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Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 47

Heat Pumps in District Heating and Cooling Systems

Executive Summary

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Executive Summary

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 today's 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.

Structure of the annex work:

The work of Annex 47 has been divided in the following topics:

Task 1: Market overview: The present status and the possible changes for the future on country level as well as on European level are described.

Task 2: Demonstration projects. Different existing heat pump implementations in district heating grids are described in 39 cases.

Task 3: Reviews of different concepts/solutions: describe different implementation possibilities for heat pumps in the district heating grid.

Task 4: Implementation barriers, possibilities, and solutions: describe barriers for the integration of heat pumps as well as possible solutions.

Task 5: Dissemination.

Market overview

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. Based on its results, the project also suggests that large-scale heat pumps (HP) should have a big role to play in future DH systems in order to develop flexible and supply safe systems.

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.

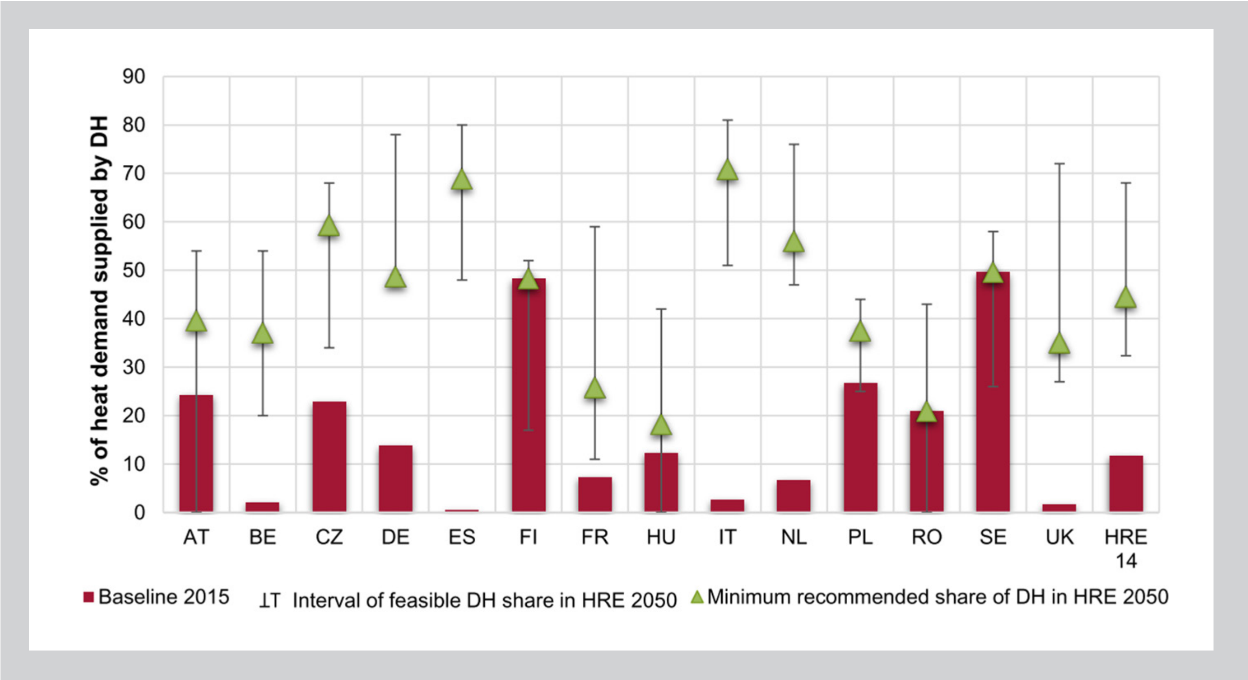

Figure 1: Share of district heating in 2015 (Baseline 2015), recommended level of district heating share in Heat Roadmap Europe 2050 (HRE2050), and the range of economically feasible district heating within a 0.5% total annual energy system cost change sensitivity [1].

In the HRE4 project, three main scenarios were developed:

- 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 redesigned heating and cooling sector that also includes energy savings. This scenario is solely based on proven technologies and does not depend on unsustainable amounts of bioenergy.

