Denmark is a major success story in terms of its use of both CHP and district heating. But how did this decentralized energy situation come about? Jesper Lorentzen runs through the series of government interventions which transformed the country's energy markets, starting with the first law on heat supply, enacted in 1979.

Decentralized Denmark

how Denmark developed its DE

The oil crises in 1973–74 and at the end of the 1970s resulted in the formulation of a definitive energy policy in Denmark to reduce the country's almost 100% dependency on oil. One consequence of this policy was a successful change in Denmark's heat supply.

As early as 1903, the first CHP system was built at Frederiksberg Hospital in Copenhagen. The first large public district heating (DH) system was developed in Copenhagen in the 1930s based on surplus heat from local electricity production. In the 1950s and 1960s DH supply was extended to most of the country's large cities. When the law on heat supply took effect in 1979, there were about 700,000 DH installations.

This article outlines the drivers and the means to reach a target of having more than 50% of all dwellings connected to a DH network in which the heat is produced from CHP or from biomass and where distributed energy production plays an important role. This article provides a brief description of some of the decisions and choices that have been particularly significant in the development of heat supply in Denmark into a highly decentralized system not only with respect to heat

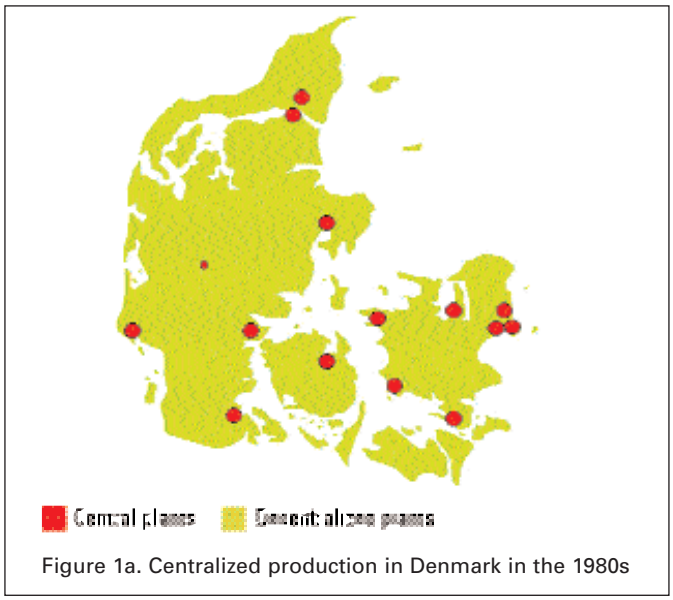

Figure 1a. Centralized production in Denmark in the 1980s

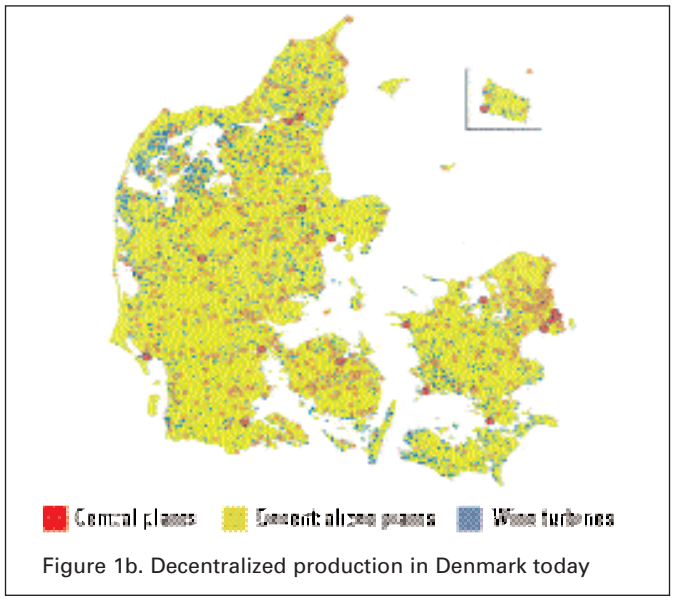

Figure 1b. Decentralized production in Denmark today

production but also with respect to power generation.

Figures 1a and 1b illustrate the development of decentralized energy from the mid-1980s. Figure 2 shows a breakdown of heating sources for Denmark's 2.5 million homes in 2000.

