CHINA’S QUEST FOR NEW DISTRICT HEATING REFORMS

Ole Odgaard examines the Chinese district heating system and assesses its challenges and need for new regulatory reforms as well as technical solutions.
This policy brief is written by Ole Olggaard (see page 12 for short bio) and published by ThinkChina. Editors: Martin Bech and Jørgen Delman.

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China’s Quest for New District Heating Reforms

In this policy brief, Ole Odgaard examines the Chinese district heating system and assesses its challenges and need for new regulatory reforms as well as technical solutions. The potential for further collaboration with Danish public and private stakeholders is highlighted.

The Policy Brief

- Argues that Chinese district heating system stakeholders lack clear guidelines and that sub-optimized district heating systems have emerged in many areas;
- Proposes that a closer co-operation between Denmark and China on technical and regulatory matters could advance and benefit the commercial exchange between the two countries.

Heat zones in China

The Chinese planning system has entitled about two-third of China to indoor heating systems – see Figure 1 (the orange zone), as the Northern provinces have a strong continental climate.

Figure 1. China’s great heat division and heating zones.

This indoor heating area includes 15 Northern provinces in cold climates, occupies 70 pct. of the national land area, and is home to 40 pct. of the population.
About 300 million people live in densely populated urban areas in China’s indoor heating zone. In those areas centralized heating serve 70 to 80 pct. of the population.

District heating (DH) is rarely assigned a supply monopoly in the feasible supply areas. Thus DH plays an important but not exclusive role in providing heat to the centralized heating systems. Individual gas-fired boilers are commonly used in the cities, while inefficient and polluting stoves and small boilers are still widely used in cities and country towns for space heating.

**District Heating**

China now ranks second after only Russia for the largest installed capacity of DH.

The total length of district heating pipes is 160,080 km. in 2012, which is more than 17 times compared to 1995. In recent years, more than 10,000 km. of pipe length is added each year.

The total DH sale amounted to 3,241 Petaloule (PJ) in 2013. The DH was originally based on steam, but has increasingly shifted towards a more energy efficient supply of hot water. Today all newly developed DH is based on hot water, which is the dominant supply form – see Figure 2.

*Figure 2. Total DH supply in China: 2001-2013.*

Half of all major cities have DH systems. DH is supplied to residential areas as well as commercial and institutional areas. Since the start of the 1990’s DH has experienced a significant growth – see Figure 3.

The supply area of DH has increased almost 20-fold from 1990 to 2013. This impressive growth has increased the supply area of DH from 2 pct. of China’s total floor area in 1990 to 10 pct. in 2013.

The market share of DH ranges at 30 pct. of the potential DH area, as DH is reserved for the centralized heating areas in Northern China only.
Residential buildings account for about 70 pct. of the total DH area, and commercial buildings account for about 30 pct.

Figure 3. Supply area of Chinese district heating: 1990-2013

However, it must be noted that industries take the lion’s share of DH for commercial buildings and process heat. Thus 68 pct. of the total DH deliveries went to industries in 2012. DH for heating in buildings makes up only 32 pct. of the total DH deliveries.

Local initiatives and new national supply zones
This impressive growth of DH is the result of mainly local efforts rather than a national blue print plan. Supply of electricity has always been a national concern, while district heating to a much larger extent has developed by local initiative. The reason is that DH is distributed and consumed locally, while electricity can be transmitted and consumed on a regional or national level.

There appears to be a lack of clear guidelines for the stakeholders. Some industries have exploited their surplus heat in the form of DH, which local governments have supported and implemented in a variety of different set-up’s. Areas with new housing blocks may have installed large boiler stations to meet the indoor heat requirement. Other residential areas have gradually expanded their service area and have chosen to supplement the basic heat supply from CHP’s with additional heat supply from nearby industries etc. A sub-optimized DH system has emerged in many areas, although optimal DH capacity design and utilization also takes place in some city areas.

In recent years DH has spread to 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 is applied mainly in public buildings and factories. It may constitute the beginning of new heat zones in
China. The Ministry of Housing and Urban-Rural Development considers enlarging the indoor heating zone by including the upper belt of Southern China, where the winter temperature is below 5 °C in cold and humid winter days. That may include a population of 100 million people.

