District heating
The role of district heating in future energy supply

SUMMARY

As part of the energy agreement, it was agreed to "draw up and present an analysis of the role of district heating in future energy supply before the end of 2013". The primary focus of the analysis is to identify how district heating is to be produced in future and the extent to which district heating should continue expansion, or perhaps be restricted. The analysis of district heating focuses on the period up until 2035, with perspectives up until 2050.

The analysis was performed by COWI and Ea Energianalyse. The analyses using the Balmorel optimisation model were performed by Ea Energianalyse, whilst the calculations for the heating atlas were carried out by COWI. To ensure cohesion with the other analyses in the energy agreement, Energinet.dk, advisors and the Danish Energy Agency have been in close dialogue during the whole process.

With the energy agreement of 22 March 2012, an agreement was made to initiate a number of analyses and reports aimed at ensuring a sufficient knowledge basis, and to inform the most economic and effective solutions in the transition of energy supply into clean renewable energy. In the coming years, ambitious targets on energy savings and electricity generation on the basis of wind power may become particularly significant for the economics of district heating and combined heat and power.

A key question is in which situations the macro and micro economic benefits of district heating are higher than the costs. The benefits of district heating primarily arise from effects of scale from exploiting solid fuels for combined heat and power, better possibilities of recovering surplus heat, and finally possibilities for increased flexibility and improved integration of wind power in the energy system. With increased focus on effective exploitation of scarce resources, efficient electricity from combined heat and power will be of higher value compared with electricity from condensing power plants, and this will benefit district heating. This will also increase the value of heat pump solutions; both for individual and collective solutions. Individual supply will be particularly favoured where the district heating grid needs high temperatures, which heat pumps in the district heating supply have difficulties providing in an energy-efficient manner.

In future, wind power fluctuations are expected to determine when heat production should be produced using heat pumps or through combined heat and power. The value of being able to store heat for hours, days or even weeks will thus increase. For individual installations, only short-term storage of heat will be realistic, whilst collective installations may benefit from the scale advantages of large heat storage facilities.

Transition of the energy system towards a fossil fuel independent energy supply challenges district heating in two ways:

- Lower heating demands: new requirements for the energy consumption of buildings, as well as requirements for savings in existing properties, will reduce the economic foundation for district heating. This is because the costs of the district heating grid itself, as well as the losses in the grid, depend particularly on the length of the grid, whereas heat savings mean that costs will have to be distributed between still fewer energy units.
- Less thermal electricity generation: another challenge is the increased volumes of wind power expected in the electricity system. The wind power share of electricity consumption will be increased to 50% by 2020, and is expected to rise further subsequently. CHP plants will take on a new role in the overall energy system, as they act more as medium-load facilities and backup capacity rather than as base-load facilities. A lower number of operating hours and less predictable operations challenge both technology and the economics of the system.

Therefore, it is by no means a matter of course that there will continue to be welfare-economic incentives to further develop district heating. On the contrary, the heat losses and the maintenance costs in certain district heating areas means that over time district heating will give way to individual solutions. Therefore, the question is how district heating and production capacity can be organised to best underpin the green transition.

The Danish and European electricity sectors were liberalised about 15 years ago. Developments are moving towards more comprehensive market integration and expansion of the electricity transmission capacity between Denmark and its neighbouring areas. For example, Energinet.dk expects the capacity of cross-border electricity connections up until 2025 to increase from about 150% to more than 200% of the average Danish electricity consumption per hour. In terms of electricity, Denmark is a relatively small country, with very open borders. The plans for making further market coupling with full integration between all electricity systems all the way from France in the south to Finland in the north are expected to be implemented in spring 2014 .

Analysis

The analyses were performed using the Balmorel optimisation model in combination with a heating atlas for Denmark developed especially for this task. In the optimisation model, electricity and heating supply is expanded up to 2050 at the lowest possible cost, taking into consideration the political targets, international market prices as well as available technologies. The heating atlas maps Danish heating consumption and heating production in detail and analyses the local competitiveness of district heating compared with individual solutions. The analyses using the optimisation model were performed by Ea Energianalyse, whilst the calculations for the heating atlas were carried out by COWI. The models are used iteratively and under the assumption of considerable heat savings in both individually and collectively supplied areas.

Three optimisation models were set up and calculated:

A. Wind model. Optimum expansion of the energy system under the assumption of scarce biomass resources up to 2050 as well as with the existing tax and subsidy structure.

B. Wind model. Without taxes and subsidies (in the following referred to as "wind welfare-economic model"). As A but calculated without taxes and subsidies.

C. Baseline model. With existing tax and subsidy structure and with no special Danish targets after 2020. However, the EU's ambitious CO2 targets for the entire model area still apply.

The choice of optimisation model was coordinated with the other analyses in the energy agreement. The wind model is closely linked to the wind scenario of the Danish Energy Agency. It is thus based on the same restriction of the biomass resource in 2050 as assumed by the wind scenario of the Danish Energy Agency.

The models are supplemented by a baseline model, which is a sensitivity calculation without restrictions on imports of biomass, and where only the existing instruments apply. The long-term political targets for Denmark are not controlling parameters. Even though the baseline model has no restrictions on biomass imports and is not linked to the long-term political targets for Denmark, the baseline model largely follows the wind model. In other words, the analysis shows an overlap between the wind model and a model with the current framework conditions and with no special Danish targets and restrictions on biomass use.

However, the current district heating analysis assumes that the EU will maintain its ambitious targets for carbon reduction up to 2050, as described in the "Roadmap for moving to a competitive low carbon economy in 2050". Specifically for the Nordic countries and Germany, carbon reduction of 95% up to 2050 is still assumed, and this will result in pronounced expansions of renewable energy in all the countries surrounding Denmark.

