Denmark – Answer to a Burning Platform: CHP/DHC

The first oil crisis in 1973-74 and the oil price crisis of 1979, caused Denmark serious troubles. At the time, Denmark was very (more than 90 %) dependent on imported oil for its energy supply. Already existing structural problems in the Danish economy were exacerbated by the effects of energy price increases in 1979. The balance of payment deficit increased and employment fell. The effects were felt throughout society.

Until the seventies, energy matters hardly mattered at all. Only in 1973 was energy established as an administrative area for the government, at the time, in the ministry of trade, but later in a ministry for energy. The main focus of the energy policy of the period was:

- establishment of a strategic oil reserve,
- a national debate on nuclear power (the nuclear option was abandoned in 1985),
- development of national resources of oil and gas in the North Sea,
- introduction of gas in Denmark
- law on electricity supply
- law on heat supply (including heat planning)

A. Opportunities

The situation in Denmark in the seventies provided some opportunities. As mentioned, imported oil was the dominating source for energy. Indigenous resources of coal do not exist, and development of oil and gas fields in the North Sea only began in the early seventies. A number of large, thermal power plants were situated along the coast, with easy access to cooling water and deep sea harbors for importing coal. Having no potential for hydro power itself, but being connected through the Nordel cooperation to the power grids of Norway and Sweden, these plants provided backup capacity to the hydro dominated power sectors of those countries. Already at the time, waste heat from these power plants was used in district heating systems in the larger cities. District heating accounted for around 30% of the demand for space heating, but was totally dependent on oil, either through the heat from the large power plants, which were oil fired at the time, or through heat from local, oil fired heat only boilers.

B. Energy Sector Organization: Cooperatives

The Danish energy sector was (and partially still is) radically different in terms of organization, when compared to other countries. The traditional Danish cooperative movement was a means of economical organization under leadership of consumer- or producer -controlled corporations, where each individual member owned a part of the corporation, and where the members of the corporations divided the eventual year-end financial surplus amongst them. Much of the electricity and district heating distribution outside the major cities was organized as cooperatives, and still is today. In the cities, electricity and heat distribution was mainly carried out by municipal utilities, but unlike elsewhere, these utilities were not allowed to finance other municipal activities such as schools or buses. The before mentioned large power plants were again organized as cooperatives, with electricity distributors as owners. This form of organization, without a traditional profit motive, offered little resistance to government intervention in the sectors for electricity and heat. In some cases, changes were introduced and implemented through a political agreement between majorities of parties in the parliament, with the legislative instrument left as an unused but clear threat.

C. A basic compromise

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The largely cooperative electricity and district heating sectors had already in 1956 agreed upon a principle for allocating costs and benefits between the electricity and heat sides in cogeneration, covering the situation where district heating was purchased from plants owned by the electricity sector. This is the case with around 2/3 of all Danish district heating. Heat was considered the marginal product, and the benefit of cogeneration was defined as the fuel cost of heat production on boilers minus actual fuel cost paid by the heat side. This was divided 50/50 between electricity and heat, but during the massive expansions of district heating networks in the 80'ties and 90'ties, the electricity side forfeited their share of the benefit for the first 12 years of the contract period, as their contribution to the massive investments.

D. First response

The first response to the energy challenges of the seventies was to reduce consumption. Energy saving campaigns, ban on driving cars on Sundays, no lighting in shop windows after shop closure and many other simple measures were introduced but gradually removed as the supply situation improved. Maybe the initiatives did not save much energy, but they surely drove home the message to the Danes: These are serious problems! This made the quite interventionist energy policy acceptable by the public.

A more long term policy was formulated from the mid 70'ties, when a national energy plan was introduced. The initiative was taken to start working towards a national heat plan and also the first energy tax was introduced. The tax was to maintain the economic incentives to save energy, as the price for oil fell on the international market, and has gradually increased over the years.

