Annex 47: Heat Pumps in District Heating and Cooling Systems

Svend Pedersen, Denmark

District heating in general, and heat pumps connected to the grids in particular, are predicted to play a key role in the energy grid and supply in the future. With the implementation of district heating, it is possible to cover up to 50% of the heating demand in Europe, and heat pumps can deliver around 25% of the energy to the district heating grid. The Heat Roadmap Europe 4 scenarios with a larger share of district heating in the energy system show that CO_2 emissions can be reduced by more than 70% compared to today's situation.

District heating replaces fossil fuels

Annex 47, which looks into the aspects of heat pumps in district heating systems, has been an important annex under the IEA Heat Pumping Technologies program, since gradually more countries realize that district heating is a way to phase out fossil fuels.

Initiating a new Annex

The project group consists of members from Austria, Denmark, Sweden, Switzerland, and United Kingdom, and during the project period the interest for heat pumps in district heating has grown in other countries. Consequently, a new annex has been initiated which looks into the "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks".

Annex 47, which started in 2016, is now finalized, and all the reports and case studies are available at https://heatpumpingtechnologies.org/annex47.

Large-scale heat pumps show great potential

The Heat Roadmap Europe 4 (HRE4) project showed that for the vast majority of European urban areas, district heating (DH) is a cost-efficient solution, which can provide at least half of the total heat demand in the 14 countries included in the study, while efficiently reducing CO_2 emissions and the primary energy demand of the heating and cooling sector (see Figure 1). Based on the results, the project also suggests that large-scale heat pumps (HP) should play a large role in future DH systems in order to develop flexible and supply-safe systems.

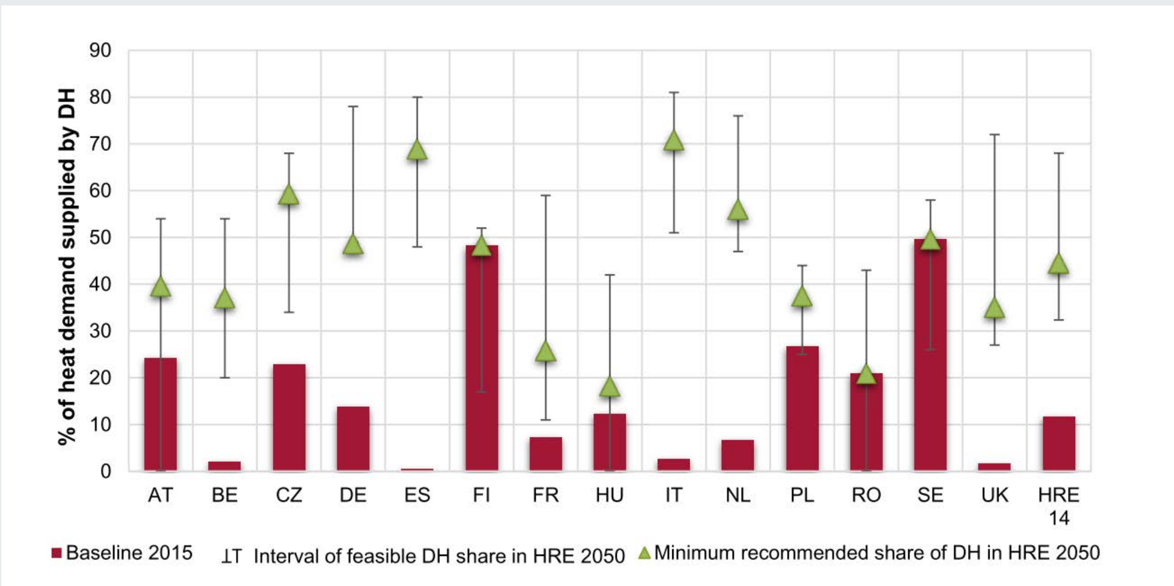

Fig. 1: Share of district heating in 2015 (Baseline 2015), recommended level of district heating share in Heat Roadmap Europe 2050, and the range of economically feasible district heating within a 0.5% total annual energy system cost change sensitivity.

