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Grohnheit, Poul Erik; Mortensen, Bent Ole Gram

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District heating as the infrastructure for competition among fuels and technologies

区域供热作为燃料与技术竞争之基础设施

Poul Erik Grohnheit¹, Bent Ole Gram Mortensen²

¹ DTU Management Engineering, Technical University of Denmark, Building 426, Produktionstorvet, DK-2800 Lyngby, Denmark, pogr@dtu.dk

² University of Southern Denmark Department of Law, Campusvej 55, DK-5230 Odense M, Denmark, bom@sam.sdu.dk

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Abstract - District heating networks offer the possibility of competition between a wide range of fuels for combustion as well as technologies for comfort heat and cooling in buildings. For decades, cogeneration of electricity and heat for industrial processes or district heating has been a key technology for increased energy efficiency. Additional technologies suitable for small-scale networks are heat pumps, solar panels and local biomass in the form of straw or biogas. For large-scale urban networks, incineration of urban waste and geothermal heat are key technologies. With heat storages district heating infrastructure can contribute significantly to balancing the intermittency of wind power.

This paper is an update of the authors' article published in Energy Policy in 2003 focusing on the European directives focusing on competition in the electricity and gas network industries and promotion of renewables and cogeneration but limited support for the development and expansion of the district heating infrastructure. It was partly based on a contribution to the Shared Analysis Project for the European Commission Directorate-General for Energy, concerning the penetration of combined heat and power (CHP), energy saving, and renewables as instruments to meet the targets of the Kyoto Protocol within the liberalised European energy market.

The update will focus on recent research on district heating in North Europe, which covers not only the physical infrastructure, but also the very important immaterial infrastructure, such as the legal and institutional framework. This includes the experience with market places for electricity trade on an hourly basis over the last two decades. Improved modelling tools and modelling experience will add to the development and performance of district heating systems.

Finally, we summarise the tasks for a European policy concerning the future regulation of district heating networks for CHP, emphasising the need for rules for a fair competition between natural gas and district heating networks and the need for integration between energy systems.

Keywords Infrastructure; District heating; Competition, Energy market, Legal Framework.

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I. INTRODUCTION

The primary intention of the EU electricity and gas directives is to make the electricity and natural gas markets part of the internal market. The overall objective has been to increase the availability of electricity and gas at more competitive prices for the benefit of the final consumers. The same objective was the motivation for the nationalisation of the electricity and other energy industries in several Western European countries – notably France, UK and Italy – a few decades earlier.

All these measures share the same strengths and weaknesses: They may increase the efficiency of energy supply by a single energy carrier – electricity or gas – by economies of scale, rational organisation and standardisation, or by introducing competition into an industry that is dominated by monopolies. On the other hand, they may be obstacles to a synergetic use of the various energy carriers at the local or regional level. The best illustration is the very different penetration of CHP for district heating in North West Europe.

This paper was originally based on a contribution to the Shared Analysis Project for the European Commission DG Energy, concerning the penetration of CHP, energy saving, and renewables as instruments to meet the targets of the Kyoto Protocol within the liberalised European energy market [1,2]. It focused on obstacles and lost opportunities for the development of district heating systems as a necessary infrastructure for further penetration of these technologies, emphasising the legal issues systems [3,4]. In recent years the concept of 4th Generation District Heating (4GDH) includes the relations to District Cooling and the concepts of smart

energy and smart thermal grids [5]. This includes surplus electricity to be used in district heating [6]. Further, promotion of district cooling may increase efficiency [7].

During the last decade several EU and national research projects have focused on the integration of low carbon and renewable technologies for electricity and heat into the European energy market.

We are using Denmark as the main example, because the penetration of district heating has gone much further than in the large countries in north-west Europe, in spite of no significant difference in climate and the urban physical structure. District heating systems is the backbone of the physical infrastructure that will allow 50 % or more of the Danish electricity demand to be supplied by wind power.

The immaterial infrastructure is just as important as the physical infrastructure for the integration of wind. Especially the physical commodity exchange (energy exchange) – Nord Pool Spot – operating the world's largest electrical power exchange with a day-ahead market and an intraday market has become an important part of the Nord European power market. The main part of Nord Pool Spot is owned by the TSO's in Norway, Sweden, Finland and Denmark.