It was also decided to develop internal resources of energy, mainly the reserves of oil and natural gas, which had been found under the North Sea. A national gas grid was to be established, to replace not only the use of oil in the heating sector, but also to replace coal in the power sector. This met opposition from the electricity sector, and natural gas mainly became a substitute for coal through the later development of the decentralised (localised) CHP on natural gas. Electricity production at these plants partially replaced production at the large, central and coal based condensing/extraction plants near the major cities.

E. Heat planning

The heat law was implemented in 1979. The law introduced heat planning as a new instrument. National targets for the heat planning was the introduction of natural gas, increased use of waste heat from cogeneration, industry and waste incineration and the use of biomass for heating in areas deemed unsuitable for natural gas and without sources of waste heat.

Municipalities conducted heat planning for all areas, particularly identifying areas suitable for "collective" heat supply, meaning either district heating or natural gas. Buildings in other areas were left to individual heating solutions. Potential sources of surplus heat were identified, and municipalities were responsible for providing an appropriate heat load, either through expansion of existing district heating systems or through establishment of new ones.

Municipalities were given the option of making connection to district heating or gas networks compulsory. If the option was exercised, as it was in many cases, consumers had nine years to connect. Even though compulsory connection provided security for the large investments in district heating networks, the persuasive argument for district heating was mostly the fact that district heating was and still is the cheapest heating option for a building.

F. Price regulation

Price regulation on district heating was also introduced with the heat supply act of 1979. The fact that district heating in Denmark supplies a large number of individual houses, together with the option of compulsory connection, gives it a dominating position in the heat market and, for all practical

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purposes, a natural monopoly. Therefore the act specifies that district heating must be operated as a non-profit activity, with cost-based pricing. Establishment of this principle met little or no resistance, as the sector already was operated by what was already non-profit organisation: Consumer owned cooperatives or municipal utilities.
The average price for district heating, based as it is on the cost of supplying the heat with no profit, has remained below the price of the most likely alternatives like oil, gas or electricity. Today it is about 1/3 lower than the price for individual oil heating.

G. CHP development

It was realised early, that the most promising target for energy efficiency efforts was the power sector, mainly the large power stations mentioned previously. Large transmissions systems were built in Copenhagen and in some other large cities, in order to transport vast amounts of heat from the large extraction/condensing power plants to existing but expanding distribution systems in the area. There has never been any support for these CHP plants, but some state support for conversion of existing buildings to use district heating was provided during the expansion.

But further growth of the use of CHP was agreed upon politically in the late 80'ties, and implemented as a change to the heat supply act. Through the years 1990 to 1998 a large number of district heating systems outside the major cities converted to new production technology and/or to a new fuel. Existing heat only plants based on coal or oil converted to CHP on natural gas if gas was available. Gas-based heat-only units also converted to CHP. Waste incineration plants converted to CHP and district heating producing units in areas without natural gas converted to biomass.

Conversion to natural gas-based CHP initially only happened slowly, due to uncertainty about the economics in these long term investments to be made by the district heating companies. A feed-in tariff and purchase obligation was placed on the electricity system for the electricity was not sufficient. But introduction of a direct support scheme, with 0,015 €/kWh from 1992, for these new, localised CHP systems, clearly improved the incentives, since the time schedule for the whole process was more or less met. The direct support was reduced in 1997 to 0,0095 €/kWh for all localised CHP plants, except the smallest.

The economic attractiveness of localised CHP was so high that a number of small, completely new CHP-based district heating schemes was established. Some were clearly too small and too vulnerable to the increase in gas prices after 1999, and had to be given extra state support to be able to operate with tolerable heat prices for their consumers. However, the number of district heating consumers affected by these problems only equalled around 1 % of all district heating consumers in Denmark.

H. A huge success

Expansion and construction of new district heating systems, increased use of waste heat from cogeneration, industry and waste incineration and also a switch from fossil fuels to biomass in heat only production produced the desired results. 60 % of all households were heated with district heating, fossil fuels for heat only production in district heating almost ended and half of all electricity was produced by CHP.

