Case Studies

https://heatpumpingtechnologies.org/annex57/

ANNEX 57

Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks

Demo No.: D-005	Location/City: -	Country: Austria
Title (short and full title): fit4power2heat Exploratory study of heat pump pooling concepts in urban district heating networks		
Schedule of the demo project (research study): 2017-2019		**Year of realisation:** -
Leader organisation (owner, constructor, solution developer, research inst., etc.): AIT Austrian Institute of Technology GmbH		
Participating organisations – demonstration project part (involved other organisations): ENGIE Gebäudetechnik GmbH ENGIE Energie GmbH		
Budget of the demo (invest/monitoring etc.): € 250k		
Published articles (paper, article etc.): • Terreros, O. et al.: fit4power2heat – Sondierung zur Realisierung des Wärmepumpenpooling für städtische Wärmenetze. Final Report 2019. https://nachhaltigwirtschaften.at/de/sdz/projekte/fit4power2heat.php • Terreros, O. et al.: Electricity market options for heat pumps in rural district heating networks in Austria. Energy, Volume 196, 1 April 2020. https://doi.org/10.1016/j.energy.2019.116875		
Country: Austria	**Participating Organisation:** AIT Austrian Institute of Technology GmbH	**Contact/name:** Johanna Spreitzhofer

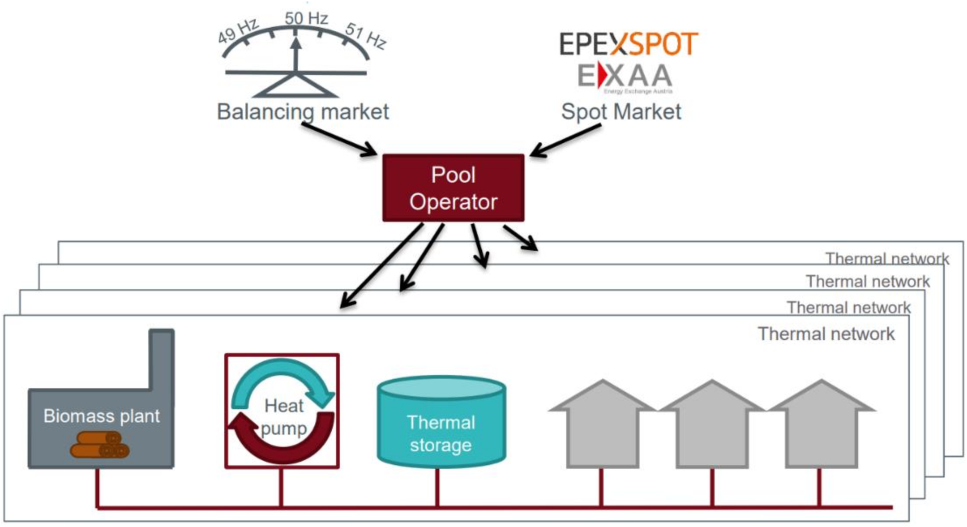

Figure 1 Overview of the fit4power2heat concept

Homepage address: https://nachhaltigwirtschaften.at/de/sdz/projekte/fit4power2heat.php

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Project classes:

RD&D status

Large-scale demonstration (results based on measurements)	Lab scale (results based on measurements)	Design study (results based on simulation)
☐	☐	☒

Type of heat pump

Decentralized HP (cold district heating)	Centralized HP with a district heating system
☐	☒
Heating	Cooling
☒	☐

Heat source of HP: flue gas, sewage water

Power supply for HP (electricity grid, PV, wind turbine etc.): electricity grid

Buildings

New buildings	Existing buildings	Mix of new and existing buildings
☐	☒	☐
Residential	Non-residential	Mixed use
☐	☐	☒

Energy storage

Battery storage		Thermal energy storage	
Centralized	Decentralized	Centralized	Decentralized
☐	☐	☒	☐

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Control for the flexible heat pump operation

Heat driven control[1]	Predictive control[2]	Rule based control[3]
☐	☒	☐

1. General description of the project

The aim of the project fit4power2heat was to develop and investigate innovative business models enabling the economic integration of heat pumps in small and medium urban heating networks by creating synergies between the heat and the electricity sectors. One main focus was the application of heat pump pooling over multiple heating networks, to enable the participation in various electricity markets (day-ahead spot market and balancing markets). Small and medium sized cities offer high potentials for integrating heat pumps due to a) less complexity of the heating network supply structure and players, b) in general lower supply and return temperature levels and c) a good availability of sources for the heat pump (e.g. waste heat, sewage water channels).