The analysis assesses that solar and wind power will represent about 25% of total electricity generation in Germany and the Nordic countries by 2025, increasing to around 40% by 2050. Such development in the international electricity market is an important framework for the Danish district heating sector. The continued expansion by Denmark's neighbouring countries of wind power and solar energy creates fluctuations in electricity prices, significantly influencing the economics of Danish CHP plants and heat pump solutions.

Furthermore, the control instruments implemented by Germany and the other countries are not without importance. Expansion of renewable energy primarily promoted through subsidies will generate lower electricity prices than if emission allowances are the primary control instrument. Not just the climate targets but also the choice of control instrument by the individual countries affects the economics of Danish district heating solutions.

Results of the analysis

The following sections describe the results of the analysis as presented through the replies to some of the questions posed in connection with the analysis of district heating.

The electricity market and electricity generation

As mentioned above, the optimisation model aims at covering electricity and heating demands in the entire model area at the lowest possible costs. The calculations assume that no special capacity mechanisms are introduced to ensure the security of supply on the electricity market.
If, due to increasing electricity demand and the phasing-out of older power plants, a lack of capacity arises, electricity prices will increase until the capacity is brought about by market conditions. Renewable energy installations supported through direct or indirect subsidies have the opposite effect and keep electricity prices down.

Average electricity prices in Germany are expected to increase to around DKK 450/MWh by 2025 and around DKK 500/MWh by 2035. Up to 2025, electricity prices in Norway, Sweden and Finland will be maintained at roughly their current low level of around DKK 300/MWh and will increase after this . Danish electricity prices follow the German prices in particular, though at a slightly lower level. However, in 2020, German and Danish prices will be higher than indicated by the forward market (November 2013).

In the wind welfare-economic model the vast majority of the existing Danish small-scale natural-gas-fired combined heat and power capacity up to 2025 will be maintained, and investments in new turbine plants will be made. This means that in this model, Danish natural-gas-fired combined heat and power will be competitive on the international electricity market, even though the number of peak load hours drops.

In the wind model the majority of the natural-gas plants will be phased out . On the other hand, significant investments will be made in biomass-fired combined heat and power plants, in part because of the tax incentives. In the wind model, the Executive Order on approval of collective heat supply plant projects (orders concerning combined heat and power) applies for the entire period. If the order concerning combined heat and power lapses without other changes to the framework, combined heat and power from natural gas will likely be phased out without further expansion with new capacity in biomass and waste.

Should district heating be further expanded?

The analysis establishes a number of assumptions on future heating consumption focusing particularly on the development in heating consumption in the existing building stock. The new analysis assumes a 30% reduction in heating consumption in the existing building stock up to 2050. To this is added new buildings (which take up very little space in the total calculation) where tighter requirements in building regulations have been included. The potential for expansion of district heating is then examined.

Today, the ratio between district heating and individual heating supply is about fifty-fifty, and the analysis shows a welfare-economic in expanding district heating. As seen in Table 1, the welfare-economic potential represents 62% in 2035 compared with about 50% today. Calculations of potential solely take into account the supply for the relevant year, and not for the more long-term transition. Therefore, the potential of 69% in 2020 should be viewed as a short-term potential during a transition process. The potential is primarily in concentrating existing district heating areas. There is only a very limited basis to expand district heating to cover new areas.

Heating demand [PJ]	2013	2020	2035
Denmark	199	189	166
Urban areas	160	152	134
District heating	50%	69%	62%

Table 1. Assumptions about the development of district heating consumption throughout Denmark and in urban areas. Results for district heating coverage in 2020 and 2035 in the wind welfare-economic scenario.

The analysis shows that it will be cost-effective for all heating consumers not using district heating in existing district heating areas to convert to district heating. Furthermore, it will be cost-effective to convert a small number of heating consumers in urban areas without a district heating supply.
In the models with the existing subsidy and tax structure, a larger part of the heating consumption is converted to district heating, particularly in the medium term up to 2035.

A number of sensitivity analyses have been performed of the economic potential for expanding district heating. Important results from these analyses include:

- Grid connection: Generally, all possible customers are assumed to be connected to the district heating grid in new areas. By reducing this figure to 90% of the possible customers, district heating coverage is reduced by about 3-4 percentage points.
- The composition of individual heating installations: The assumed composition of heating instal lations for the consumers that are connected to the district heating grid is very important. As more consumers convert from oil-based individual supply to individual supply based on renewable energy, the company-financial potential for converting to district heating will fall.
- Heat savings: If annual heat savings are lower than anticipated, the district heating coverage will increase by 0-5 percentage points depending on the year of calculation, and on whether company finances or the welfare economy are taken into consideration. If annual heat savings are considerable, the district heating coverage will fall by 0-5 percentage points, again depending on the year of calculation, and on whether a company financial or welfare-economic approach is used.

How should district heating be produced?

Globally, biomass is a limited resource and the basis for calculations in the district heating analysis is that this limitation will have a significant effect on the Danish energy sector such that only about 70PJ in biomass and waste will be available for electricity and district heating production in 2050. Of this, 25PJ will be biogas. Assumptions for available biomass volumes are coordinated in close connection with the scenario analyses from the Danish Energy Agency in which scenarios for the overall Danish energy system are set up, including for transport and industry.

In the wind welfare-economic model, the share of combined heat and power in overall heat supply continues to be high up to 2035. After this, combined heat and power will be considerably reduced (Figure 1). The reduction at the end of the period is mainly due to developments in the international electricity market with, increasing wind power and restrictions on the use of solid fuels. Furthermore, there is a general assumption of considerably increased surplus heat in major cities . In the wind model with existing taxes and subsidies and with preservation of the combined heat and power requirements, combined heat and power, solar heating and heat pumps make up a larger part of the heating supply.