The majority of the DH plants are based on coal, which is expected also to be the case also in the coming decades, although natural gas may enlarge its market share. In 2008, coal made up 91 pct. of the total energy supply to the DH sector, which increased moderately to 92 pct. in 2012. The DH sector represents 5-7 pct. of the total coal consumption in China. The amount of coal used for DH may be underreported, as it does not include amounts used by Combined Heat and Power (CHP) plants – the coal consumption of CHP is accounted for in the national statistics as thermal power generation.

A fairly large share of the coal-based boilers from the 1980’s and -90’s have low efficiency rates at 60-65 pct. Furthermore, in some cities, the heat loss from DH ranges at 20-50 pct. due to poor insulation and water losses. Thus, the government has promoted an Energy Conservation and Retrofit Plan on Residential Buildings and Districts Heating Systems in the Northern 15 provinces.

Future heat planning can also reap great benefits by including a compulsory analysis of alternative fuels other than coal. Similarly, district cooling ought to occupy a more prominent role in urban heat planning. District cooling gains importance as large office buildings and commercial centres are developing in parts of North China with a strong continental climate and cities in Southern China.

**Combined Heat and Power**
The more energy efficient combined heat and power (CHP) plants have been promoted vis-à-vis DH plants – see Table 1.

**Table 1. Power capacity of thermal power generation and CHP: 1995-2013**

<table>
<thead>
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<tbody>
<tr>
<td>Thermal Generation Capacity</td>
<td>189 GW</td>
<td>283 GW</td>
<td>391 GW</td>
<td>710 GW</td>
<td>870 GW</td>
</tr>
<tr>
<td>CHP Capacity</td>
<td>17 GW</td>
<td>29 GW</td>
<td>70 GW</td>
<td>167 GW</td>
<td>252 GW</td>
</tr>
</tbody>
</table>

CHP units with a capacity of less than 6 MW are not included.

CHP accounted for 9.0 pct. of the total thermal electricity generating capacity in 1995, which increased to 10 pct. in 2000, 18 pct. in 2005, 23 pct. in 2010 and 29 pct. in 2013. See Figure 4.
Since 2004, the growth in CPH has over-performed the policy targets. Firstly, by mid-2008 the 2010-target of 123 GW was reached and, secondly, in 2009 the 2020-target of 200 GW was fulfilled – 11 years ahead of schedule. In 2010, CHP made up 36 pct. of the installed DH capacity.

The above data shed light on the development of CHP capacity – not on the actual contribution of electricity and DH. The scarce data available suggests that CHP contributed 13.5 pct. of the actual electricity supply in 2005. CHP takes a more prominent share of the national DH consumption, as CHP accounted for 46 pct. of the total DH consumption by 2012. Boilers accounted for 51 pct. of the DH consumption, while 2-3 pct. was supplied by solar heating, heat pumps etc.

The CHP plants mainly use coal and natural gas as fuels. A noteworthy new regulation is that new coal-fired power plants will only be permitted, if they cogenerate heat as combined heat and power plants. Due to this policy, nearly 30 pct. of total coal-fired installed capacity is expected to be CHP.

Especially natural gas is used at the recently installed plants near the big cities with the prime purpose of supplying DH to the city population. E.g. natural gas is reported to make up 70 pct. of the current heating energy mix in Beijing’s DH system, while the share of coal has been limited to 20 pct. – other fuels contribute with the remaining 10 pct.

As gas is a more expensive fuel, coal has been replaced by natural gas to a less extent at the heavy industries, which have the largest CHP capacity in China. However, the adoption of more strict environmental regulation may well change this pattern in the coming years towards 2020.

Thus, the heat market comprises of multiple suppliers. Individual heat sources as well as collective heat supplies with a variety of fuels are present. See Figure 5, which shows the heat generation in North China.
Figure 5. Heat generation in North China: 1996-2008.

The trend is clear: DH and especially CHP are on the way to become the major heat supplier in urban China. It is a much more energy efficient heat supply, which saves fuel – often in the form of coal or gas. Furthermore, filters and scrubbers are easily installed and electronically monitored on the DH and CHP plants, which helps to combat pollution in the form of sulphur dioxide and nitrogen oxides etc.

