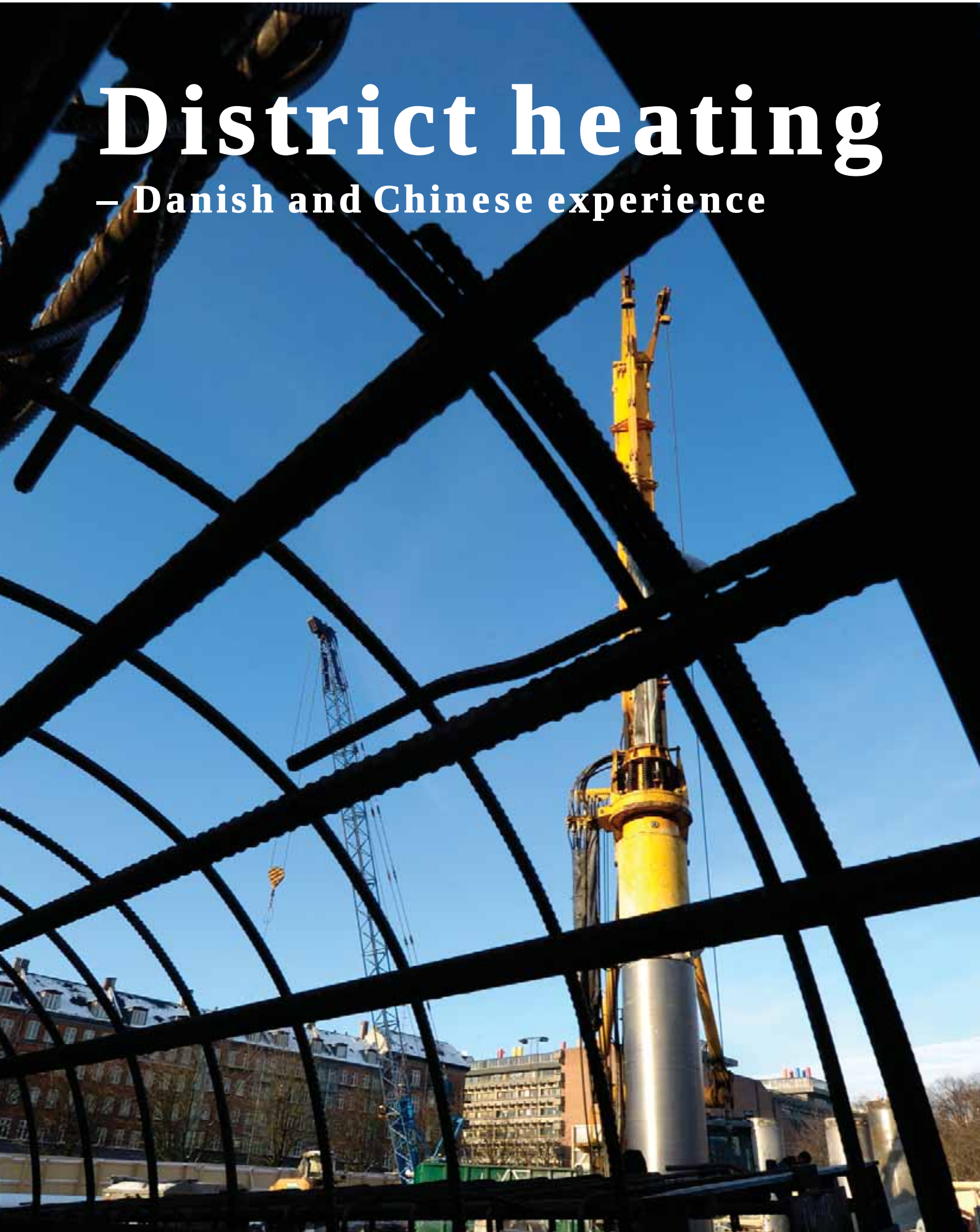
DANISH ENERGY AGENCY

DBDH

District heating

– Danish and Chinese experience



Preface

Between 250 and 300 million people live in densely populated urban areas in Chinese regions where indoor heating is required. In those areas centralized heating systems serve 70 to 80 percent of the population. The total area covered by centralized heating systems has increased tenfold between 1990 and 2004. At present, district heating plays an important role in China with half of all major cities having implemented district heating systems. But there are still opportunities to be harvested.