II. INFRASTRUCTURE FOR SPACE HEATING AND COMPETITION AMONG FUELS AND TECHNOLOGIES

The infrastructures for electricity and natural gas are mature in most European countries. The natural gas infrastructure is dependent of a single fuel, which must be imported to the European Union in increasing amounts, although biomass offers an alternative within their resource limitations. The district heating infrastructure can exist in all scales, but requires a higher heat density than gas networks – and water-based heating systems in buildings.

2.1. THE URBAN HEAT MARKET

Fig. 1 describes the urban heat market as a hierarchy of building levels and heating technologies. Half a century ago solid fuelled stoves in single rooms were dominant even in urban areas. The customers were independent of collective systems and could be free to choose their supplier of coal, coke, fuel wood or paraffin. Today, these systems are found only in outdated flats. Electric heating is an additional choice that requires limited investment, but it may be too expensive for the – often poor – residents. In many cities the introduction of natural gas has improved the standard of living at moderate costs

In some countries – in particular the United Kingdom – natural gas is frequently used for water-based radiator systems supplied from an individual boiler in each flat. This system is dominant for single-family houses in areas with natural gas supply in most countries in northwest Europe. The introduction of competition in the gas sector based on the natural gas market directive has given the customer free choice among several gas suppliers. Also new technologies may become available for gas customers in the near future, which may increase fuel efficiency and competition, in particular

micro-scale CHP in the form of gas engines or fuel cells. However most of these new technologies are gas-only technologies with limited flexibility concerning base and peak load.

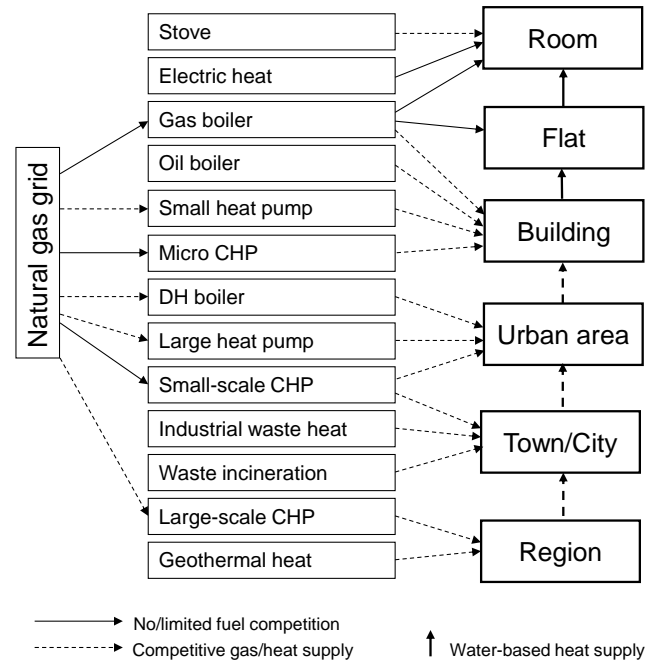


Fig. 1. The urban heat market.

The principal advantage of larger water-based heat distribution system is that they enable more competition among fuels and technologies both in the short and long term, and possible also cheaper heat supply. On the other hand, these systems require investment in infrastructure over decades and regulation, which may reduce the short-term choice of the individual consumers. District heating itself is a system in competition with other systems [8].

District heating for single-family houses is best established as a part of the development of sites for detached or terraced houses together with electricity, water and sewage. At this level competition from a natural gas grid or individual boilers may be detrimental for energy efficiency and recovery of investment. Larger groups of single-family houses with water-based heat distribution systems or blocks of flats or offices will have a local infrastructure that may be supplied by connection to an urban-wide district heating system in competition with large gas-fired boilers or small-scale CHP.

Larger district heating systems, covering a whole town or an urban region, offer more opportunities for competition between fuels and technologies for heat supply, in particular urban waste incineration, industrial waste heat, or transmission of geothermal heat.

2.2. OVERLAPPING INTERNATIONAL ELECTRICITY AND GAS MARKETS

The electricity and gas markets are becoming more overlapping. New gas transmission lines may not only have impact on the gas trade. It may also lead to further integration of the European market for wholesale electricity. With the increasing capacity of gas-fired electricity generating units, gas will be used for electricity generation, where the price of electricity is highest. The organised markets for spot and future electricity already exist. Nord Pool Spot now operates in Norway, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Germany and the UK. The spot and futures markets of Nord Pool have become a model for power exchanges in the Netherlands, Germany, Poland and Spain.