2. Building and system description of the project

Figure 1 shows an overview of the fit4power2heat project concept. In Austria there is a large number of small biomass-based district heating networks, which were built about 20 years ago. They are reaching the end of their technical lifetime and are operating with lower efficiency compared to modern plants. Installing additional heat pumps in those grids can improve the overall efficiency of the heat plants, by utilizing the flue gas as a source. Several heat pumps within different heating grids can be operated in a coordinated way, forming a heat pump pool. This allows the heat pumps to become active participants in the different electricity markets, like the day-ahead spot market and the balancing markets (manual and automatic frequency restoration reserve, mFRR / aFRR).

In fit4power2heat, this concept was analysed with simulations, using a techno-economical optimization model of the heating systems and the interaction with the electricity markets. Various scenarios were calculated, comparing different types of heating grids, different heat sources as well as different electricity markets.

[1] Operation of heat pumps to the cover heat demand depending on ambient temperatures
[2] Operation of heat pump using a model based heat demand prediction
[3] Heat pumps are controlled by a set of predefined rules (e.g. heat pump operation with blocking time)

3. Energy supply – scheme of the heat supply system:

The analysed heating grids consisted of biomass boilers and thermal storages. The heat pumps were integrated in two different ways: In the first option, the flue gas from the biomass boiler was used as the source for the heat pump. In the second option, an external heat source was used, namely sewage water.