HEAT PLANNING

Denmark passed its first heat supply law in 1979. The law contained a framework of regulations, procedures and timetables and also clear priorities for the heat planning in Denmark and was the beginning of new, public planning. The overall headline was to divide the country into three categories: areas suited for district heating, areas suitable for use of natural gas and rural areas with continued individual supply.

The planning process was divided into three phases, which where implemented during a period of some years. This kind of planning process was also used in the physical planning and included public hearings to reflect local conditions and considerations.

In the first phase, local authorities were to prepare reports on their heat requirements, the heating methods used and the amounts of energy consumed. They were also asked to assess heat needs and heating possibilities. The local plans were aggregated at county level to prepare regional heat supply summaries.

In the second phase, local authorities were to prepare a draft of future heat supply needs while the county councils prepared regional summaries. On this basis, the county councils then prepared a definitive regional heat plan, which became the third phase in overall heat planning.

The plans were required to show:

- in which areas the various forms of heat supply should be prioritized
- where future heat supply installations and pipelines should be located.

This planning made it possible to combine the desire for more environmentally friendly supply with the desire to benefit from the investments made following approval of the national natural gas project in 1979. As a response to the dependency on oil it was decided to develop a completely new gas distribution system based on the production of gas in the North Sea.

During this process, the possibilities for cogeneration of heat and electricity were examined (phase one and two) to exploit surplus heat from electricity generation.

With the 1986 Agreement on Cogeneration of Heat and Power (CHP), decentralized cogenerated heat and electricity became a major energy policy priority. The background for this agreement consisted of several ingredients:

- the technology of small cogeneration installations driven by natural gas had matured
- the political focus was on the economic consequences of high energy prices
- there was a need to establish new power capacity.

The agreement was made between the government and utilities,

which were obliged to arrive at a capacity of 450 MW of electricity at decentralized CHP installations in total. Furthermore, it was emphasized that research and demonstration projects should be extended to various types of installations, such as those processing biomass and waste.

Obligatory connection and a ban on electric heat

The first law on heat supply also gave local authorities the power to oblige new and existing buildings to connect to either district heating or natural gas. The objective was to promote collective supply systems (district heating and natural gas) as a means of achieving economically sound use of energy. Most consumers were obliged to connect to individual natural gas or DH systems.

In 1982, the obligation to connect was finalized in an executive order that was essentially unchanged until the most recent amendment in 2000. It remains in effect. The ban on installing electric heat in new buildings dates back to 1988. It arose from the desire for more efficient energy use. In 1994, the ban was extended to electric heat installations in existing buildings with water-based central heating systems. The objective with the ban was to prevent the installation of domestic electric heat in areas that had public heat supply or that were zoned for such supply.

The ban on electric heat remains in effect but will most likely be adjusted to make it possible to use electricity for heating in new buildings that have very low heating demands.

In practice, the ban and obligatory connection made it possible for local authorities to ensure that energy supply companies' earnings were not undermined by an insufficient number of connected consumers, in turn ensuring that investments made were not lost.

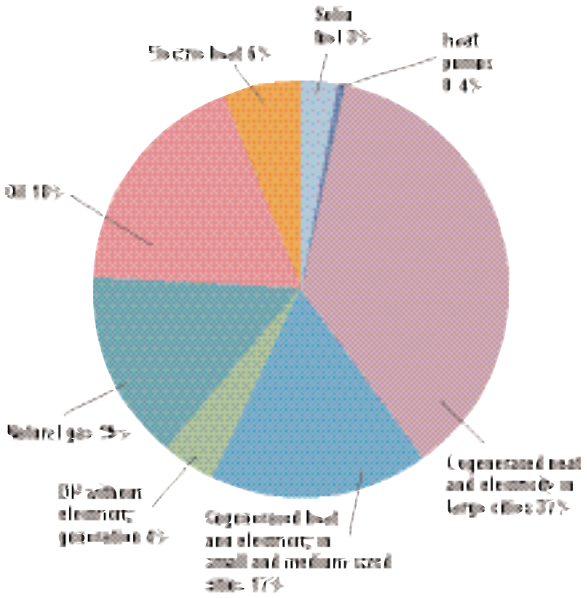

Figure 2. Heating Denmark's 2.5 million households (2000)

Supplementary instruments

As early as 1979, the energy plan, known as the Danish Energy Policy, presented initiatives to enable consumers to save energy.