2.3. THE 'SINGLE ENERGY CARRIER' DIRECTIVES AND DISTRICT HEATING

The common rules of the two energy market directives (electricity and natural gas) are similar, but the two network industries are treated separately. The disadvantages of the separate treatment of the electricity and gas grids regarding the creation of the internal market are small, because there is only a limited potential for competition between these two types of grids. However, none of them are considering the district heating systems, although the district heating networks offer the possibility of competition between natural gas and a range of other fuels on the market for space heating.

The law and regulations regarding anti-competitive agreements and abuse of dominant position may apply not only to the electricity and gas markets but also to the heat market. However, part of the heat market is supplied by a third network industry, district heating, which provides a market for several competing types of fuels and technologies, including natural gas, various types of biomass combustion including incineration of urban waste, and combined heat and power (CHP). The heat market might be left in a regulatory 'vacuum' only regulated by national provisions and the general EC Treaty provisions, while CHP producers can be regulated by both the electricity and gas market directives and parallel national legislation. This may involve a risk of conflicts between the different set of rules.

Several of those technologies that may be victims of this regulatory conflict are supported by EU policy as means to meet environmental challenges or technologies to meet the target of sustainable development, including international obligations to reduce the emissions of greenhouse gasses.

III. CONSUMERS' CHOICE, INFRASTRUCTURE AND COMPETITION

The regulatory frameworks for district heating, electricity and natural gas are normally very different. However, some common characteristics exist, in particular with regard to large-scale district heating networks. Competition involving CHP exists in different ways. As supplier to district heating grids certain possibilities in competition with existing suppliers seem open. Vertical disintegration (unbundling)

exists also within the district heating market. There are examples of markets for district heating, which seem relatively mature and already use market mechanisms in buying heat.

3.1. HOUSEHOLD CONSUMERS

Both European and national competition authorities tend to have a bias towards cash-and-carry items with low transaction costs, and high discount rates in the choice of production technology. These features are compatible with goods and services that are internationally traded. With some innovative types of regulation, the development in the late 20th Century demonstrates that competition can be introduced in industries that were considered as natural monopolies, in particular telecommunication, public transport, electricity and natural gas.

Other markets have features that are very different from these, e.g. the real estate market. In particular the market for resident-owned housing is characterised by long-term investments, very high transaction costs, and low personal discount rates. For most individuals and families the housing market is far more important than the energy market.

3.2. LOCAL GOVERNMENT AND CUSTOMER CHOICE

A key issue in the development of district heating systems has been the role of local government and local interests in the electricity supply industry and other utilities. In some countries local government is directly or indirectly owner of utilities or has an important influence on physical planning and urban/regional development. It is worth mentioning that in those countries, where the electricity supply industry was nationalised into a single dominant vertically integrated organisation, there has been very little development of district heating systems.

Some of the traditional instruments that were used by local government for the development of these systems do not comply very well with the liberalised markets. Customer choice of supplier is a basic element of the liberalisation of energy markets. However, the individual choice by consumers may be counterproductive to the target of creating a competitive market for space heating with competition between fuels and technologies. Thus, limiting the consumers' choice on the local level – e.g. by regulation in the form of zoning that requires the use of particular heating systems, in particular district heating – will add to competition on the energy market as a whole.

The opposite of individual choices is collective decision by public planning. Such decisions may provide better solutions for the individual customers. The collective decisions may enable competition among fuels and technologies that are not available for the individual customer. In countries with tradition for individual home ownership financed by long-term mortgage loans, there is also a tradition for very strict physical planning and regulation. While new district heating grids in existing neighbourhoods may be too expensive, this may not be the case for new developments. Here, district heating becomes an alternative to investments in a new gas grid with individual boilers.

3.3. COMPETITIVE ELEMENTS IN NETWORKS FOR HEAT SUPPLY

The principle that is used for introducing competition in the electricity and gas supply industries is that generation and supply are subject to competition, while the grid activities – transmission and distribution – remain natural monopolies subject to regulation. A similar concept may be developed for district heating, either on a national level or harmonised for the Member States of the European Union.

Large-scale district heating networks have some characteristics that are similar to the electricity market. Although there is no example of an urban district heating grid with full-feature third party access and competition between many suppliers, there are examples of unbundling between competing heat producers using a variety of primary fuels and technologies, a monopoly transmission company, and several local distribution companies. The latter may be subject to various elements of competition, in particular competition between local heat production and purchase from the transmission grid.