In Denmark, development and implementation of district heating gathered speed in the aftermath of the international two oil crises in the 1970s. As a result of comprehensive national analyses of different alternatives for supply of heat and power it was decided to focus on an expansion of the fuel efficient combined heat and power system in Denmark. The solution was district heating.

District heating plays a central role in the heat and power infrastructure in Denmark. By now, Denmark has obtained decades of valuable experience with combined heat and power plants and district heating systems. In fact, the first combined heat and power plant in Denmark was built more than 100 years ago in 1904 with the core purpose of supplying a large hospital with electricity and heat. Today, the Danish district heating system provides nearly two thirds of the total heat demand and more than half of all electricity produced in Denmark comes from combined heat and power plants. Moreover, six out of ten Danish consumers receive heat from a district heating system or a combined heat and power plant, making district heating essential to the Danish heat and power infrastructure.

With a focus on clean energy Denmark has worked closely with China during the past decade. The two

countries have now established a new common platform for cooperation on energy policy development. The China National Renewable Energy Center is a good example on how the Danish and Chinese government administrations are finding new ways to tackle challenges of energy supply and climate change. Combining district heating with renewable energy supply sources is a win-win solution with numerous possibilities that remain to be fully explored. And there are still significant potentials for further use of district heating systems in China, including further development of the use of renewable energy.

Beginning with a brief historical review of district heating in both China and Denmark this publication presents ideas on how Denmark and China with mutual benefits can work towards developing and improving district heating so it continues to be one of the best solutions for providing households with reliable, cheap, clean and energy efficient heat and power. I welcome this publication and embrace its objective.

Martin Lidegaard
Danish Minister for Climate, Energy and Building

The history of Danish district heating

Denmark is not least known for Scandinavian design and the fairytales of Hans Christian Andersen. But Denmark is also one of the most energy efficient countries in the world. The widespread use of district heating (DH) and combined heat and power (CHP) is one of the most important reasons why it has been possible to increase energy efficiency and reduce carbon emissions over several decades – a small fairytale in its own right.

The first combined heat and power plant in Denmark was built back in 1903. It was a waste incineration plant which made it possible to handle waste in an environment-friendly way, and to provide electricity and heat to a new hospital. Thereby, the plant solved two problems at the same time.

Towards fuel efficiency

During the 1920's and 1930's, a collective district heating system was developed based on waste heat from local electricity production. District heating also supplied some urban areas with heat and accounted for around 4 % of the Danish heat supply. From here on, district heating from combined heat and power expanded in the larger Danish cities and in the 1970's, around 30 % of all homes were heated with the use of district heating systems.

At the time of the energy crisis in 1973/1974, energy consumption per capita had risen to very high levels. This made it evident that it was necessary to save energy – including energy for space heating – to decrease the dependency of imported fuels and to reduce the consumers' heating expenses. Therefore, it was decided to expand the fuel-efficient combined heat and power system to not only the larger cities, but also to medium and small-size cities in Denmark.

CHP production efficiently utilises fuel, because excess heat from the generation of electricity is used in district heating systems instead of merely releasing it into the sea or air.

Modern district heating in Denmark

Today, more than 60 % of heating in private Danish houses is provided by district heating – not only for space heating, but also for hot tap water.

Denmark has six large central DH areas with a total heat production of approximately 70 petajoules (PJ) per year. There are also around 400 smaller decentralised DH areas with an annual heat production of app. 60 PJ.

In 2011, the production of district heating in Denmark amounted to 132 PJ. 76.3 % of all district heating was produced in cogeneration with electricity (CHP), thus saving around 30 % of fuel compared with separate generation of heat and power.

Nearly 700 CHP plants today

Figure 1 shows the development over the last two decades in district heating production by type of production plant.

As this figure shows, DH production from especially small-scale CHP units has developed significantly over the years. Today, Denmark has around 670 centralised and decentralised CHP plants.