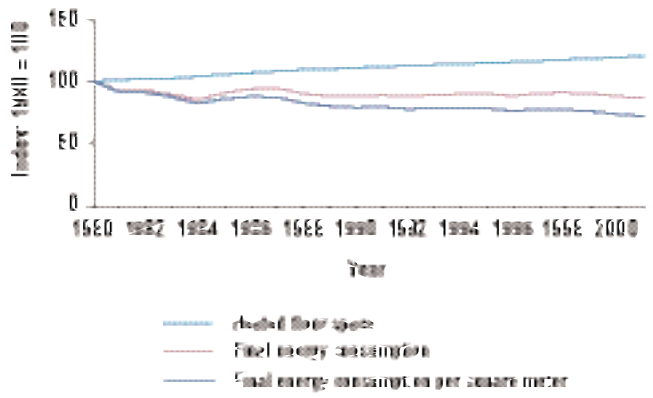

Figure 3. Space heating energy use in Danish homes

For example, initiatives were undertaken to improve building insulation, and a heat appraisal programme for houses was set up. Energy savings were introduced according to the logic that energy saved needed to be neither produced nor imported. Figure 3 shows the effect of the totality of programmes and incentives. It shows the average heat demand per heated square metre of building.

During the 1970s and 1980s, taxes were levied on fuels used in heat generation with the objective of encouraging the use of environmentally friendly energy and efficient energy use. Biomass and biogas were exempted from taxes. Figure 4 shows the tax collected for different types of fuel. Although oil and gas prices fell at the end of the 1980s, the tax level was maintained to ensure that consumers would continue to be motivated to save energy.

Supply subsidy and development of environmentally friendly fuels

The conversion to more environmentally friendly fuels and the use of cogeneration at new plants through the use of new technology was achieved by means of various subsidy and grant programmes.

For example, the Energy Research Programme (ERP) for energy research was set up in 1976. The goal was – and is – to prioritize and support energy research and technological development to increase energy efficiency and decrease the environmental impact of energy production.

In 1981, the Development Programme for Renewable Energy (DPRE) was put in place. The objective in this case was to supplement the ERP so that research into renewable energy could lead to commercially viable technologies.

Private consumers or enterprises could receive subsidies for advanced systems or standard-certified renewable energy installations. Implementation of biofuel boilers, solar heat installations and heat pumps derived particular benefit from the subsidy programme. For example, the DPRE supported the

More than 10,000 biomass boilers were set up

setting up of more than 10,000 biomass boilers.

Test stations and research centres with special knowledge in a particular field could receive a subsidy for carrying out type approvals of renewable energy installations and for disseminating knowledge and information.

After more than 20 years of such support, many environmentally friendly technologies and fuel installations became so technologically and commercially mature that they no longer required subsidizing. For this reason, the 2002 Finance Act discontinued the DPRE's subsidy system.

ENVIRONMENT AND ELECTRICITY CAPACITY

In the 1990s, there was widespread conversion from heat production using oil and coal to cogeneration based on natural gas, and to biomass-based heat production.

The first phase of Danish heat planning was to a large extent finalized at the end of the 1980s. All areas covered by the expansion plans were zoned for public heat supply (natural gas or district heating) as part of local authorities' heat supply plans.

Conversion towards CHP

With an amendment to the law on heat supply in 1990, a new planning system was introduced to adapt policies to future heat supply requirements. A so-called 'project system' was developed. Previously, major changes were made to a plan after phases such as public hearings. This method was advantageous for designing the main supply system, deciding which geographic areas should be supplied by district heating and which by the natural gas system. However, the planning process was time consuming and not suitable for the handling of small changes, ie the replacement of a boiler at the DH