But such a high share of CHP, in combination with another Danish success: 20 % wind power, presented a new problem. At certain times, electricity production from localised CHP and wind power exceeded national demand, and had to be exported with a loss. The loss was financed by electricity consumers, who paid the whole cost of the feed-in system through a premium on the electricity price.

I. Present CHP regime

The feed-in system was changed in 2005 to a system where all localised CHP above 5 MW are obliged to sell their electricity production at market prices. There is no longer any purchase obligation on electricity from localized CHP, and there is also no extra support for CHP plants above 25 MW.

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As a safeguard for the heavy investments made when converting to CHP, existing localized CHP plants over 5 MW are given a non-production related subsidy, corresponding to that received in the period 2001-2003, 20 years from the date of the grid connection and for at least 15 years as from January 2004. The support decreases as electricity market prices increase and disappears when market prices reach a certain level. Plants under 5 MW receive a subsidy depending on when electricity production takes place, and this combined with the electricity market price, provides a three-tier tariff.

The new system has reduced problems with excess electricity production from CHP but not problems arising from production on wind turbines. Another consequence has of course been an increase in the use of heat only boiler units in district heating and thereby also increased use of fossil fuels. These fuels can, however, to a great extent be replaced with biomass or other renewables. District heating is presently prevented from replacing taxed fossil fuels with untaxed renewables through the heat planning system, due to concerns about state revenue from energy taxation. This does not support national goals to reduce CO_2 emissions and meet a 21 % Kyoto target reduction, and should be changed.

J. Lessons learned

What are the lessons learned with regard to district heating and CHP from more than thirty years of Danish energy policy?

It is possible, with a determined effort to change the composition of the energy input of a country and to improve its overall energy efficiency. The challenges faced by Denmark in the seventies were certainly no greater than those posed today by climate change. A combination of planning and market mechanisms has worked in Denmark, and there is little indication elsewhere that one or the other alone has provided similar results.

Heat planning was a good instrument to ensure expansion of district heating networks and the use of available sources of waste heat or renewable fuels. Planning for the heat supply of buildings has proved to be no more difficult or controversial than planning for the provision of other services, like sewage or waste treatment, where individual choice may entail serious consequences for the community as a whole or the environment.

Focussing on electricity production efficiency and at the same time providing a concentrated heat load through district heating made a rapid and large increase in the use of CHP possible. Only promoting CHP, without at the same time developing district heating, would perhaps make industrial uses the only growth area for CHP.

The feed-in tariff system with a purchase obligation placed on the electricity sector combined with the direct production support was enough to incentivize the development of localised CHP in Denmark. Differentiation between systems of varying sizes could perhaps have given a more balanced distribution of support, and clearly, some small schemes should never have been built.

Today Danmark possesses a modern and extensive heat infrastructure that has already demonstrated its ability to change production technology and fuel in a short period of time. This will undoubtedly prove valuable when Denmark and the heating sector have to adjust to the challenge presented by climate change. Investments were huge, but district heating systems have a long life and will provide their services for many years to come.

K. Case Study Written and Submitted by:

Birger Lauersen, Manager International Cooperation & Communication, Danish District Heating Association, email bl@danskfjernvarme.dk

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The International CHP/DHC Collaborative

The International Energy Agency launched the International CHP/DHC Collaborative in March 2007 to help evaluate global lessons learned and guide G8 policy makers, industry and other nations as they attempt to assess the potential of CHP and district energy as an energy technology solution.

The Collaborative includes the following activities:

- collecting global data on CHP/DHC
- assessing growth potentials for key markets
- developing country scorecards with data and relevant policies
- documenting best practice policies for CHP and DHC
- convening an international CHP/DHC network, to share experiences and ideas

Participants in the Collaborative include government and industry Partners, as well as over 300 government, industry and non-governmental organizations that provide expertise and support via the Network.

If you are interested in participating in the Collaborative or want more information, please visit **www.iea.org/G8/CHP/chp.asp.**

For More Information about the IEA's International CHP/DHC Collaborative: Contact Tom Kerr, email **tom.kerr@iea.org.**

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