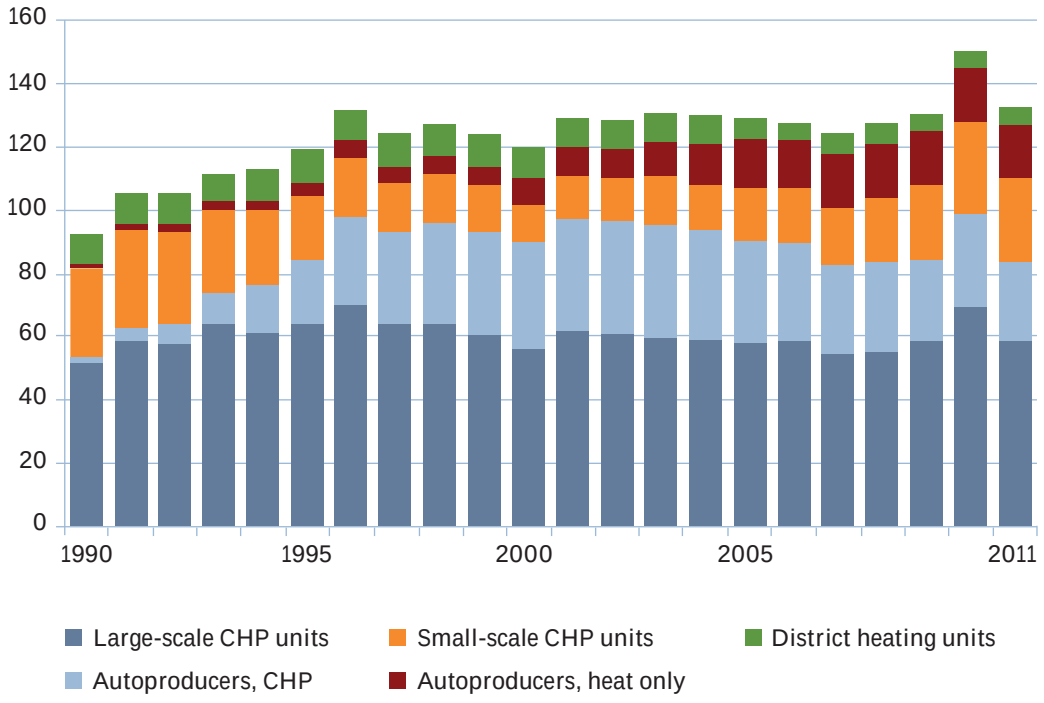


Figure 1: DH production by type of production plant

Main characteristics of Danish district heating

Denmark's relatively large central DH areas typically consist of a number of distribution networks interconnected by a transmission grid. Heat is produced at a variety of different plants including large extraction plants (based on coal, biomass or natural gas), municipal waste plants, surplus heat from industry, and peak load boilers.

An example of a large central DH area is the Greater Copenhagen DH system, as shown in figure 2. It is by far the largest system in Denmark supplying 35 PJ of district heating annually. The distance from the eastern to the western part of the system is approximately 50 km.

A variety of decentral areas

The smaller decentral DH areas are typically areas consisting of a single distribution network supplying no more than 1,000 consumers. Heat is produced by one base load unit and one or more peak load and reserve units. The base load unit is typically a natural gas CHP unit, a biomass boiler (e.g. straw or wood chips), or a municipal solid waste plant. The peak load and reserve boilers are typically simple boilers based on oil or natural gas with low investment costs. Some plants install these years supplementary solar heating or electric boilers.

Who owns the plants?

With regard to ownership of plants in Denmark, there are various forms. The largest plants are owned by large energy companies, while smaller plants are typically owned by production companies, municipalities, or cooperative societies.

Common for all DH areas in Denmark is that the supply is driven by the actual demand. Consumer installations include variable flow and measurements of actual demand which means that the consumers have an incentive to save heat. Payment for heat is most often divided on a fixed part (per installation) and a variable part (per gigajoule of consumption).

In recent years, the share of renewable energy in district heating production has increased. This is partly because some CHP plants in the large DH areas have changed from using fossil fuels to biomass. Figure 3 next page shows the development in district heating production with regard to fuel composition over the last two decades.