Furthermore, there is (still) a huge untapped potential for CHP at the large-scale industries, as only 20 pct. of the CHP potential was used by 2005. Coal fired boilers still dominate, overlooking potential co-production of electricity. A notable factor for the future CHP planning and ongoing attempts to optimize the overall energy efficiency.

Potential DH markets and the present Five-Year Plan (2010-15)
The Chinese urbanization is progressing at unprecedented speed these years and entails great potentials for DH. Half of China’s population now lives in urban areas, as compared to 19 per cent in 1980, and China may have as many as one billion urban residents in 2030.

Northern China, where the need for DH is greatest, is expected to increase its building stock from 4 billion m² in 2004 to 10 billion m² in 2024.

Currently, the policies related to DH in the upcoming 13th five-year plan have not been made public. However, DH had a prominent position in the previous five-year plan and there is no indication that this should not continue in the new plan.

Looking back, the 12th Five-Year-Plan sets a number of short term targets with implication for China’s DH sector:

CHP and industrial surplus heat are on the way to become the backbone of China’s urban heat supply.
The capacity share of CHP plants in relation to DH plants shall increase from 36 pct. in 2010 to 43 pct. by 2015.

A heating reform that covers 400 million m² building area in northern cities by 2015 with strengthened energy saving goals.

Biomass are planned to supply 50 million m² of urban heating area by 2015

Ground-source heat pumps are planned to cover a heating area of 350 million m²

1,000 natural gas-fired CHP plants are planned nationwide.

1,000 geothermal projects are planned with an heating/cooling area of 50 million m²

100 solar thermal heating projects are planned with a heating area of 1 million m²

Thus, the way shall be paved for more renewable energy in the DH sector. Besides geothermal and solar thermal heat, biomass and organic waste have great potentials.

These policies signal the future DH priorities, which are expected to be strengthened in the next Five-Year-Plan.

According to the National Development and Reform Commission, the installed biomass power generating capacity should increase to 5.5 GW by 2010, which was attained. This capacity should contribute with 1 pct. of the primary energy consumption. By 2020 the capacity shall reach 30 GW, accounting for maybe 4 pct. of primary energy consumption. If feasible, some of these power plants could be designed as CHP’s, thereby contributing to the development of renewable energy-based DH in China. Furthermore, biomass-based DH could replace the widespread coal-based boilers in some areas – this appears to be 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 – not cities.

Need for reforms and new technical standards – a few examples

An economic viable DH must not only focus on efficient production of DH, the end-use of DH must also be designed in a manner to avoid waste of heat. Thus energy savings are as important as low heat fees.

The key is to improve room temperature control and to improve building thermal insulation. Heat metering and proper building energy standards are vital keys.

Lack of temperature control is widespread in China. Overheating causes 20-30 pct. of the energy to be wasted. If overheating was eliminated, 15-20 pct. of the energy used in Northeast China could be saved.

If thermostats became widespread and a more rational heat planning was adopted, lower consumer heating bills could be attained. That would also provide investments security for the DH company, as the DH demand would not decrease due to the end-users DH saving investments in
higher insulation etc. Thus the DH supply can be designed optimally and be used efficiently for many years.

The distribution of DH can also become more efficient. The national standard recommends 115-130 °C for supply and 50-80 °C for return. The design value of the primary heat network is usually 130 °C/70 °C – i.e. relatively high temperatures. Single pipes with insufficient insulation are the mainstream, which cause heat loss through the network pipes.

Heat losses are also caused by hydraulic imbalance and water leakage. It is important to have accurate flow control to substations, buildings and end-users in order to better match the heat demand with the precise heat consumption. This is often hindered by the common case of few, large substations instead of many smaller and more flexible substations. In short: Substations could serve individual buildings instead of a large block of buildings.

The distribution of DH is often inefficient due to improper selection of water pumps and large pressure drop in valves and filters. Furthermore, the leakage detection wires system are sometimes not embedded in the DH piping system, which makes it difficult to effectively monitor the water loss and thus avoid water leakage.