There is now more than twenty years of experience with competition and market organisations in the electricity sector. There are only some few examples of attempts to introduce third party access and competition into district heating grids, and there are many examples of elements of competition between district heating and natural gas grids:

- Competition in the planning of grid distributed energy in new developments, where a license for grid development should be granted either to district heating or natural gas, but not both.
- Competition among heat generators (industrial waste heat, incineration of urban waste, CHP from large-scale and small-scale generators, heat-only boilers with combustion of different fuels).
- Competition among owners of boilers for peak load either through long-term contracts or a short-term market. In an interconnected district heating system, heat supply from boilers is important to overcome temporary capacity limitations in the grid.
- Outsourcing of operation and maintenance of grids or administration of supply, metering and billing of customers.
- Takeover of a district heating system by a utility company that is operating on a national or international scale
- The development and implementation of competitive elements for grid distributed energy network takes time and requires the development and implementation of new software and information systems.

The history of liberalisation of the electricity and gas sector already has numerous examples of delays and chaotic implementation due such practical issues, which are vastly underestimated in the more ideological discussion on liberalisation and competition in network energy industries.

IV. THE EUROPEAN MARKET FOR DISTRICT HEATING

In the Communication from the Commission to the Council and the European Parliament of October 1997 “A Community strategy to promote combined heat and power (CHP) and to dismantle barriers to its development” (COM(97) 514 final), it was stated that: “CHP is one of the very few technologies which can offer a significant short or medium term contribution to the energy efficiency issue in the European Union and can make a positive contribution to the environmental policies of the EU.” In 1994 less than 10 % of the electricity generation in the EU was combined production with significant variations among Member States: From more than 30 % in the Netherlands, Denmark and Finland to less than 5 % in the UK, France, Greece and Ireland. The maximum technical potential of CHP has been assessed by different studies to 40 % of the total electricity generation in the mid-1990s. In a recent study the potential for district heating in Europe has been indicated to 46 percent of all excess heat in EU27 (corresponding to 31 percent of total building heat demands) is located within identified strategic regions [9].

This potential includes CHP for both industrial steam raising and district heating and cooling. Increased energy efficiency in industrial processes and space heating will reduce the technical potential for heat supply from CHP, which is dependent of the heat densities of the local heat markets. However, past experience has shown that the penetration of CHP has been widely different in the countries in north-west Europe, in spite of no significant difference in climate and urban physical structure. The main explanation is the relative power of various institutions [2]

4.1 THE MARKET POTENTIAL FOR CHP, WASTE INCINERATION AND GEOTHERMAL ENERGY

CHP for space heating is available only via infrastructure in the form of a heat distribution system in an appropriate scale. Large extraction-condensing power stations with an electric capacity of several hundred MW will need an interconnected district heating grid for the sale of its potential for cogenerated heat. Small-scale CHP units are designed for a local water-based heat distribution system for a building, or a local group of buildings, a village or a small town.

The largest district heating systems in the European Union are in Berlin Copenhagen, Helsinki, Hamburg, Stockholm and Paris. None of these systems have been developed over a short period according to a single initial plan. They were developed over decades for different reasons by adding new elements to the existing infrastructure, often taking advantage of temporary and unusual situations, e.g. the high oil prices in the period 1973-1985. The most constant elements have been local or national actors with a consistent interest in finding ways and means for expanding the district heating markets and networks.

Increased energy efficiency in space heating by better insulation will reduce the technical potential for heat supply from CHP, which is dependent of the heat densities of the local heat markets. On the other hand, a given heat market will

become a basis for a much larger generation of electricity, because of a very significant increase in the power-to-heat ratio. The power-to-heat ratios for new combined-cycle gas turbine (CCGT) or gas engines are about 1.0 compared to 0.4 for traditional gas turbines a decade ago. Thus, the same heat market will become the basis for a much larger electricity generation.

Waste incineration. In Denmark waste incineration is an integrated part of district heating systems, delivering base load. Incineration of municipal solid waste in Denmark started in 1903 in a densely populated municipality with little access to space for landfill. The energy was used for a district heating system established at the same time and for generation for the local grid. It was built opposite to the new municipal hospital with supply of central heat for the hospital and electricity for the local grid.

District heating grew significantly during the 1960s – mainly driven by excess heavy fuel oil from the new-established Danish refineries. This gave a market for the heat from waste incineration plants, which was established in many medium-sized towns. The mismatch between the seasonal variation in the heat demand and the all year-round supply from waste incineration plants was gradually solved by expanding district heating grids and interconnection of smaller separate grids. With the high penetration of waste incineration in Denmark, the volume of incinerated waste will decrease, because waste treatment policies aim at increasing recycling on the expense of waste incineration [10].