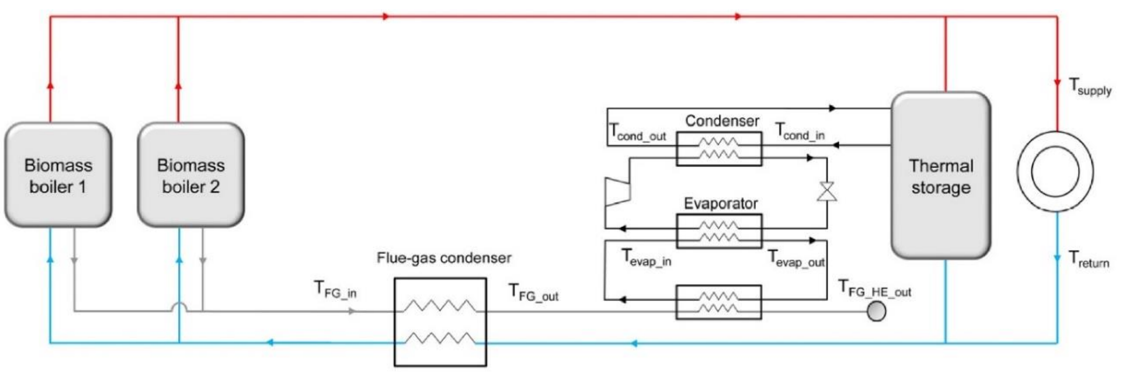

Figure 2 Scheme of the heat pump integration using flue gas as a source

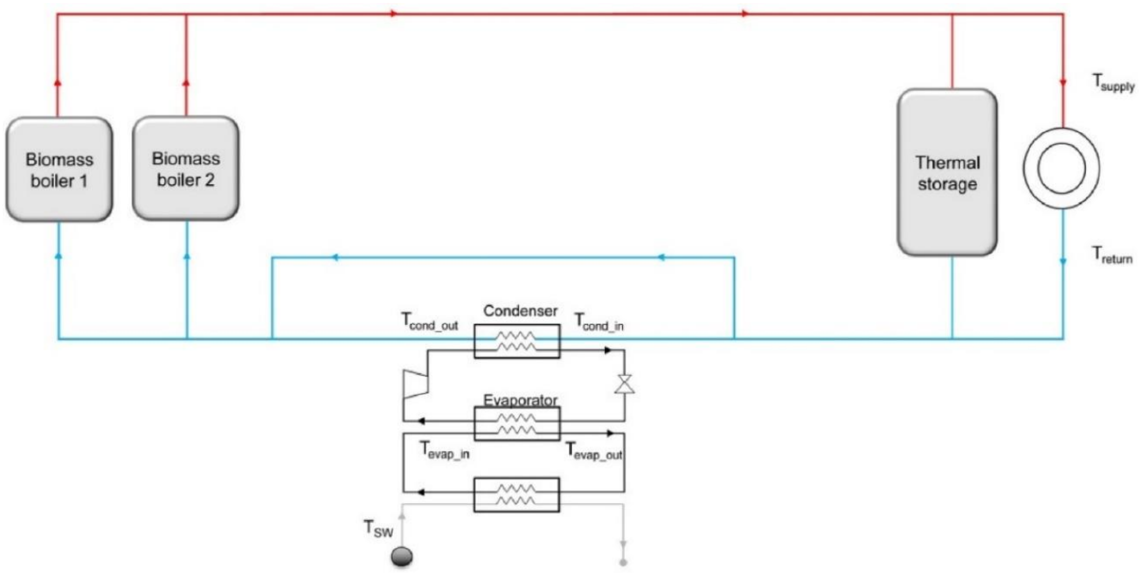

Figure 3 Scheme of the heat pump integration using sewage water as a source

4. Flexibility – scheme and control strategy of the system:

To simulate the behaviour of the heating system, an operational optimization model was developed, using mixed integer linear programming. The model provides the cost optimal operation strategy for the components in the energy system. These components, which include the biomass boilers, storages and heat pumps, were imported into the model in the form of unit specific data. The input data for the biomass boilers and heat pumps considered the nominal capacity, efficiency, minimum partial load operation, ramp-up rate, operation costs and fuel costs. The storage parametrization was based on the capacity, thermal loss factor and the minimum stage-of-charge. The electricity market was parametrized based on energy prices, power prices and market call probabilities.

5. Description of the business model with a flexible HP-operation

In fit4power2heat two different business models were developed, both from the perspective of the heat plant operator. The first one considered the investment in all new system components, including the biomass boiler and the thermal storage tanks. In the second business model, only the investment in the heat pump was considered; it was assumed that the other components were already existing and still functional. According to the simulation results the feasibility of both business models could be shown. However, the increase in EBIT (earnings before investments) was only moderate (up to 8% in the best case). Therefore, the associated risks must be further assessed when making the investment decision. The most profitable use case was the one using flue gas as a source for the heat pump and providing automatic frequency restoration reserve. It was best for the heat pumps to bid low energy prices and therefore increase the call probability for aFRR.

In order to counteract the high investment costs, alternative financing models such as contracting, external financing (crowdfunding, crowd investing, crowdlending) and leasing could be further analysed.

6. Results of the project

Through integration of heat pumps in small district heating grids and participating in the electricity markets, heat generation costs could be reduced by up to 17,7% for the use cases with flue gas as a source for the heat pump, and up to 27,5% for the use cases with sewage water. An example of those results can be seen in Figure 4. According to the feasibility assessment, the use cases with flue gas present the highest profitability. According to a sensitivity analysis, the results are mostly influenced by fluctuations in the biomass price and call probabilities from the balancing markets.

The project showed that heat pumps can be active players in the electricity and heat sector. They can increase the hosting capacity of the power grids and counteract high investment costs for grid expansion. They can also expand the capacity of the district heating network and allow new customers to be connected. They also extend the lifespan of existing biomass boilers by reducing annual operating hours. Heat pumps improve the overall efficiency of the system and result in higher profitability. The profitability of the networks can be further improved by heat pump pooling. Energy costs can be reduced by optimizing energy purchasing at times when prices are low in the day-ahead market.

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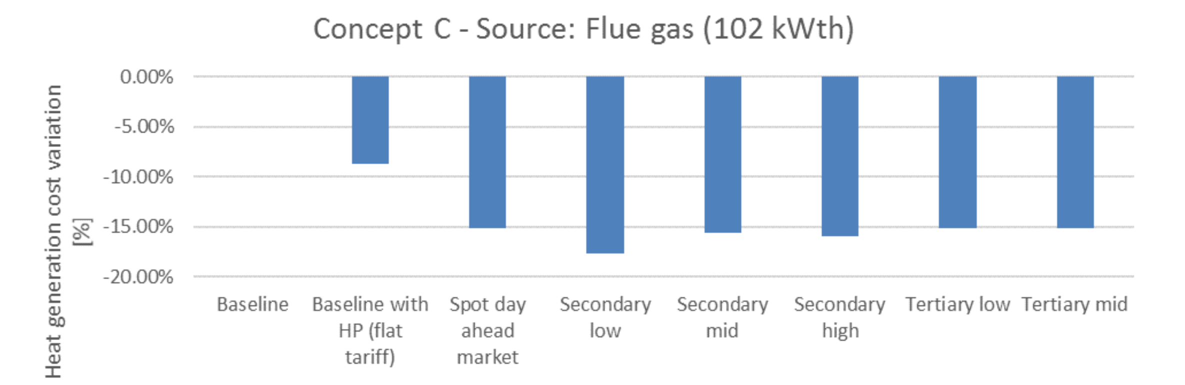

Figure 4: Resulting reduction of heat generation costs through participating in various electricity markets, in one of the simulated heating grids

7. Challenges / socio economical barriers and opportunities

The socio economical barriers for the integration of heat pumps in district heating include:

- Changing political framework
- Lack of trust
- Lack of standardised solutions
- Lack of know-how (especially for small heating grid operators)