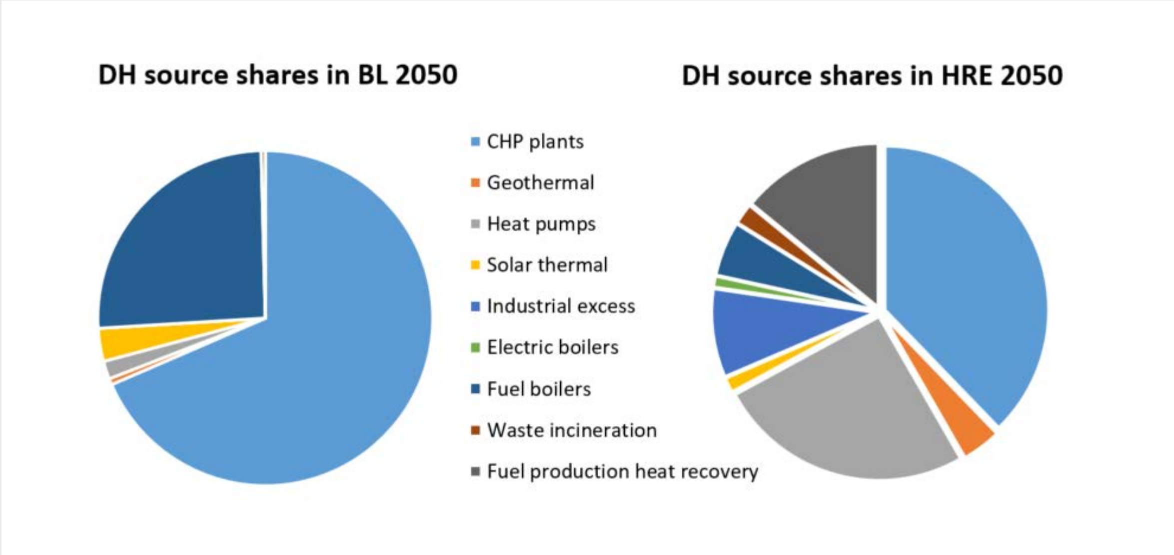

Fig. 2: District heating sources share for BL 2050 and HRE 2050 scenarios.

According to the HRE4 project, the European share of DH in the heating sector should increase from 12% (current values) to 50% by 2050. This is an important shift in the European heating sector, and it shows that DH can be cost-effective and essential to significantly reduce CO_2 emissions in the energy sector.

Three main scenarios were developed in the HRE4 project (see Figure 2):

» BL 2015 – baseline scenario representing the current situation of the heating and cooling sector, based on data from 2015.

» BL 2050 – this scenario represents the development of the baseline scenario under the current agreed policies regarding savings and RES, etc., but without any additional measures to improve the decarbonisation of the system.

» HRE 2050 – scenario representing a highly-decarbonised energy system with a redesigned heating and cooling sector, which also includes energy savings. This scenario is solely based on proven technologies and does not depend on unsustainable amounts of bioenergy.

In the modelled energy efficiency scenario for 2050 (HRE 2050), DH is supplied mostly by decarbonised energy sources, and 25% of the total DH demand is met by large-scale HPs. This scenario would bring a higher variety of energy supply to the DH, which will increase the flexibility of the system, as well as the security of supply. The HRE 2050 scenario shows that it would be possible to achieve a much more decarbonized DH in 2050 than in the BL 2050 scenario, reducing CO_2 emissions by more than 70%.

An attractive alternative

One of the main objectives of Annex 47 is to show the possibilities regarding the implementation and integration of heat pumps in district heating grids. Thus, one aim was to create an ideas catalogue, which shows different implementation cases. 39 different cases have been described where heat pumps are integrated in a district heating grid.