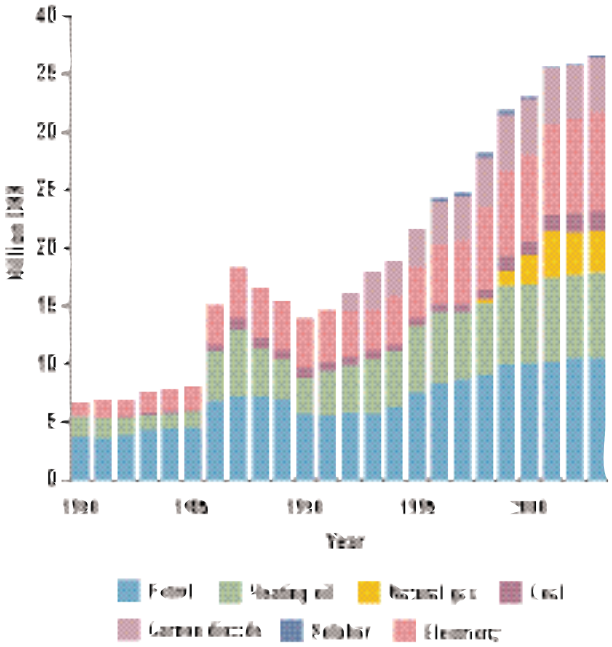

Figure 4. Danish tax revenue from different fuels

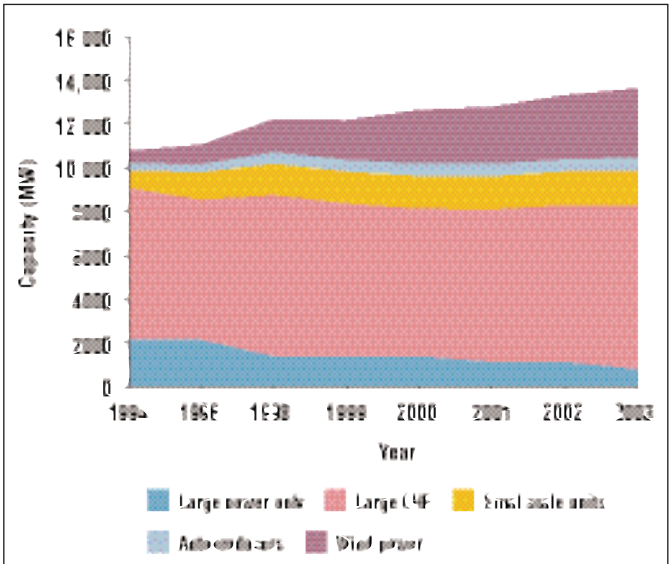

Figure 5. Power generating capacity by source

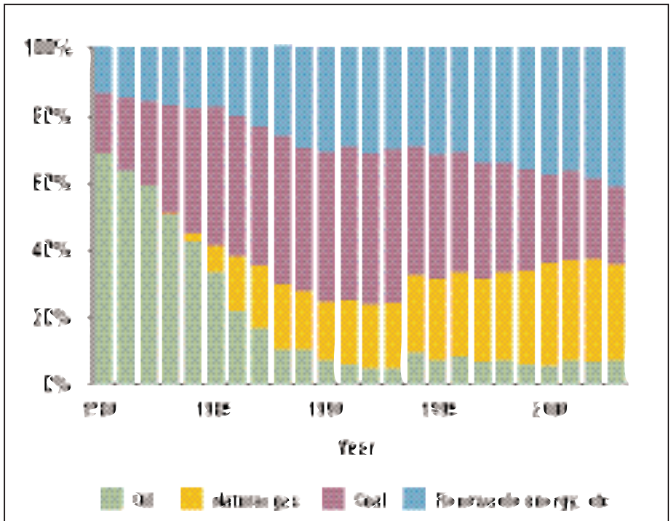

Figure 6. District heating production in Denmark by fuel

station or the connection of a new block of flats to the gas grid. The new approach made it more simple with clear procedures on how to check whether the concrete project was in line with the master plan and whether the project was the best seen from socio-economic and environmental points of view. The objective of the agreement was to promote expansion of decentralized CHP through:

- conversion of existing installations to cogeneration
- conversion from coal and oil to natural gas
- increased use of environmentally friendly fuels.

The agreement was a solution to two particular issues: reducing Denmark's carbon dioxide emissions and ensuring economically sound use of energy through the expansion of the natural gas grid. It should also be seen as a means to satisfy a growing need for electricity capacity. Instead of expanding the capacity of

central plants, the idea was to expand capacity based on heat demand around Denmark.

