant, the facility will have earnings from sale of both electricity and heat. Electricity is sold on commercial terms with a subsidy of DKK 0.07 (1 Eurocent)/kWh in order to promote environmentally friendly electricity production from waste incineration. In addition, the facilities which established CHP production capacity before the so-called differentiated tariff system lapsed enjoy transitional terms. For a certain number of years the transitional scheme ensures that the facilities obtain an electricity price corresponding to the level at the time when the facilities were required by the Danish Energy Agency to convert to CHP production.

In order to protect the heat consumers, the heat price cannot exceed the lowest of the costbased price and the substitution price. For this reason the price of heat produced from waste in Denmark is generally lower than the price of other heating sources (renosam, 2006).

## 6.3 GATE FEES

The part of the expenses that cannot be covered by earnings from sale of electricity and heat must be covered by a gate fee, as the waste-to-energy facilities must be non-profit, i.e. the lower the energy earnings, the higher the gate fee. Typically, the gate fee, i.e. the actual cost for the household/industry of having its waste incinerated, is in the order of DKK 100 to 200 (€ 13 - 27) per tonne excluding taxes. The average gate fee including all taxes in 2012 was at 455 DKK/tonne (€61/tonne) (BEATE, 2013).

The Danish gate fees are the lowest in Europe where gate fees of more than DKK 1,000 (€ 150) per tonne may be found.

In an international context the low gate fee in Denmark is attributable partly to the extensive energy recovery from waste and partly to the generally well-operated and efficient facilities in Denmark (Renosam, 2006).

## 7 CHALLENGES AND OPPORTUNITIES

Denmark is not yet meeting the 2020 EU recycling target of 50% of certain materials in the household waste stream. This will probably need to involve separate treatment of biowaste and increased source segregation of other recyclable materials as well.

In order to meet the EU requirements and to reduce the resource and environmental burdens from solid waste management, the Government of Denmark in 2013 published their vision on future management of waste and resources in Denmark. The vision includes an increase in recycling of household waste, while incineration should decrease. This will entail more materials being sent back into the economic cycle with benefits for the environment.

In “Denmark without Waste” (Danish Government, 2013) the Government is proposing the following overall focus areas:

- 1 Increase recycling of household waste
- 2 Increase collection and recycling of electric and electronic waste
- 3 change from incineration to biogasification and recycling
- 4 Better exploitation of nutrients such as phosphorous in organic waste
- 5 Improved quality in recycling of construction and demolition waste

**TABLE 2 IMPORTANT EFFECTS OF IMPLEMENTING THE INITIATIVES IN THE NATIONAL RESOURCE STRATEGY (SOURCE: DANISH GOVERNMENT, 2013)**

SOURCE	EXPECTED EFFECTS	2018		2022 GOAL		THE CURRENT SITUATION (2011 FIGURES)		
		Min %	Min %	Recycled %	Incinerated %	Landfilled %		
Households*	Recycling of organic waste, paper, cardboard, glass, wood, plastic and metal waste*		50	22	75	0		
	Collection of waste electronic equipment	75		68**				
The service sector	Recycling of paper, cardboard, glass, metal and plastic packaging	70		53	47	0		
	Recycling of organic waste	60		17	83			
Alle	Energy recovery from garden waste*	25		87	4	4		
	Collection of waste electronic equipment	65						
	Collection of batteries	55		47				
	Recovery of shredder waste	70		0				
	Recycling of phosphorus in sewage sludge	80		–				

Current emphasis of Danish municipalities is on expanding the separate waste collection services through a combination of:

- Increased public service level via close-by neighbourhood glass and paper containers (bring system)
- Increased kerb-side collection of recyclables and separate collection of more types of materials such as plastic and metals
- Introduction of multi-compartment receptacles (i.e. 4 compartment and 2 compartment containers) for single family houses
- Investigating the economics and logistics of co-mingled collection of a number of dry recyclables for subsequent final sorting at automatic central sorting facilities
- Investigating the economics and logistics of collection of dry residual waste for subsequent sorting at automatic central sorting facilities

## 8 PROJECTIONS OF WASTE GENERATION AND TREATMENT IN DENMARK

### 8.1 METHODOLOGY

The generation of waste is linked to the economic and demographic development, and different economic activities generate different streams of waste. In Denmark we have statistics for the generation of fractions of waste from households and different sectors of the economy and for the handling/treatment of different fractions. Applying these data and national account data a forecast model Frida is developed (Andersen and Larsen, 2012).