Research shows that large heat pumps have been integrated in the district heating networks since the 1980's, especially in the Scandinavian regions. The widespread use of district heating networks and the increasing share of fluctuating power sources such as photo voltaic (PV) and wind power, combined with decreasing electricity prices have been the driving factors, especially in Denmark. Currently, Sweden is a forerunner using heat pumps in district heating and cooling networks. Approximately 7% of the district heating demand is produced by heat pumps.

In other countries, the heat pump market consists mainly of devices for the supply of single and multi-family houses. Due to high system temperatures prevailing in many of the heating networks, adapted concepts are needed in order to be able to guarantee the cost-effectiveness of the systems. The aim of current research projects such, as fit4power2heat, is therefore to establish heat pumps by participating in various energy markets as an attractive alternative. In the last few years, many efforts have been initiated all over Europe to foster heat pump integration in district heating and cooling (DHC) networks.

Creating a sustainable system

The basis for economical operation is the correct design and hydraulic integration of the systems. Advantages can be achieved through different modes of operation. Instead of monovalent operation, additional heat generator(s) for peak load times can save a large part of the investment costs and risks.

Different circuit options can be used in order to achieve optimum operation of the system. Depending on which framework conditions exist, it is possible to exploit considerable potentials in terms of efficiency and costs. The correct design of the heat source system and the heat sink plays as much of a role as the dimensioning of the heat pump itself.

As a first clue, AIT internally developed an Excel-based tool, which can be used to pre-estimate feasibility and cost-effectiveness. With the help of simple calculations and by comparing them to already realized plants, first conclusions can be drawn. The more detailed information about the planned project, the more accurate the initial assessment can be. Through the conversion into Excel by means of VBA, and the database integrated in the tool as well as the user interface, the calculations can be carried out relatively easily and without prior knowledge of special software. The quick and easy adaptation of the underlying database is, therefore, also guaranteed.

In addition to the electrically driven compression heat pumps, thermally driven heat pumps are used as well. Depending on the field of application, the advantages of the different technologies can be used.

Best practice strategies

With reference to the results achieved by the investigations mentioned above, the importance and contributions of heat pumps in district heating networks were pointed out, and recommendations for "best practice" strategies for the operation of heat pumps in combination with a central storage unit were presented, see Figure 3:

» heat pumps with dynamic pricing and demand-side management (DSM) are more resilient to market risks as dynamic operation counteracts fluctuations in fuel and electricity prices;

» heat pumps increase the flexibility of district heating systems by expanding the heat generation portfolio, which enables higher reactivity through fast commissioning and low start-up costs as well as takes advantage of the volatility of the electricity market and thermal batteries;

» heat pumps can be used to increase renewable heat generation. In addition, low-temperature heat sources and alternative heat sources (e.g., waste heat) can be used.

Implementation barriers, possibilities, and solutions

District heating networks are essential for the future energy system, especially in urban areas. The integration of heat pumps can reduce investment risks in DH networks, increase supply security, reduce CO_2 emissions and thus contribute to the COP 21 objectives agreed on in Paris. At present, heat pumps play a minor role in European district heating networks.

Barriers to the large-scale integration of heat pumps are, e.g. the lack of heat sources (often only available in small decentralized quantities) or a low temperature level of the sources (low efficiency). Similarly, most operators (still) have a lack of experience regarding the integration and operation of heat pumps in existing district heating systems compared to well-known biomass or gas-based generation units.

Another barrier is the high temperature of the existing heat networks which reduces the heat pump's efficiency. Furthermore, the high temperatures of these networks

ANNEX 47 HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

www.heatpumpingtechnologies.org

THERMAL NETWORK OF THE JARDINS DE LA PÂLA, BULLE - SWITZERLAND

Réseau thermique des Jardins de la Pâla, Bulle

Promenez-vous sur les bâtiments avec votre sou

Fig 1: 3D view of the suppy area of the thermal network in Bulle.