The agreement was based on a solid majority of political parties in the parliament and was reinforced with energy plan Energy 2000 from April 1990, when the need for new power capacity had become an important issue. In combination with the huge number of local district heating installations established as a result of the heat planning process mentioned above, cogeneration was an obvious possibility to establish power production with an overall efficiency of around 90% rather than 40%–50%.

In practice, all possibilities for further expansion of district heating in the big cities were already fully exploited.

The conversion of DH (heat production only) to CHP was to take place in three phases, as specified in general and specific planning directives sent to all local authorities. Local authorities were also directed to ensure that this conversion was carried out. All the phases were outlined from the beginning of the process.

Phase 1 from 1990–1994 required that:

- large coal-fired DH plants with access to a natural gas supply were to convert to decentralized cogeneration fired by natural gas
- large DH plants fired by natural gas were to convert to decentralized cogeneration fired by natural gas
- waste incineration installations were to be introduced to run as cogeneration plants.

Phase 2 from 1994–1996 required that:

- remaining coal-fired DH plants with access to natural gas supply were to convert to natural gas-fired, decentralized cogeneration
- medium-sized natural gas-fired DH plants were to convert to natural gas-fired, decentralized cogeneration
- The majority of DH plants were to convert to straw, wood chip or other biofuels.

Phase 3 from 1996–1998 required that:

- small natural gas-fired DH plants were to convert to decentralized cogeneration fired by natural gas
- remaining DH plants without possible connection to the natural gas system were to convert to straw, wood chip or other biofuels.

For the most part, these conversion phases were successfully completed, which is why Denmark has the most extensive use of cogeneration in Europe.

Heat is generated automatically when electricity is generated but not necessarily in periods when the market price for electricity is advantageous. Production of heat-connected

CHP electricity increased so much that it sold to neighbouring countries for less than it cost to produce

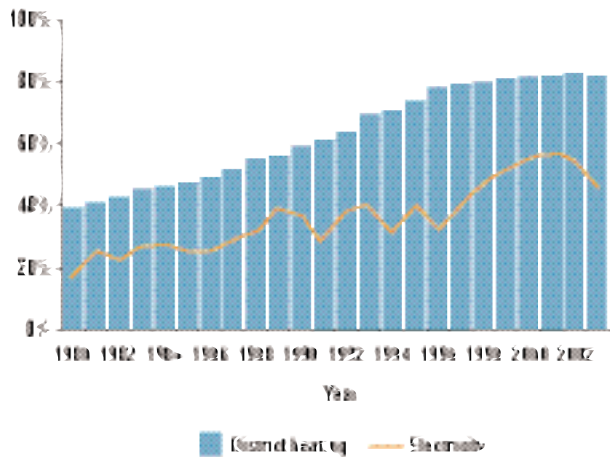

Figure 7. CHP shares in electricity and district heating production

electricity gradually increased to such an extent that during certain periods it had to be sold to surrounding countries for less than it cost to produce. The result was economic loss, for both the state and producers. Therefore, as of 1 July 2003, CHP plants were exempted from the obligation to cogenerate electricity and heat continually in order to qualify for electricity production subsidies. Now, plants are motivated to produce electricity when there is demand and when the price is therefore favourable. Since all installations besides CHP installations also have a heat-only boiler, plants can switch between CHP mode and heat-only mode.

Further initiatives to encourage more economic cogeneration of electricity and heat were introduced with a far-reaching energy agreement in March 2004.

Figure 5 shows how installed power capacity has developed since the mid-1990s.

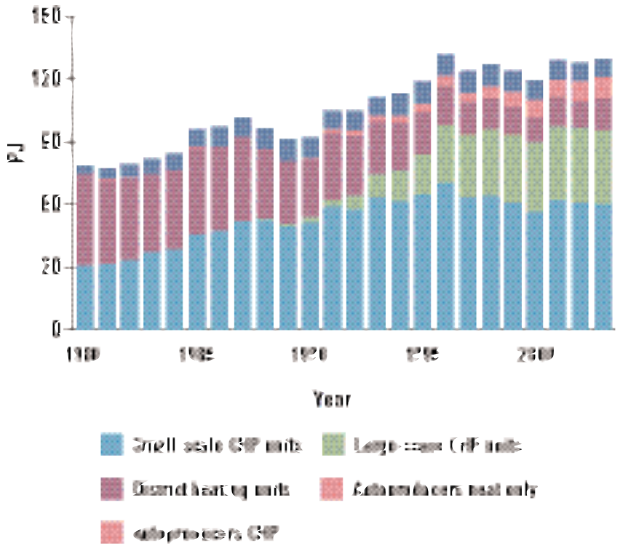

Figure 8. District heating by type of producer

Renewable energy as part of heat supply

The introduction of renewable energy for heat supply became a priority in the 1990s, when objectives were set for the increased use of biomass in both centralized and decentralized installations, as Figure 6 shows.