For the generation of waste the model is based on econometric analysis linking the generation of waste to private consumption, the number of households and the production in different sectors. Concerning the handling/treatment of waste, historical treatment shares for each waste-fraction is calculated, and in a baseline projection these coefficients are assumed constant. In alternative projections treatment shares may be changed exogenously.

### 8.2 WASTE GENERATION AND WASTE TREATMENT 1994 - 2030

The past development and a baseline projection for the generation and treatment of waste from primary sources are shown in the Figure 12 and Figure 13.

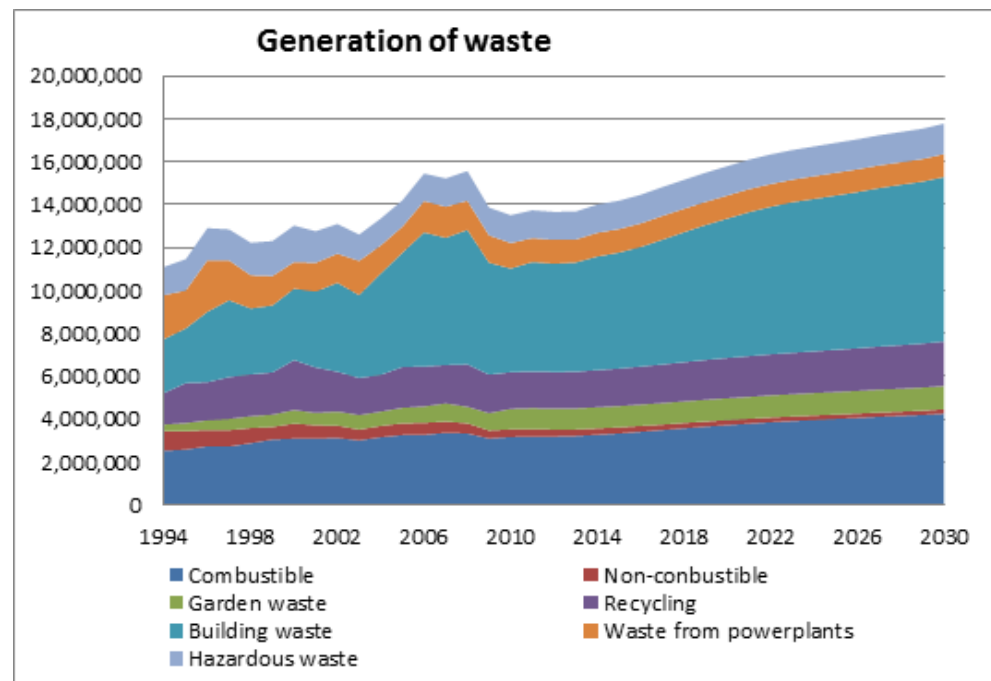


FIGURE 12 THE GENERATION OF WASTE IN DENMARK 1994-2030. PROJECTION FROM 2010.



Looking at the past development since 1994, from Figure 12 it is noticed that:

- 1 Waste from building is very large and closely correlated to the building activity that was high in the mid-2000s and decreased considerably due to the economic crises in the late 2000s;
- 2 Various combustibles, mainly daily renovation from households is fairly large and fairly constant;
- 3 Garden waste has increased significantly due to improved collection schemes.

Concerning the forecast of future waste generation to 2030 in Figure 12, the baseline projection builds on an official projection of the economic development by the Ministry of Finance (ADAM-forecast KP2012). After the economic crisis the economy is expected to recover with an annual increase in GDP of around 2% p.a. from 2014 till 2020 and to increase about 1% p.a. from 2020 to 2030. Especially the production within building and construction is expected to recover with an increase in production of 3-3.5% p.a. till 2020. As seen from Figure 1, especially waste from building and construction is expected to increase. Also the consumption by households is expected to increase with about 2% p.a. increasing the amount of combustible waste. Finally, in the baseline projection collection schemes for garden waste is assumed unchanged implying a very moderate increase in the amount of garden waste.

