Waste incineration in Denmark

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Waste incineration has a more than 100 years old history in Denmark, as the first plant was commissioned in 1903. Before the Second World War, two more plants were built, but it was not until the 1960's that incineration became widespread. The waste was then considered a cheap fuel for production of district heating. Since 1990 the Danish energy policy has favoured combined heat and power generation. This does also apply to waste incineration.

Having a net calorific value of around 3 MWh/t, waste is indeed a useful fuel. However, because of its content of PVC it produces a corrosive flue gas, which makes it a troublesome fuel for electricity production. Consequently, waste-to-energy plants are normally designed for a moderate electrical efficiency, and as a rule of thumb it can be expected that 1 tonne of waste may produce 2 MWh heat and 2/3 MWh electricity.

At present, Denmark has got 29 plants, all complying with the requirements of the EU directive on the incineration of waste. Many of the plants are placed in impressive buildings.

100 years' history

The growing urbanisation in the middle of the 19th century made it necessary to bring the urban sanitary conditions under control. An act from 1858 stipulated that Copenhagen and all provincial towns in Denmark should adopt sanitary regulations.

From this emanated the present system in which the municipalities take care of water supply, sewerage and waste management. At about the same time the first Danish gasworks were built and towards the end of the century the first electricity works were constructed, both owned by municipalities. Later on, district heating also became a typical municipal task. In many of the towns these activities were gathered under the joint term of 'The municipal works'.

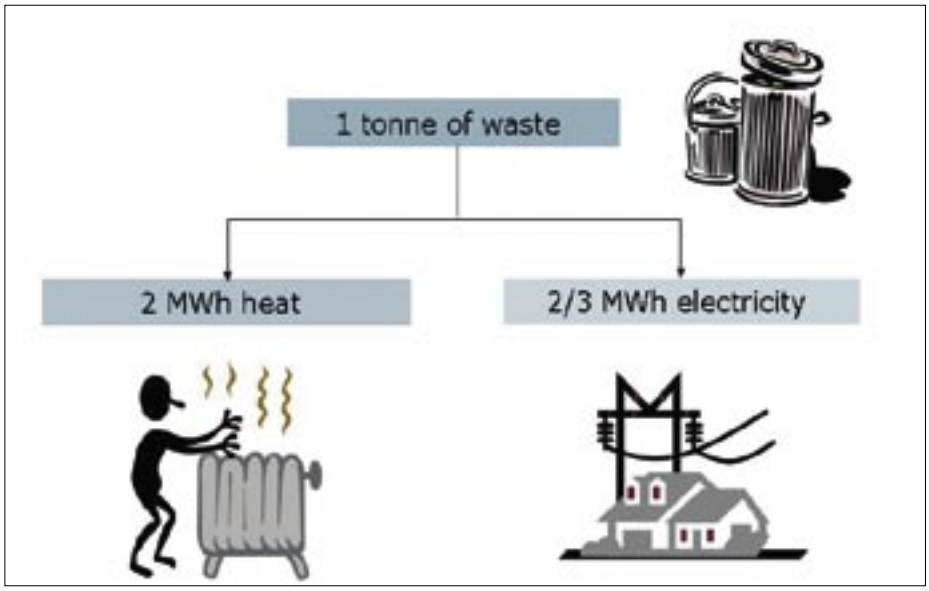
The waste collected was landfilled, and often burnt at the end of the day. By the year 1900 Frederiksberg – an enclave located in the middle of Copenhagen – had run out of available sites for landfills. As a result, the municipality built the first waste incineration plant in Denmark, inaugurated in 1903. The energy generated in the process was used for the production of both heat and electricity. The heat was sold to an adjacent hospital. In this way, Frederiksberg also became the first municipality in Denmark to establish a district heating system.

The same situation occurred in two other major Danish municipalities, Gentofte and Aarhus, in the 1930s, and the old Frederiksberg plant was replaced by a new one. By the outbreak of the Second World War, Denmark had three municipal waste incineration plants, all with energy recovery.

The war and the immediate post-war years delayed the further development of waste incineration, but around 1960 it picked up again. Then the Danish economy had improved, and women started joining the labour force. This entailed a radical change in family patterns, which also had an impact on the waste composition. Denmark became a 'use-and-throw-away' society, and the calorific value of the waste increased dramatically.

Another result of this economic growth was that a large number of newly built

Frederiksberg municipal culture and sports centre, The Boiler Hall. The buildings, which were erected in 1903 on the basis of drawings prepared by the chief architect of the Danish state-owned railway company, Heinrich Wenck, housed Denmark's first incineration plant until 1934. From 1934 to 2000 the buildings were used as a steam heating plant.



up areas – condescendingly called dormitory towns – began to sprout, and the obvious thing to do was to supply these areas with district heating instead of having an oil burner in each house. Growing environmental awareness also favoured this solution.

The desire to be able to discard waste in a sanitary manner combined with the realisation that district heating is an appropriate method of heating drove this development further. The first of these new plants only served one municipality, but in 1965 the first inter-municipal companies were formed for the purpose of establishing and operating a plant for the incineration of the waste generated in the owner municipalities.