The use of biomass, particularly in decentralized DH plants and, to a certain extent, in decentralized CHP, was supported by policy-makers and financial subsidies. In particular, the use of biomass in centralized plants was facilitated by a political agreement from June 1993, according to which electricity plants were to use 1.2 million tonnes of straw and 0.2 million tonnes of wood chip annually for electricity production by the end of 2000.

Open-field plants

In the early 1990s, DH from new plants was distributed to several large villages around the country. Most of these plants also produced electricity. Cogeneration saved fuel and was therefore more environmentally friendly. The public supply could also be extended to local industry in cases in which natural gas pipelines were laid, thus being advantageous to local industrial activity.

At the end of the 1990s, a number of open-field plants encountered financial difficulties, partly due to higher natural gas prices. In many cases, the government and natural gas companies came to their aid. In 2000, open-field plants received DKK 370 million (US$60 million) for debt rescheduling from the government and natural gas companies. In 2003, another aid package was made available, amounting to DKK 85 million ($13.8 million). During the same period, taxation of cogenerated heat and electricity was amended in favour of open-field plants and other decentralized CHP.

Economic support of decentralized CHP

The conversion of district heating plants into CHP installations required large investments. To create a balanced approach without increasing the costs of the customers of district heating, a support scheme was established.

The design and amount of support changed from 1992 to 2005. The basic idea has been to safeguard the heat customers and provide the necessary income from producing and selling electricity to the grid. For a long period it was designed as a feed-in tariff with components of both direct state aid and a market premium. All electricity consumers had to pay an extra amount to cover the environmentally friendly electricity not only from cogeneration but also from wind turbines.

The problem that the Danish energy system has faced is that under some special conditions the production of electricity from cogeneration and from wind turbines exceeds the electricity needs. Or expressed in market terms, the production of electricity continues even if the market price is very low. Heavily subsidized kilowatthours are produced when market prices are very low, leading to a socio-economic loss.

One answer to that problem is a change in the support system from 2005 to install incentives to stop production of electricity when the market electricity price is low. In reality, the market price of electricity decides whether a plant will be operated in CHP mode or in heat-only mode. Existing plants with outputs over 10 MW are eligible for an individual non-

production related subsidy corresponding to that received in the period 2001–2003. The subsidy is paid for 20 years from the date of the grid connection and for at least 15 years from 1 January 2004. The idea is to provide an economical safeguard of the existing installations and at the same time encourage the installations to act on market signals.Figure 7 illustrates the growth of and the CHP share of both district heating and of total electricity production in Denmark. Figure 8 shows a breakdown of district heating by type of producer.

Development could be seen as a long row of steps driven by political will to solve specific national challenges

This is an example showing that a decentralized energy system provides new challenges to the entire set-up. The framework providing the growth of decentralized production imposed new problems and created a need to adapt to the new conditions.

POLITICAL WILL

The described development could be seen as a long row of steps driven by political will to solve specific national challenges over a long period with increasing international building of the market.

From the beginning the problem was a dependency on heavy oil. The answer to that was the national natural gas project and the switch of fuel from oil to coal. The next phase was driven by the high costs and environmental considerations, which lead to the use of cogeneration fired by natural gas and based on local heat demands combined with biomass-fired systems plus the switch from coal to gas. The increased costs for investments was accepted and implemented into support programmes for CHP-generated electricity. Without these support programmes the imposed conversions would have led to unacceptably high heat prices. The customers connected to the district heating system as a monopoly have been, and still are, protected from high prices via a non-profit set of rules for heat pricing.

Coming from a planned system and moving towards a market-driven system has made it necessary to adjust the whole system. The perspective from now will be to develop the distributed character of the heat supply system in a way that makes it possible to meet the challenges of the electricity and gas markets.

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