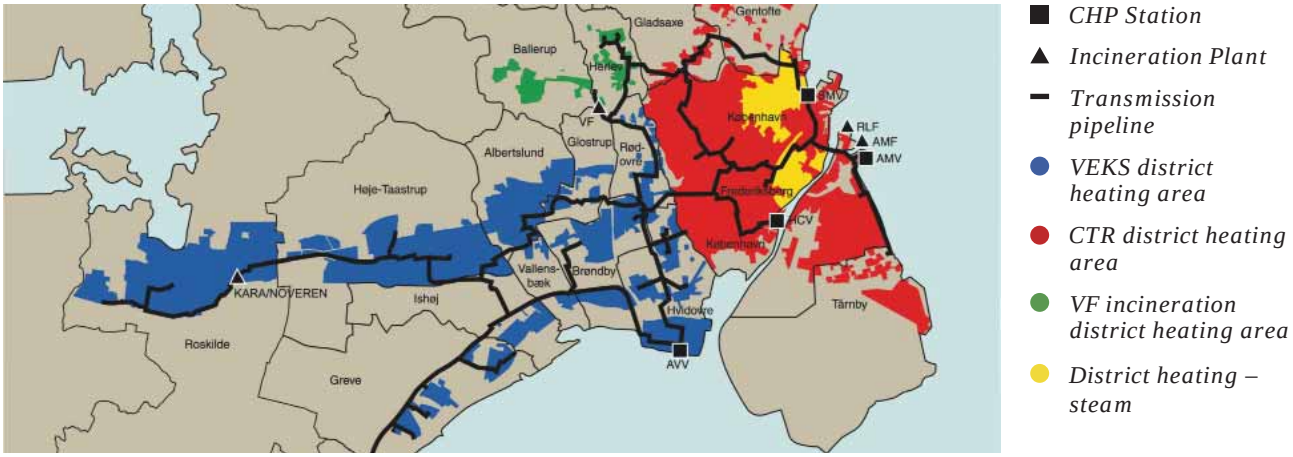


Figure 2: The Greater Copenhagen DH system – the largest Danish DH system

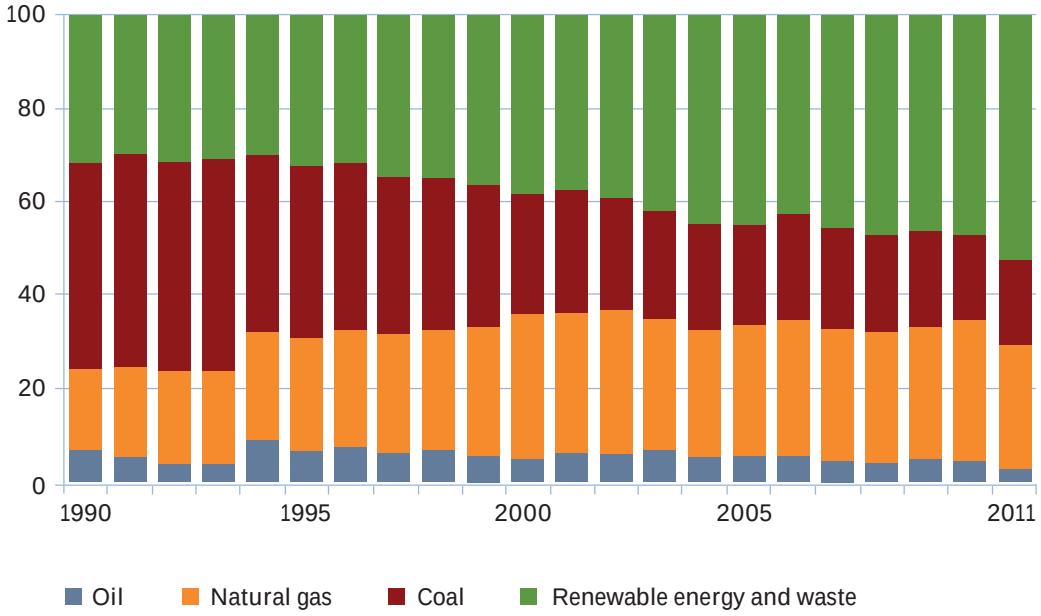


Figure 3: Fuel composition for district heating, percentage of distribution 1990-2011.

The necessity of heat storage

One very important element of both the central and decentral DH/CHP areas is that all CHP areas in Denmark have heat storages. This means that the CHP plants can optimise their cogeneration of electricity and heat according to the demand of electricity, and still be able to supply heat when needed.

It also means that CHP plants can decrease their production when there is plenty of electricity in the system, and that they can increase their production when there is a need of electricity in the system. When the corresponding heat production is higher than the heat demand, the heat is simply stored in the heat storage – and when the corresponding heat production is lower than the heat demand, heat is taken from the heat storage.

Public heat planning and the current market setup

Denmark passed its first heat supply law in 1979. The law made local authorities responsible for identifying the potential for public heating in their area.