Geothermal energy. District heating systems is an important market for geothermal energy in a larger scale. However, the Danish experience is limited. Geothermal sources are available in Denmark, but other sources for supply of district heating systems are more competitive.

District cooling. Even in a Nordic context, many buildings have a need for comfort cooling in the interest of the users. In most places, building cooling is done by means of electrically driven compressors installed in the building. The term “district cooling” refers to the arrangement where the cooling of a building is handled by centralised units which distribute cooling to multiple buyers through a heating or cooling medium via a grid. District cooling is a collective solution as an alternative to an individual cooling solution.

To simplify a little, district cooling covers two basic concepts. First, a primary solution is where cold water is produced in a facility and distributed through a network to a number of buyers. The central station can use different sources such as low temperatures in groundwater, lake water and seawater (so-called “free cooling”), and secondly energy for cooling can be obtained by utilising the energy in district heating water feeding district heating water to the end-user absorption unit which utilises district heating water to produce cooling water. The ability to convert district heating to cooling has made the technology particularly interesting to the district heating sector and thus for countries with a large district heating sector, such as the Nordic countries Finland, Sweden and Denmark.

In Finland there has been cooling in Helsinki since 1998, and now it is also used in Turku, Lahti, and Vierumäki. Denmark has not come so far; the supply of district cooling from a major public construction project only began in 2009 (in Copenhagen). The most advanced of the three Nordic countries is Sweden, where the first plant was built in 1992. Denmark has had a special District Cooling Act (Act No. 465 of 17 June 2008 on municipal district cooling) which specifically provides a basis for municipal participation in district cooling operations [7].

4.2 MODEL ANALYSES

The technology choice for electricity generation has been an important topic for traditional optimisation models, e.g. EFOM, MARKAL and TIMES, developed within the EU framework programmes and the IEA Implementing Agreement, ETSAP, www.iea.etsap.org. In a competitive market this optimisation is of limited interest. However, the same modelling tools can be useful for the analysis of different agents or market participants. A model developed for analyses of the electricity and CHP markets in the Baltic Sea Region has been used for numerous studies in many countries, including China, www.balmorel.com [11]. Very detailed data and geographical information systems (GIS) are essential tools for modelling district heating on a local level [12].

In global optimisation models, e.g. TIAM or EFDA-TIMES, which are divided into 15-17 regions, e.g. Europe or China, the district heating infrastructure can be modelled using very aggregated parameters for costs and efficiencies [13].

V. A EUROPEAN POLICY ON HEAT DISTRIBUTION NETWORKS

Numerous policy initiatives over the last decades have focused on CHP rather than district heating as a means for energy efficiency and CO₂ reduction. The emphasis from international organisations and lobbying organisations are mostly on small-scale CHP application for industries and smaller heat distribution networks, e.g. large hospitals. However, recent initiatives from the IEA are focusing on the “the network’s ability to use many heat sources including ones with renewable fuel sources” and express the concern that “market forces may drive solutions that may be shorter term than is optimum for society and discriminate against high capital technologies such as district heating.”

A community policy will be needed for support of the infrastructure necessary for further penetration of CHP, which should include framework conditions for local heat distribution networks that are compatible with the different national traditions of regulation of real property. Most of the elements for such a policy are found in existing EU legislation. However, existing legislation may contain a wide range of inconsistencies and conflicts that may be obstacles for both CHP, energy efficiency and renewables.

A community policy would also be needed to support and regulate the development of procedures for international tendering for operation of district heating networks. So far, a marked directive regarding districting heating has not been on

the political agenda. As long as district heating in Europe mainly consists of local markets it can be questioned whether such a directive falls within the competence of the EU according to the principle of subsidiarity in the Treaty. However this principle shall not prevent the EU in developing Trans-European energy infrastructure including in the area of district heading.

A key task for the Commission to promote the development of CHP would be to support the legal framework and procedures for the development of district heating grids and the interconnection between them.

The role of district heating systems for balancing wind power is becoming increasingly important. In addition to heat storages, there is a range of technologies that offer flexibility for the electric system: Electric boilers with low investment cost are useful for surplus electricity in short periods. Heat pumps and CHP require much higher utilisation times, but they operate complementary to balance wind, while producing heat. It is essential that markets and regulation offer the proper incentives for investment in both [14].

Some of the issues that were discussed in the article from 2003 [1] may be addressed in Heat Roadmap Europe [9].

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