Summary of the project

The neighborhood of Jardins de la Pâla in Bulle currently consists of 18 buildings, primarily newly constructed residential, office and commercial buildings. The supply of space heating, domestic hot water and passive cooling is provided by an anergy network.

The concept consists of pumping groundwater (approx. 8 – 12 °C) from a depth of 50 to 65 m and supplying a low temperature network (approx. 8 – 9 °C) via a heat exchanger. The thermal energy is transported via the low temperature network to the buildings, where heat pumps generate the heat required for space heating (35 - 45 °C) and domestic hot water (60°C). In addition, decentralised heat exchangers provide passive cooling of the buildings.

Detailed description of the project

The conceptual decision to develop an anergy network was determined by the fact that the existing geothermal resource had to be used as efficiently as possible. Since not all buildings have the same heat requirements, an energy supply via a low temperature network was

" GROUNDWATER USE FOR COOLING AND HEATING BUILDINGS IN A NEIGHBOURHOOD IN BULLE "

preferred. From a practical point of view, this decentralised solution offers greater flexibility in the provision of services. In addition, a low temperature network enables the use of groundwater as a source of passive cooling, which is essential for new buildings. Therefore, the solution to exploit the geothermal resource through an anergy network and decentralised heat pumps was selected.

The sizing of the plant was carried out by EKZ based on the calculated specific energy, power and temperature requirements of the individual buildings. EKZ then developed an energy supply concept that meets the overall requirements. The final decision to implement this project was made after the entire drilling, water exploration and pumping phase. A detailed analysis of the geothermal resource is essential and determines whether such a plant can be realized.

ANNEX 47 HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

www.heatpumpingtechnologies.or

INNOVATIVE WASTE HEAT UTILIZATION – VIENNA

Fig. 1: Schematic representation of the district heating and cooling networks operated by the Wien Energy GmbH (www.wienenergie.at, 09.01.2018)

Summary of the project

The Wien Energie GmbH operates the largest district heating network of Austria with a pipe length of about 1 200 km and about 350 000 connected households. Furthermore, the Wien Energie GmbH offers large customer solutions for the cooling of buildings.

For cooling purpose two concepts are available. The first one is called "decentralized", within this concept the Wien Energie GmbH installs a refrigeration center at the customer site to supply cooling energy. The second one is called "centralized", within this concept the Wien Energie GmbH installs a refrigeration center and supplies a certain number of customers with cooling energy through a district cooling network. The flow temperature in a district cooling network is about 6 °C.

"UTILIZATION OF WASTE HEAT OF A CHILLER FOR BUILDING AIR CONDITIONING VIA A HEAT PUMP FOR HEA SUPPLY INTO A DISTRICT HEATING NETWORK"

Within both concepts absorption and compressio chillers are used which require cooling devices fo heat rejection such as cooling towers or river wate Basically, absorption chiller demand higher invest ment cost but they may increase the heat demand i district heating networks during the summer month compared to compression heat pumps which onl need a connection to the electricity network as sourc for driving energy. An advantage of absorption chi

Fig. 3: Task cases. All the cases can be found at https://heatpumpingtechnologies.org/annex47.