The law of 1979 set the ball rolling and from it, other successful policies followed. Planning regulation was certainly the most important factor in the early stages of development, effectively creating the market, after which financial incentives were introduced to ensure the on-going economic viability of DH/CHP.

Today, all centralised CHP plants and most decentralised CHP plants sell electricity at the market price. Therefore, they must aspire to optimise their production according to the market price of electricity on the spot market, where prices are set for each hour. This means that CHP plant operators aim at producing most electricity and heat in cogeneration when electricity prices are high. Likewise, they try to minimise their production when electricity prices are low. This is done by active use of the heat accumulators in the system.

Subsidies for decentralised plants

In addition to the income from electricity sales on the spot market, most of the decentralised CHP plants receive a subsidy. Originally, the subsidy was granted as a feed in tariff with three different tariff levels depending on the time of delivery, but today it has been converted to an annual amount which depends on the market price of electricity.

With regard to taxes, all Danish DH producers have an incentive to use biomass as these fuels are excluded from heat taxes, whereas heat taxes are imposed on the use of fossil fuels. Furthermore, CHP producers receive an add-on of DKK 150 per MWh to the market price of electricity for electricity produced by biomass.

Investment costs versus operating costs

The establishment of DH systems requires large investments in infrastructure compared to individual heat supply options, especially because of the large investment costs in DH networks. On the other hand, the cost of operating a DH system as well as the environmental impacts are in many cases significantly lower.

This is particularly the case if heat is produced by an energy-efficient CHP unit or if heat is produced by utilising waste heat from an industrial plant, e.g. a steel plant.

The life-cycle viewpoint

When evaluating the feasibility of district heating, it is important to consider a period of years. From a “life-cycle cost” viewpoint, district heating is in many cases the most feasible solution – of course depending on among other things the heat demand and the heat density in the specific area.

The necessary infrastructure investments are in many cases paid back after some years by lower annual operating costs. The same can be said about high quality DH components which are more expensive up front than low quality components – but in many cases they are paid back by lower maintenance costs.

It should be taken into consideration that DH networks have a technical lifetime of typically 40-50 years.

The future role of district heating in Denmark

The Danish district heating system is expected to play an important role in reaching two large future political goals:

- In 2020, wind turbines shall cover 50 % of the domestic electricity supply
- In 2035, all electricity and heat supply shall be based on renewable energy.

The fulfilment of the first target increases the challenges of balancing wind power in the power system. When introducing large amounts of wind power in the system, there will be times in which the production from wind turbines covers only a minor part of the electricity demand. Similarly, there will be hours during which the production from wind turbines covers a very large part or even exceeds the electricity demand.

Different technical measures can improve the flexibility of the DH/CHP system and can help integrate wind power:

- Heat storages
- Electric boilers and heat pumps
- Bypass of turbines.

By use of **heat storages**, which are already common in Denmark, CHP plants can decrease their combined heat and electricity production when there is much electricity in the system from wind turbines and still be able to supply heat.

By using **electric boilers** and **heat pumps**, DH plants can use electricity for heat production (instead of producing electricity).

By **bypass of turbines**, a CHP plant can avoid generating electricity when there is excess electricity in the system. Instead, it can produce only heat with the same efficiency as a heat-only boiler. The flexibility of the DH/CHP system is therefore an important aspect with regard to wind power integration.

The fulfilment of the second target – which has to do with renewable energy – will require a conversion of all electricity and heat generation to renewable energy by 2035. In that respect, district heating has a big advantage because it is flexible with regard to fuels.

District heating and combined heat and power in China

District heating has been a major topic of Chinese energy policy for decades. There is a great potential for further development.

Half of all major cities in China now have district heating systems. Since the mid-1980's, district heating has experienced a significant growth. Today, the district heated floor space is almost 5 billion m^2 which corresponds to over 30 % of the total floor area in China, as shown in Figure 4.

The impressive growth of DH in China is the result of huge local efforts facilitated by sound national policies and regulations. Furthermore, in some regions industries have exploited their surplus heat in the form of DH – supported by local governments and implemented in a variety of different set-ups.

Different systems – difference in efficiency

Many new housing areas have installed large boiler stations to meet indoor heat requirements. Other residential neighbourhoods have gradually expanded their service area and have chosen to supplement the basic heat supply from CHP's with local agreements on additional heat supply from nearby industries.