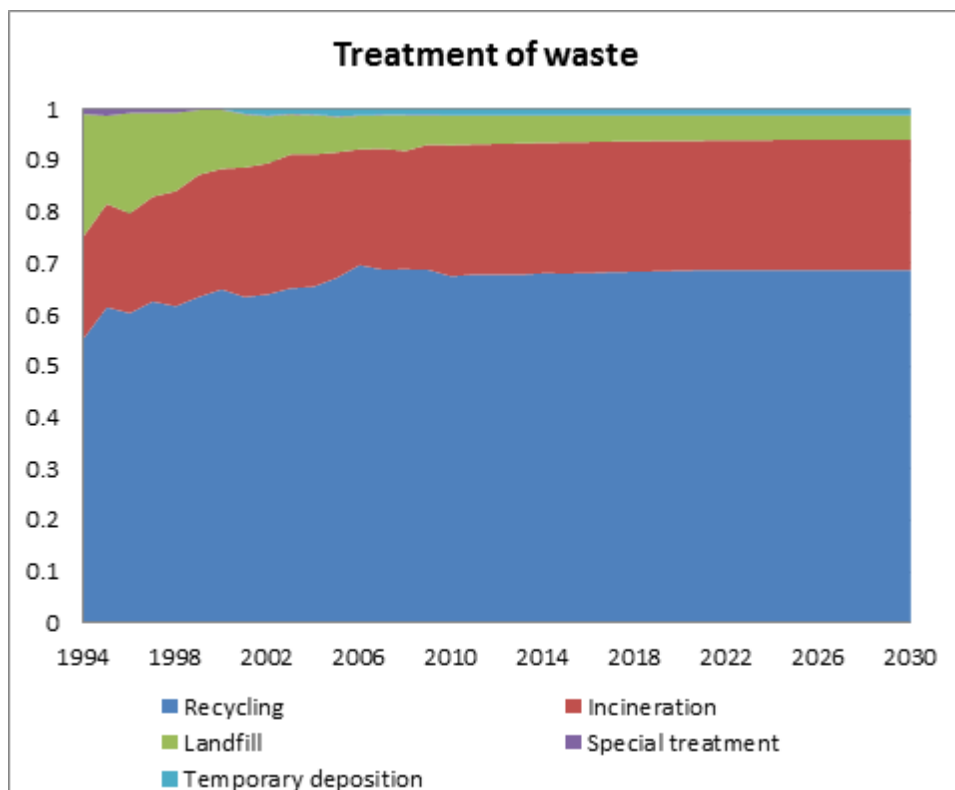


FIGURE 13 WASTE TREATMENT IN DENMARK 1994 – 2030. PROJECTION FROM 2010.

Looking at the past development since 1994 in treatment shares, from Figure 13 it is noticed that:

- 1 The share recycled has increased to approximately 70% in 2010. This is mainly building waste, waste from power plants and waste collected for recycling (1/4 of the amount recycled);
- 2 the share incinerated has increased to about 25% in 2010 (this is mainly daily renovation from households);
- 3 Waste that is landfilled has decreased considerably to about 5% in 2010.

Concerning forecast of future waste treatment to 2030 the baseline projection assumes constant treatment coefficients per waste fraction. However, the change in the weight of different fractions of waste implies that the past development where landfilled waste decrease and recycling increase is continued, but the change is marginal. The share incinerated is projected to be almost constant at 25%.

### 8.3 THE DANISH RESOURCE STRATEGY

The Danish Resource Strategy (DRS) published in 2013 focuses on the treatment of waste assuming that amounts of waste are not affected by the initiatives. The strategy includes initiatives to increase:

- Recycling of bulky waste;
- Recycling of daily renovation from households;
- Recycling of dry fractions and organic waste from the service sector;
- Incineration of garden waste.

Aggregated the DRS implies that in 2030 approximately 1 mio. tons of waste is diverted from incineration to recycling, increasing the recycling rate from 70% to 75% and decreasing the share incinerated from 25% to 18% (landfilling is increased marginally).

Increased recycling of waste from households and the service sector is a challenge and requires additional separation of waste into recoverable materials. Ongoing issues are:

- Source separation versus centrally sorting of materials. Especially, the economy in alternative technologies and the quality of recovered materials from daily renovation is discussed.
- Idle incineration capacity when amounts of waste for incineration decrease. Import of waste for incineration is discussed.
- To comply with recycling targets, recycling of bio-waste from households is required and this poses a specific challenge as very few municipalities have facilities for recycling of household bio-waste.

## 9 LITERATURE

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Danish domestic waste is collected at the households on a weekly or biweekly basis. An increasing number of municipalities have source separation of organic waste for either composting or biogasification. Recyclables are either collected at the households, in bring banks or at amenity sites or by a combination of these three collection systems. Bulky waste and garden waste is also collected at the household or/and at the amenity sites, but collection schemes are very different from municipality to municipality as the municipalities have the overall responsibility of providing treatment and disposal capacity for all waste.

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