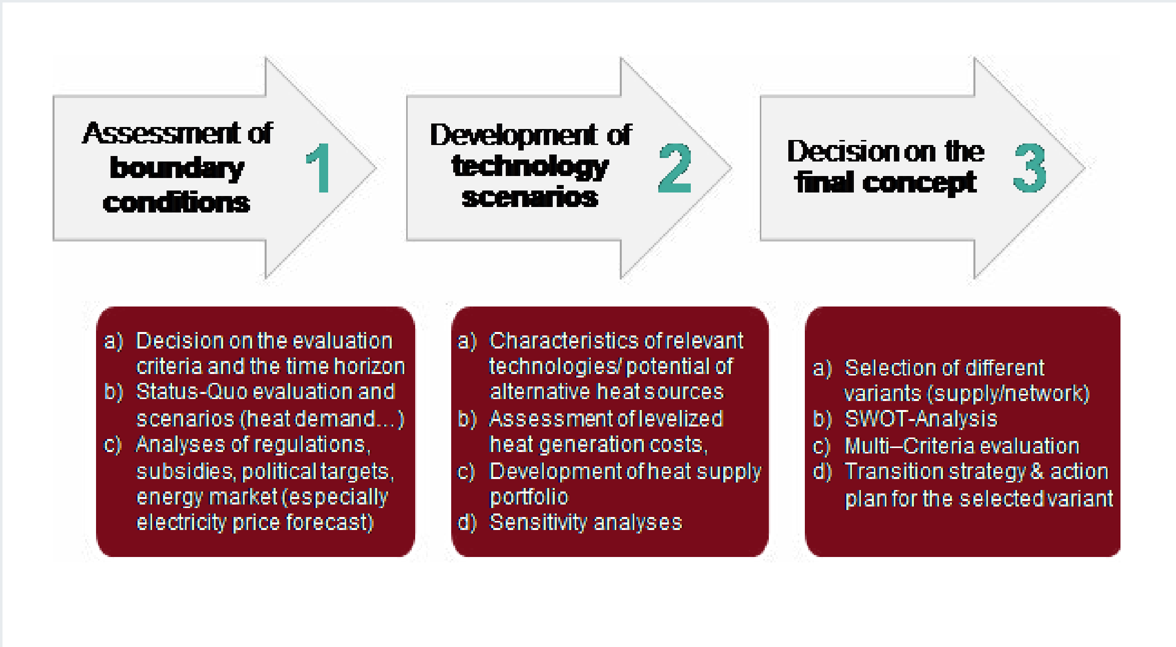

Fig. 4: Three phases for the development of a heat supply strategy (Source: AIT).

lead to large heat losses especially in residential buildings, which make heat networks almost unsustainable in very energy- efficient buildings. Thus, low temperature networks implementation would help to increase the use of heat pumps in these networks.

An opening for R&D projects

Nevertheless, in recent years there has been greater acceptance of heat pumps among district heating operators. This has led to many innovative heat pump projects. The optimum combination of heat generation plants in DH networks depends on the various parameters and is correspondingly individual for each network. A method for the development of sustainable heat supply concepts for district heating networks consists of three phases as shown in Figure 4.

To achieve a sustainable heat supply which includes a significant proportion of alternative heat sources, the implementation of more demonstration sites is necessary. The success factors are:

- » Strong partners (companies, institutes, start-ups, etc.)
- » Projects (demo, best practice, show up experiences and motivation to install HPs)
- » Learning by doing (requires pioneers who are willing to "pay their dues ")
- » Energy spatial planning (localizing waste heat, avoiding double infrastructure)
- » Standardized solutions (R&D, cost degression/ economy of scale)
- » Price signals (to the use of fossil fuel; reduce the burden from tax and levy on clean energy)

A key technology in future district heating

District heating in general, and heat pumps connected to the grids in particular, are predicted to play a key role in the energy grid and supply for the future. With the implementation of district heating, it is possible to cover up to 50% of the heating demand in Europe, and heat pumps can deliver around 25% of the energy to the district heating grid. The Heat Roadmap Europe 4 scenarios with a larger share of district heating in the energy system show that the CO_2 emissions can be reduced with more than 70% compared to the current situation.

Heat pumps can be a key technology in the future district heating grid in different ways:

1. Heat pumps can act as a balancing technology when the electrical production fluctuates.
2. Heat pumps phase out fossil fuels from the energy system.
3. Heat pumps make it possible to use very low (below 60 °C) and ultra-low (below 45 °C) temperatures in the district heating grid.
4. Heat pumps make it possible to minimize grid losses in the district heating grid.

SVEND VINTHER PEDERSEN
Senior Specialist
Danish Technological Institute
Denmark
svp@teknologisk.dk
https://doi.org/10.23697/x1qs-ps12