The efficiency potential is listed in Table 2, which shows the heat loss in a typical DH section in Beijing.

**Table 2. Loss of DH in Beijing based on a typical building’s annual heat consumption per m²**

<table>
<thead>
<tr>
<th>Different heat loss items</th>
<th>Location</th>
<th>GJ</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat loss in distribution pipeline</td>
<td>From heat generation plants to substations</td>
<td>0.005</td>
<td>1.1%</td>
</tr>
<tr>
<td></td>
<td>From substations to heat buildings</td>
<td>0.01</td>
<td>2.2%</td>
</tr>
<tr>
<td>Disequilibrium heat loss</td>
<td>Between substations</td>
<td>0.015</td>
<td>3.3%</td>
</tr>
<tr>
<td></td>
<td>Between heat buildings</td>
<td>0.03</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>Between heat users in a building</td>
<td>0.03</td>
<td>6.7%</td>
</tr>
<tr>
<td>Heat loss of excessively supplied heat</td>
<td>Heat generations</td>
<td>0.03</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>Substations</td>
<td>0.03</td>
<td>6.7%</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>0.15</td>
<td>33.3%</td>
</tr>
</tbody>
</table>

Therefore, the central government issued heat reform guidelines in July 2003, which have been revised and updated regularly. The retrofit process was direct and supervised by joint efforts of Ministry of Housing and Urban–Rural Development (MOHURD) and Ministry of Finance (MOF). The investment assessing centers and energy efficiency testing organizations were authorized to evaluate the effect of fund utilization efficiency and building energy efficiency, respectively – see Figure 6. Similar processes are still in place in the area of retrofitting.
Arrows between local governments and construction and finance sections

As mentioned, the DH sector has mainly expanded by generic development rather than by macro-level blue print planning. Thus the sector is characterized by a variety of technical, institutional and economic set-ups. A more uniform national policy is gradually developing with the heat reform and the many local pilot schemes paving the way for new policies. This may foster the adoption of new, central policies, which are needed in order to evoke stability and confidence building measures for the investors and decision makers. This is important for the development of future DH as well as retrofitting the existing installations.

The Chinese government’s new initiatives are backed up by 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. They have recommended a host of policy changes in this regard. Among the frequently suggested reforms or amendments are:

A) Rationalization of Heat Supply

- The DH sector is highly fragmented with many local heat supply enterprises. It appears that merging enterprises into a few DH companies in each city could bring forward economy of scale and more optimal heat planning.
- The very large potentials for use of industrial surplus heat to DH should be exploited. International experiences could be looked into. E.g. the EU endorsed an energy efficiency directive in 2014, which makes it compulsory to use industrial surplus heat for district heating, if the payback time is less than 4 years. This applies if a new heat production unit is build or if an existing is renovated and it has a thermal capacity above 20 MW.
• Third party access should be sought for – by e.g. tenders/biddings. If the DH market is sufficiently large, an unbundling between producers and distributors could be an option as part of a medium to long-term reform to increase competition.

• Lack of heat plans has fostered uncoordinated establishment of heat supply networks and companies. Municipal heat planning based on environmental and least-cost considerations could improve the socio-economy and heat efficiency – in some cities considerably. National guidelines for heat planning should be ensured.

• Supply of hot water for other purposes than heating should be integrated into the heat planning. Co-production and co-supply of DH and hot water could be a more energy efficient solution in many apartment blocks and neighbourhoods.

• District cooling should be part of the heat planning, where appropriate.

• The choice of fuel should be a compulsory and prominent part of municipal heat planning. The alternatives to coal, i.e. natural gas, renewables, waste etc. should be considered and analysed to a much higher degree. Guidelines with specific references and standardized methods should facilitate this.

• Many isolated coal-fires boilers with low efficiency should be eliminated, if a connection to DH network is viable or if the boilers are converted to cleaner fuels. This should be done by the preparation of heat plans and business plans.

• DH based on outdated technology with low efficiency should be rehabilitated and modernized – i.e. demand-driven DH systems with variable-flow technology, computer monitoring etc.

B) Policy Structure in terms of Energy Tax and Support to DH/CHP

• An energy tax or CO₂ tax could be added to the fuel price in order to appreciate costs and promote energy efficient DH.

