Final report

1.1 Project details

Project title	EUDP 2016 IEA HPT Annex47." Heat Pumps in District Heating and Cooling Systems"
Project identification (program abbrev. and file)	**Journalnr.:** 64016-0087
Name of the programme which has funded the project	**EUDP-2016**
Project managing company/institution (name and address)	**Tilsagnshaver (projektansvarlig virksomhed):** **Virksomhed/institution:** **Teknologisk Institut Telefon: 72202000** **Adresse: Kongsvang Alle 29, 8000 Aarhus C** **E-mail: svp@teknologisk.dk**
Project partners	Johnson Controls Industries, Dansk Fjernvarme Grøn Energi, Ålborg Universitet.
CVR (central business register)	56976116
Date for submission	09-08-2019

1.2 Short description of project objective and results

English:
The objective of the annex is to, gather information and ideas for politicians and stakeholders and planers of energy systems in urban areas regarding possibilities and barriers regarding implementation of heat pumps in district heating and cooling systems. Its an objective to describe how heat pumps can be implemented in both new and old district heating systems in the best way.

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.

Dansk:
Formålet med dette annex er at indsamle information og ideer til politikere og beslutningstagere og planlæggere af energisystemer i byområder vedrørende muligheder og barrierer i forbindelse med gennemførelsen af varmepumper i fjernvarme og fjernkølingssystemer.
Et mål vil være at beskrive, hvordan varmepumper kan implementeres i både nye og gamle fjernvarmesystemer på den bedste måde. De forskellige typer af integration vil blive beskrevet. Vil blive beskrevet Forskellene og muligheder i integrationen i både centrale og lokale systemer.

Fjernvarme og specielt varmepumper forbundet med fjernvarmenettet forudses i projektet at spille en nøglerolle i energisystemet og energiforsyningen i fremtiden. Med implementering af fjernvarme er det muligt at dække op mod 50% af Europas varmebehov i fremtiden. Var-

mepumper kan dække op mod 25% af forsyningen til fjernvarmenettet. Heat Roadmap Europe 4 scenarierne viser at ved en større andel af fjernvarme i energi systemet vil CO_2 emissionen kunne reduceres med mere end 70% set i forhold til situationen i dag.

1.3 Project objectives

Annex 47 work 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.

1.4 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.

1.5 Project objectives

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Task 5: Dissemination.

1.6 Project results and dissemination of results

Today, there is a wide focus on using energy more efficiently. District heating and cooling (DHC) systems present a solution to increase the overall energy efficiency. A solution to increase the share of renewable energy in DHC systems is to introduce heat pumps in the system.
At the working team meeting and the National Team Meeting of the IEA Heat pump programme in October 2013 in Nurnberg, Germany, heat pumps in DHC systems were the focal points of discussion. Many subjects were discussed: How to implement heat pumps in thermal grids with multiple energy sources, heat pumps with multiple functions, e.g. domestic heating, heating of hot tap water, and the management of the demand side.
Several projects have been carried out concerning the implementation of heat pumps in DHC systems all over the world.
It is necessary to show how heat pumps can be implemented in DH systems, from large cities to urban areas or settlements, in a smart and sustainable way so that the CO_2 reduction becomes as large as possible for the entire system. It is also very important to show how the different types of implementation of heat pumps in DH systems can increase the efficiency of the DH system and increase the use of waste heat and renewable energy, both directly in the DH system, but also on the production side. Obstacles to the implementation must to be uncovered and experience from existing projects should be identified.
The objective of this Annex was to gather information and ideas for policy makers, decision makers, and planners of energy systems in urban areas concerning the possibilities and barriers related to the implementation of heat pumps in DHC systems.
One objective has been to suggest how heat pumps can be implemented in both new and older district heating systems in the best way. The different types of integration have been described. The differences and possibilities in integration in both central and local systems have also been described.
The possibilities of increasing a larger share of renewable energy or using excess heat in the different systems by using heat pumps have been a focus area and so has the minimizing of the system losses by using heat pumps.
Existing projects where heat pumps are integrated in district heating systems have been described for each participating country (Austria, Switzerland, Sweden, Denmark, UK).

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, is 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.