A sub-optimized DH system has emerged in many areas, although optimal DH capacity design and utilization also takes place in some city areas. There are therefore huge differences between the different DH systems in China – also as far as the level of efficiency is concerned.

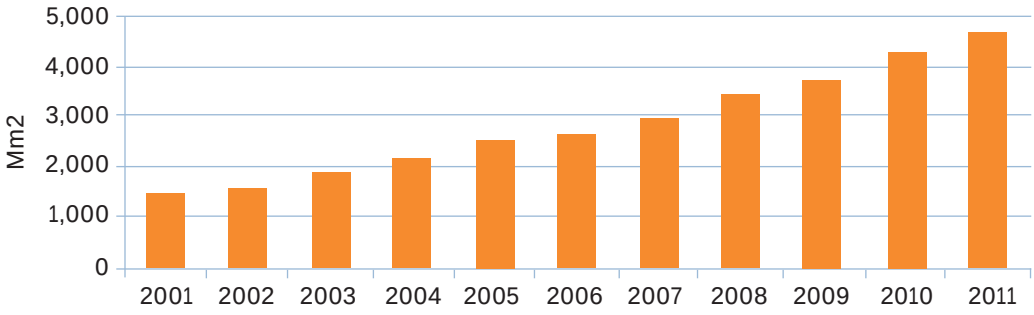


Figure 4: District heating floor space in China

New Chinese heat zones

In recent years, district heating has spread to include urban areas in Shanghai, Jiangsu, Zhejiang and Anhui – i.e. areas previously not entitled to indoor heating, as they are located in Southern China. This development may constitute the beginning of new heat zones in China.

The Ministry of Housing and Urban-Rural Development also considers enlarging the indoor heating zone even more by including the upper belt of Southern China where the temperature frequently drops below 5°C on winter days. This potential change encompasses a population of 100 million people.

Because the climate in these Chinese regions is not much different from the Danish climate, many of the obstacles and barriers for future development of DH are the same. Considering the already established and mutually beneficial cooperation between Denmark and China, this could be the next fruitful chapter in the history of Danish-Chinese cooperation.

CHP plants cover more than 50 %

In order to increase the energy efficiency and save fuels, DH has increasingly been produced on combined heat and power (CHP) plants. Today, more than half of China's district heating consumption is covered by CHP. However, there are still huge untapped potentials for CHP at the large-scale industries.

Great potential for district heating

The Chinese urbanization is progressing at unprecedented speed these years. This entails a great potential for district heating. Half of China's population now live in urban areas, as compared to 19 % in 1980. China may have as many as one billion urban residents in 2030.

In the short term, the 12th Five-Year-Plan sets a number of targets with implications for China's DH sector:

- The capacity share of CHP plants in relation to DH plants shall increase from 36 % in 2010 to 43% by 2015.
- A heating reform that covers 400 million m2 of building area in northern cities by 2015 with strengthened energy saving goals.
- 1,000 natural gas-fired CHP plants planned nationwide.
- 1,000 geothermal projects planned with a heating/cooling area of 50 million m^2.
- 100 solar thermal heating projects planned with a heating area of 1 million m^2.

Thus, China has paved the way for more renewable energy in the DH sector.

Biomass in great growth

Besides geothermal and solar thermal heat, biomass has great potential for China. By 2020, the capacity will reach 30 GW, accounting for app. 4% of total capacity. This is an increase of more than 450% in primary energy consumption, compared to 2010. It is likely that some of these new power plants could be designed as CHP's, and could thereby contribute to the development of renewable energy-based DH. Biomass-based DH could also replace the widespread coal-based boilers in some areas – which perhaps is an easier option.

The logistical challenges associated with the huge supplies of biomass warrant attention. County capitals and other large towns in the countryside are likely to be potential sites for these plants.

The future role of district heating in China

The next step to further develop Chinese DH could be a more uniform national policy. This would evoke stability and confidence building measures for investors and decision makers. The Danish history of experience in this field proves that the gains from such an approach are huge – and that it benefits local consumers as well as the state itself.

What do international experts think?