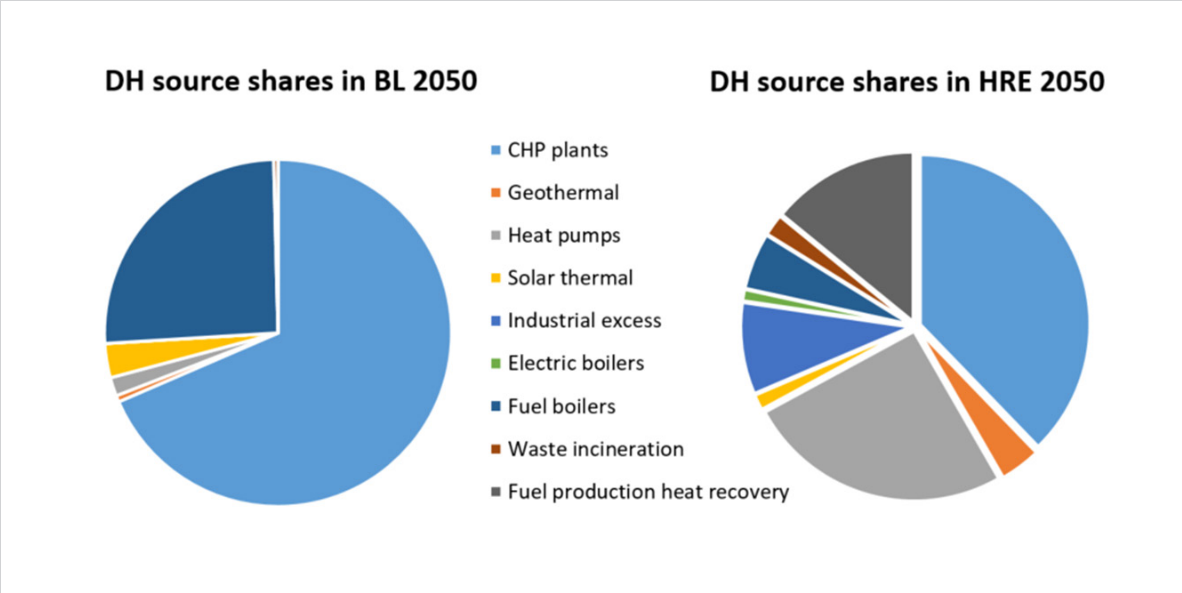

Figure 2: District heating sources share for BL 2050 and HRE 2050 scenarios [1]

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, see Figure 2**. 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, which **reduces CO_2 emissions with more than 70%**.

Demonstration projects

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. It was, therefore, an aim to create an ideas catalogue which shows different implementation cases. It has been possible for the project group to describe 39 different cases where heat pumps are integrated in a district heating grid. All the cases can be found at the Annex 47 website .

Figure 3: Task cases

Review of different concepts/solutions

The 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 as well as the increasing share of fluctuating power sources like photo voltaic (PV) and wind power combined with decreasing electricity prices have been the driving factors. 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. Because of 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. It must be mentioned that especially in the last few years many efforts were initiated all over Europe to foster heat pump integration in district heating and cooling (DHC) networks.

Above all, 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.

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

As a first clue, the 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 compare 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, also thermally operated heat pumps are used. Depending on the field of application, the advantages of the different technologies can be used.

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

- 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 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 i.a. 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 efficiency of the heat pumps. Furthermore, the high temperatures of these networks lead to high heat losses, especially in residential buildings, which make heat networks almost unsustainable in very energy-efficient buildings. Therefore, the low temperature networks implementation would help to increase the use of heat pumps in these networks.

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 as shown in Task 2.

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 is described in Task 3, and it consists of three phases as shown in figure 4.

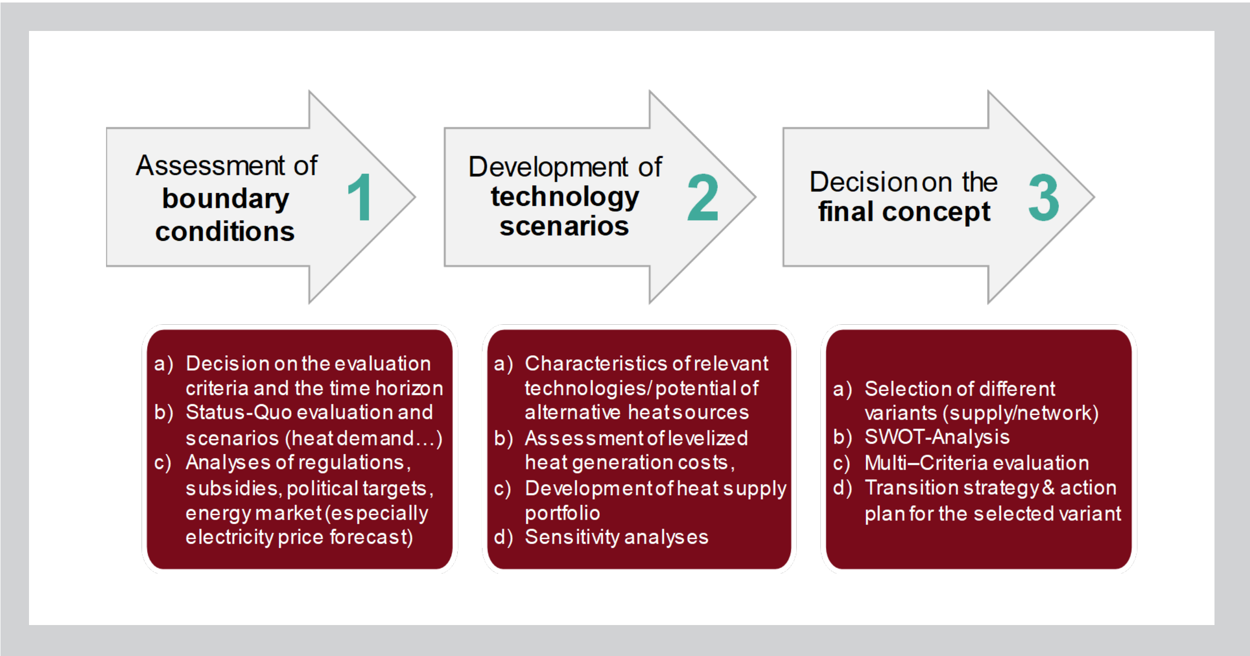

Figure 4: Three phases for the development of a heat supply strategy (Source: AIT) [7]

To achieve a sustainable heat supply, which includes a significant proportion of alternative heat sources, the implementation of more demonstration sites is necessary. 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 its 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)

www.heatpumpingtechnologies.org

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