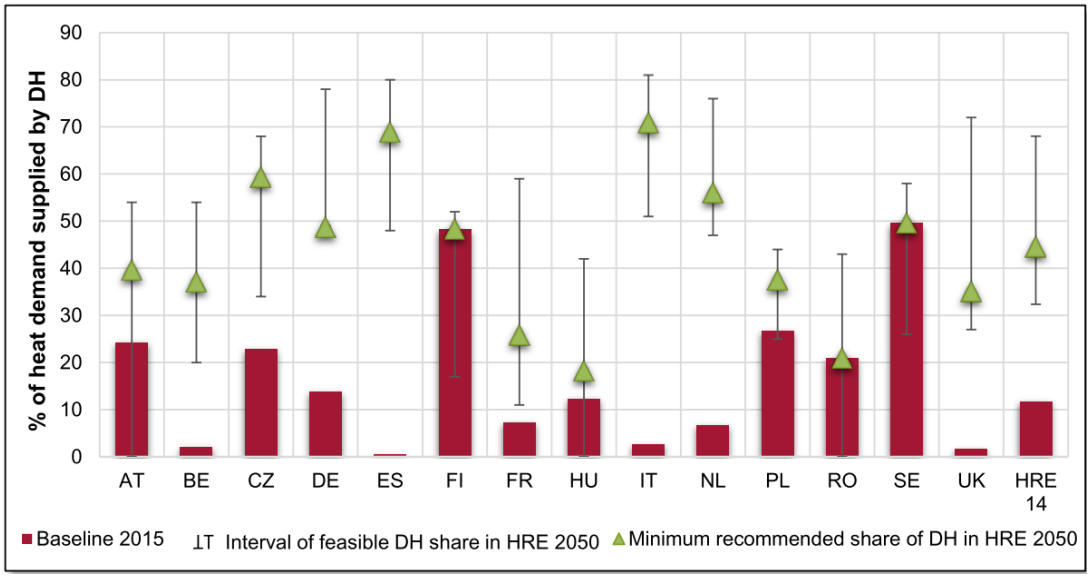

Figure 1: Share of district heating in 2015 (Baseline 2015), recommended level of district heating share in Heat Roadmap Europe 2050 (HRE2050), and the range of economically feasible district heating within a 0.5% total annual energy system cost change sensitivity [1].

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.

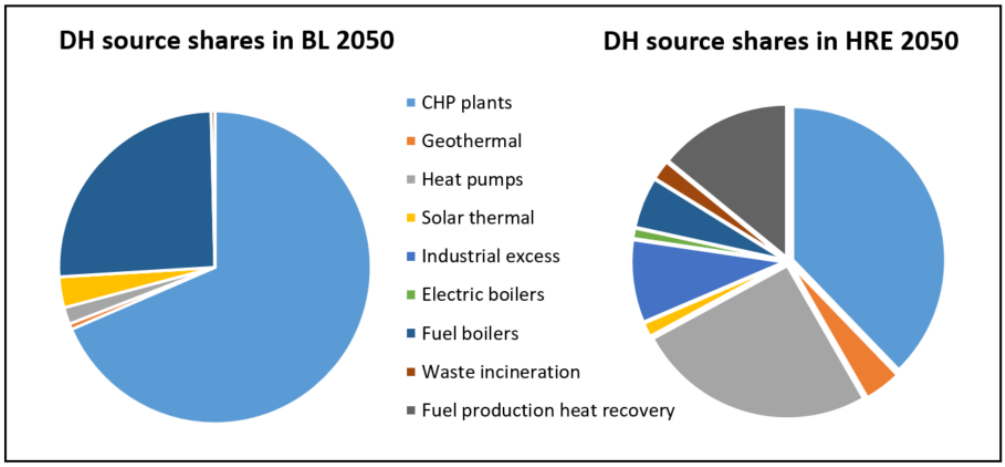

Figure 2: District heating sources share for BL 2050 and HRE 2050 scenarios [1]

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 webpage[1].

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,

[1] https://heatpumpingtechnologies.org/annex47

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 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 heat pumps efficiency. 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.