• The revenues from the energy tax or CO₂ tax could eventually be used for financial support to new DH and CHP projects or retrofitting projects, according to the Danish Experiences. As explained below, the tariff system has depleted the DH companies for financial resources. Thus some kind of support could be considered in the form of a capital investment subsidy, a CHP electricity production subsidy, or a low interest loan to ease possible finance problems.

C) Tariff System

• Coal is sold at market prices, while electricity and heat are often subsidized. Full coverage of justified costs for production and distribution of DH should be reflected in the tariffs. That will enable the DH to raise finance for maintenance and to raise efficiency.

• Heating tariffs and billing systems based on a flat rate per m² should be replaced by payment for actual consumption. Heat meters and room temperature regulators etc. are rarely found in buildings before 2008. Only 400 million m² of floor area of a total 4.4 billion m² are metered, of which only 150 million m² are being billed by the meter. About 15-20 pct. of heat can be saved by converting a floor-based heating tariff to a consumption-based heating tariff, along with installation of radiator control valves.
The consumer-based tariffs should be assigned for at least the building level. Today many tariffs are based on (subsidized) costs from a group of buildings or an entire residential area with maybe thousands of residents.

The tariff should take form as a two-part tariff: 1) A variable tariff, where the consumers pay for the actual heat. This gives an incentive to save heat. 2) A fixed tariff – a capacity component – which reduces the revenue risks associated with a fluctuating demand for DH. The fixed part of the tariff ensures a guaranteed payment to the DH company, which limits the risk premium and enables the investor to achieve commercial bank loans.

D) Institutional reforms associated to tariffs

- DH companies have to submit a proposal for tariff increases to the local government with each increase in coal price. As the local governments typically prefer affordable tariffs for the consumers, tariff increase proposals are often not approved. Instead tariff increases should be approved by an (semi-)independent authority according to fixed rules for true heat costs and deadlines for administrative decisions.
- The partially subsidized tariffs should be replaced by targeted subsidies for the low-income consumers, so the true cost tariffs do not hurt the vulnerable groups. This need is highlighted by case studies, which found that the 10 pct. of consumers with lowest income used 23 pct. of their out-of-pocket expenditure for heat expenditure.
- The property boundary between the DH company and the property owner often prevents cost effective DH. The DH networks connecting the heat substation to the building are often constructed and owned by the real estate developer. The real estate owner has no incentive to maintain the substation, which cause waste of resources and energy by leaking heat and water. Thus the substations should be transferred to the DH companies – by lease, transfer of ownership or the like.
- The actual working of the typically very general directives on DH should be monitored in order to ensure a regular streamlining of laws and decrees. The responsible government body should be assigned some kind of independent authority separate from heating company ownership, operation and management, as it oversees prices and quality of services.

Conclusion

All of the mentioned challenges could be considered as inputs to China’s on-going efforts to develop the DH/CHP sector in a sound and cost-effective manner. All regulatory suggestions have been implemented and continuously made more sophisticated in Denmark. Nearly all technical solutions have been implemented in Denmark as Danish DH and CHP plants use a variety of fuels on both small and large scale plants. Thus for Danish public and private stakeholders, priority should be assigned to not only technical issues, but also institutional reforms. The Chinese government acknowledge this need and have formulated several policies in this regard.
The implementation of such institutional reforms could maybe be carried out together with more technical support for the phase-in of more renewable energy. The DH/CHP sector could eventually combine these efforts with the development of guidelines for a more responsive heat sector – i.e. a DH/CHP sector capable of adjusting its supply according to fluctuating wind power by the use of heat pumps, solar heating and electric boiler etc.

**Short bio: Ole Odgaard**

Ole Odgaard (born 1958) holds a Ph.D. on economic and institutional reform in rural China. He has been living 5 years in China from 1982 onwards. He has been employed at the Danish Ministry of Foreign Affairs, where he was posted at the Royal Danish Embassy in Beijing in 1992-1995. He is now a senior advisor at a Danish ministry – his work focuses on energy planning, renewable energy and combined heat and power in Denmark as well as energy and climate policies in China. He has published several books and many articles on China.
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