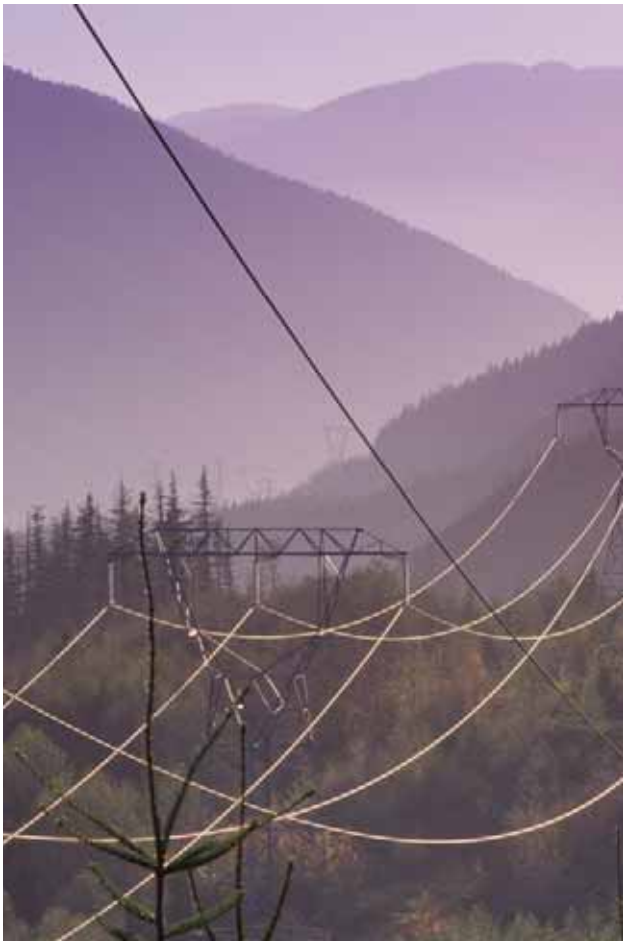
A number of experts from the World Bank, the Asian Development Bank, the International Energy Agency, the Danish Board of District Heating and other actors involved in DH in China have made a number of recommendations of both institutional and regulative character as well as on concrete policy changes. These include:

- **Rationalization of heat supply**
  Local heat and business plans should be developed. This includes plans for merging of DH companies, pooled operation, rehabilitation of outdated and low-efficient technology, and demand driven supply with variable-flow technology.

- **A policy structure in terms of energy tax and support to DH/CHP**
  Tax revenue could be used for financial support to energy efficient DH/CHP projects.

- **A heat tariff system**
  A fixed tariff combined with a variable tariff where the customer pays for the actual amount of heat to gives incentives to save heat.

- **Institutional reforms**
  Tariff increases should be approved by an independent authority according to fixed rules for true heat costs. Partially subsidized tariffs should be replaced by targeted subsidies for low-income consumers. To improve the efficiency of substations, the ownership could be transferred to the DH companies.



The Danish DH and CHP sectors are based on all of these and also other recommendations. In light of this, Denmark is in a strong position to assist the ongoing Chinese efforts to develop the DH/CHP sector in a sound and cost-effective manner. Also, Danish experiences with particularly biomass-fired CHP's and district heating could inspire future cooperation between Danish and Chinese parties.

Not just a technical challenge

As the recommendations above highlight, priority should be assigned to not only technical issues, but also institutional reforms. The Chinese government acknowledges this need and has formulated several policies in this regard.

Danish Board of District Heating

The Danish Board of District Heating (DBDH) is a private organisation promoting district energy for a green city development. DBDH represents the leading players within the Danish district heating sector.

This includes:

- Heat and combined heat and power production companies and waste incineration companies
- Heat transmission and distribution companies
- Private consulting companies, R&D institutions and training institutes
- Manufacturing companies of plants, systems, components and products for the sector
- Contractors.

DBDH implements conferences, seminars and exhibitions with the purpose of making consolidated experience available worldwide. Furthermore, DBDH develops and maintains cooperative agreements with district heating organisations abroad for the purpose of exchanging information related to all aspects of district heating.

You can read more about DBDH at www.dbdh.dk.

Danish Energy Agency

The Danish Energy Agency is responsible for handling all national and international agreements and tasks linked to the production, supply and consumption of energy in Denmark. The Agency also deals with efforts to reduce emissions of greenhouse gases, and oversees the legal and political frameworks for reliable, affordable and clean supply of energy in Denmark.

The Agency is part of the Danish Ministry of Climate, Energy and Building.

Read more at www.ens.dk.

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