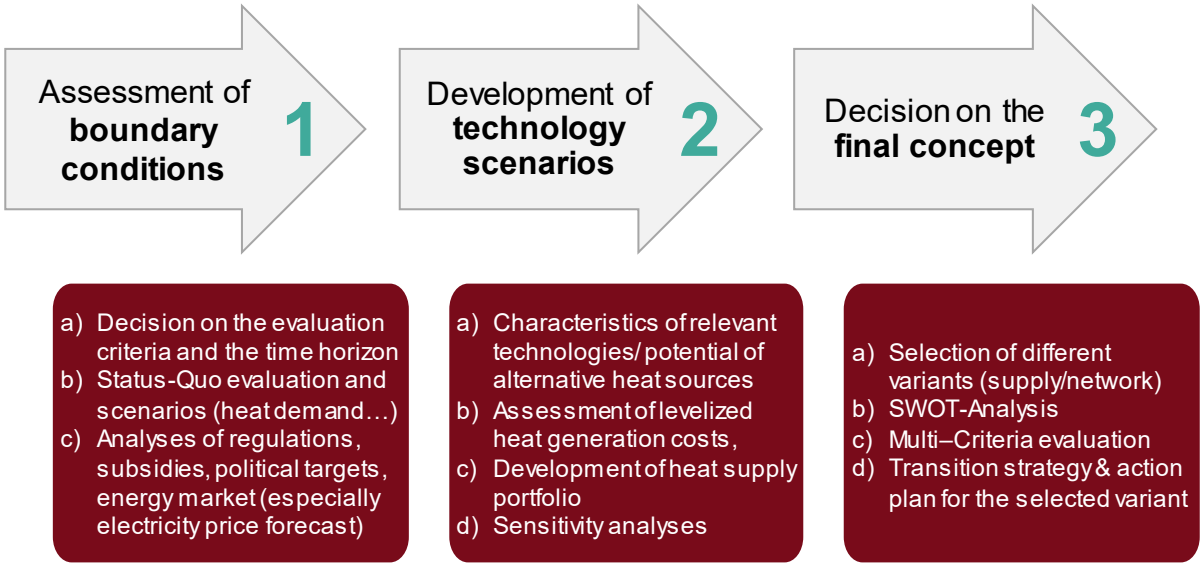

Figure 4: Three phases for the development of a heat supply strategy (Source: AIT) [7]

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)

Dissemination of the results

The results of the project and all the reports, presentations and articles are available at the IEA Heat Pump Center webpage. At the webpage are all the implementation cases described as well, as an inspiration catalogue. https://heatpumpingtechnologies.org/annex47/

The project has been presented at different conferences:

Workshop/conference name	Date	Presenter	Title of presentation
European Heat Pump Summit. Location; Nuremberg.	October 2017	Svend Pedersen	Annex 47 Heat Pumps in District Heating Systems
4rd, 4DH Conference, Copenhagen	2018	Dr. Ralf Roman Schmidt	
4rd, 4DH Conference, Copenhagen	2018	Diego Hangartner	

1.7 Utilization of project results

The project shows that the energy saving potential and the market for heat pumps in District heating systems is huge and it's growing. District heating is in many countries seen as one of the solutions to decarbonisation and to increase the efficiency of the heating sector. Since the project started has the interest in heat pumps in district heating been growing. Barriers within the heat pump sector are minimized and heat pumps are now seen as a solution to make a better link between the electrical grid and the district heating grid.
The interest in the project has increased and there is a huge interest in a new following project regarding district heating and heat pumps, also from the IEA TCP for district heating and cooling.
Johnson Controls are selling more heat pumps for district heating systems and the case stories made in the project are good examples for new project developers.

1.8 Project conclusion and perspective

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:

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4: Heat pumps make it possible to minimize grid losses in the district heating grid.

The project has showed that the potential is huge, and heat pumps and district heating is definitely one of the key solutions if the political goals regarding decarbonizing of the heating sector, phase out of fossil fuels and should be reached. Heat pumps are also one of the solutions to create more flexibility in the electrical grid which means that the use of renewable sources can be increased.

Based on the results of the project has the Executive Committee for the IEA TCP for Heat Pumping Technologies encouraged the project group to create a follow up project regarding heat pumps in district heating systems. The project group has based on the results made a new annex proposal in collaboration with the IEA TCP for District Heating. The international interest is growing and new countries are showing interest in a following project.

Annex

All reports and presentations are available at the webpage:
https://heatpumpingtechnologies.org/annex47/