Nordforbrænding, commissioned in 1969, Architect: Finn Monies

A major break-through happened in 1970, when two large plants in Copenhagen were comissioned: Amagerforbrænding and Vestforbrænding (see front page photo). Both of these companies are inter-municipal, serving not only Copenhagen but also a number of neighbouring municipalities. This has since become the predominant way of organising waste-to-energy facilities in Denmark.

Nevertheless, when the first oil crisis occurred in October 1973, 92% of Denmark's energy consumption was based on oil. Thus the cut back on oil supplies came as a shock to the country, and a long-term energy policy had to be developed. At first, the policy focused on reducing dependency on oil and increasing the supply reliability. The power stations were requested to reconvert to coal firing, and large district heating transmission networks were established in order to ensure the greatest possible exploitation of the surplus heat generated at the local power stations.

The incineration plants also benefited from this new energy policy as it became easier to sell district heating. When taxes on oil and coal for heat supply were introduced, the plants could raise their untaxed heat prices correspondingly. Consequently, the number of incineration plants increased to 48 in 1982.

In the late 80s, however, the environmental consequences of waste incineration became evident and required more advanced flue gas treatment.

Moreover, the greenhouse effect became an additional political parameter, and in 1990 the Danish energy policy was amended to encourage cogeneration of heat and power. As a consequence, a number of municipalities with district heating plants, including incineration plants above a certain minimum capacity, were asked to convert from district heating production to combined heat and power production. The Ministry of the Environment followed up by a ban on the landfilling of waste suitable for incineration by 1 January 1997.

Nordforbrænding today, after it has been extended by a new CHP line. Architects: Cubo Arkitekter A/S

Amgerforbrænding and, in the background Amagerværket (see the following article). Both plants were commissioned in 1970. Architect: Jørgen Maglebye

Svendborg Kraftvarmeværk. Architects: Boje Lundgaard & Lene Tranberg

Sønderborg Kraftvarmeværk. Architects: Friis & Moltke A/S

Finally, the implementation of the EU Waste Incineration Directive of 2000 has strengthened the environmental requirements for waste-to-energy facilities.

These changed framework conditions have resulted in the number of plants being reduced to 29, but also that Denmark today possesses a modern incineration capacity capable of burning the waste and converting it to useful heat and power – in compliance with the strictest environmental requirements.

Further information on the history of waste incineration in Denmark may be found in '100 Years of Waste Incineration in Denmark'. (Heron Kleis and Søren Dalager, Babcock & Wilcox Vølund and Rambøll, 2004).

Waste as a fuel

The incinerated waste is primarily household waste, bulky items and combustible commercial wastes from industry, institutions, shops and offices. Some plants also receive clinical waste and/or sewage sludge. On the other hand, waste oil and chemicals are kept apart and treated at the central Danish hazardous waste treatment facility, Kommunekemi in Nyborg.

Household waste consists mainly of kitchen waste, paper, plastics and other combustible material. About 20% is made up of solid, non-combustible material such as glass and metals. The commercial wastes are of a composite nature, but wood, paper and plastics are commonly found.

Consequently, the delivered waste varies in quality not only from one plant to another, but also from day to day at any given plant, and the analysis can only be stated in broader terms as:

Combustibles:	40-60%
Water:	15-35%
Ash:	25-35%

The high contents of water and ash reduce the net calorific value to around 10.5-11.0 GJ = approx 3 MWh per tonne. Compared to other fuels, waste is richer in elements like chlorine (Cl) and heavy metals (most importantly: lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr) and Nickel (Ni). It is also richer in ash than most other fuels. Most of the chlorine is found in waste PVC, which is converted to the corrosive gas hydrogen chloride (HCl) during the combustion process. Consequently, the flue gas from waste incineration is more polluted than the flue gases from most other fuels.

This has important implications on the design of the incineration furnaces, their flue gas treatment and ash handling equipment. If waste is used as a fuel for raising steam, the HCl in the flue gas reduces the permissible superheating temperature

The Danish Waste-to-Energy plants. Plants shown in yellow are connected to central heat transmission systems.

and the achievable electrical efficiency in a waste fired combined heat and power (CHP) plant.

In such a plant, a rule of thumb is that 1 tonne of waste (3 MWh) may produce 2 MWh heat and 2/3 MWh electricity.

Normally, the waste is combusted upon its arrival to the plant. Only bulky items are shredded before being introduced into the furnace. This type of incineration is often referred to as *mass burn incineration*.

The Danish plants

At present, Denmark has 29 incineration plants. 21 of these facilities are publicly owned by one or more municipalities, while eight are owned and operated by energy companies. These eight facilities have signed binding agreements with a number of 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.

All of the plants are mass burn incineration plants, and they all produce hot (>120 °C) or warm (<120 °C) water for district heating. 15 of the plants are CHP plants, while 9 have one or more CHP lines in combination with lines that only produce hot water for district heating. The remaining 5 plants are small and only produce heat.

The plants comply with the requirements of the EU Waste Incineration Directive. Some plants have wet flue gas treatment systems, some have semi-dry and some have dry. For further information on these techniques, see the article about Emissions on page 18.

Architectural gems

Steam boilers for waste incineration plants are up to 40 m tall. Consequently, the new CHP lines built in the recent years have required the erection of large, completely new or extended buildings.

Fortunately, some of the leading Danish architects have seen a challenge in designing these buildings. Throughout this issue a number of such buildings are depicted and the names of their architects are quoted in the texts.

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