ANNEX 47 | HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

REPORT

IEA Heat Pumping Technologies Annex 47

Heat Pumps in District Heating and Cooling Systems

Task 4: Implementation barriers, possibilities and solutions

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1 INTRODUCTION

The integration of renewable and alternative energy sources can reduce investment risks in heating networks, increase security of supply and at the same time reduce CO_2 emissions and thus contribute to the COP 21 objectives.

At present, many operators of district heating (DH) networks are facing an uncertain future due to fluctuating energy and fuel prices, competition from other energy sources and declining specific heating demands of buildings. To reduce fuel consumption and increase security of supply, it will become increasingly important to integrate alternative heat sources into heating networks. Renewable energy sources such as solar or geothermal energy and ambient heat as well as waste heat from industry and service sector will play a big role in the future energy systems. Heat pumps (HP) are particularly suitable for making use of low temperature heat sources (e.g. waste heat).

The use of alternative heat sources in heating networks can increase the overall efficiency and reduce both CO_2 emissions and investment risks. This contributes directly to maintaining the future viability of heating networks.

Heat pumps raise the temperature of a heat source (e.g. air, surface or ground water, soil, water bodies [1] and waste heat from industry and service sector) with the help of drive energy (usually electricity) to provide temperature at desired level on a heat sink (district heating network). The smaller the temperature difference between heat source and heat sink, the more efficient are heat pumps. For the integration of heat pumps in heating networks, it is important that the heat source has the highest possible temperature level or to have low-temperature networks. Another possible heat source is the use of flue gas condensation in thermal combustion plants. In some countries, flue gas condensation is already being operated with the help of heat pumps in some biomass boilers and CHPs.

This report identifies and describes lessons learned and recommendations for action as well as the technical, legal, social and ecological barriers and opportunities for heat pumps in district heating networks. These are based on discussions with various stakeholders in several workshops. In particular, the results of the project "heat_portfolio" (FFG project funding number: 848849 [2]) are highlighted. Finally, some possible solutions and business models are outlined.

1.1 Need for action

Many district heating network operators are currently facing economic difficulties due to fluctuating and unsure energy prices (e.g. rising fuel prices and low electricity revenues). The following need for action can be identified to reduce fuel consumption and increase security of supply:

- In order to reach national/international climate and energy targets, it is necessary to integrate significant shares of renewable heat sources (e.g. solar/geothermal energy) and power-to-heat plants (e.g. ambient heat via HPs). However, these sources are often small-scale or decentralized and/or have a low temperature level and/or are not (simply) controllable over time.
- Energy efficiency needs to be increased throughout the conversion chain, one key factor is reducing system temperatures. This allows the usage of (unavoidable) waste heat potentials from industrial processes, reduction of heat distribution losses and pumping costs but also transport capacity increasement.
- Development of new business models that meet future requirements, such as i) trend towards smaller, decentralized systems, ii)) stronger customer and service orientation, iii) increased interaction with the power system and iv) investment risk minimization in generation plants, grid infrastructure and storage facilities.

1.2 Current generation structures of heating networks in participating countries

1.2.1 Austria

About half of the energy used for district heating in Austria comes from biomass (15%) and waste incineration (25%) as well as industrial waste heat, geothermal energy and other sources (8%), the other half is produced from fossil sources, mainly natural gas (40%) [3]. Highly efficient combined heat and power (CHP) plants are mostly used for district heating generation in urban areas. In some cases, gas-fired CHP plants cannot be operated profitably longer owing to changes on the international energy markets (e.g. low electricity and high gas prices). Due to the difficult economic conditions of CHP plants, production has increasingly shifted to heat only boilers (HoB) in recent years [3]. Biomass (especially in the form of wood chips) plays an important role in many rural heating networks. The local availability of biomass can currently be assumed to be sufficient; in 2011 about 7% of the wood intended for energy usage[1] was imported [4]. However, there is a risk that world market prices will rise in the medium- to long-term due to rising demand and the competition for use due to material recycling. Another challenge is the phasing-out of subsidies in many biomass heating (power) plants.

1.2.2 Denmark

The heating demand for households and industry is covered by district heating 48% and district heating supplies 63% of all households with heating. In 2013 was 72,8% of all district heating produced in cogeneration with electricity (CHP), almost 50 % was produced at large scale CHP units and around 16 % produced at Small scale CHP units. The energy for district heating is mainly from waste used at waste incineration plants 48% which are placed near to urban areas. Around 30% of the energy used is from gas mainly used at smaller CHP plants and 16 % from coal used at larger CHP plants. The trend during the last decade has been that coal is phased out and waste has been implemented as energy source. At rural plants has there been a change in the production from small gas driven CHP engines to gas boilers, or straw or wood boilers and in the last couple of years has thermal solar plants and heat pumps also been implemented in the production mix. The reason for that change is that more wind power is implemented in the electricity production.

1.2.3 Sweden

Today four heating technologies dominates the Swedish heating market: district heating, heat pumps, electrical heating and biofuel boilers. District heating covers over half of the total heating demand, while heat pumps and electrical heaters together has one third of the market [5]. In Sweden there is district heating in 285 of the county's 290 municipalities [6] and the total grid extends to approximately 24,000 km. The major part of the district heating companies is publicly owned, whereas some large like Vattenfall or E.ON. are not. District heating has had a significant growth in delivered energy since mid-20th century, with a flattening trend during the last couple of years primarily because of market saturation. There is a positive contribution to the district heating deliveries from new building construction, which however is (partly) compensated for by more energy efficient buildings [7].

The dominating fuel for production of district heating in Sweden is biofuel (41%) followed by waste incineration (22%), flue gas condensation and industrial waste heat together stands for almost 20%. The share of fossil fuels is low, only 4% of the mix [8]. 2016 7% of the district heating was produced by heat pumps. The amount of heat pumps rapidly increased during the 80s and stabilized with a heat production around 7 TWh/a, but since year 2000 the share of heat pumps in the mix has slowly decreased from 16% to 7% 2016 [9].

[1] Since saw by-products and bark from imported round timber are also used for energy recovery, the total share of imported timber in energy recovery is higher.

1.2.4 Switzerland

According to the Swiss Association of District Heating (in German VFS), about 30% of the energy used in district heating systems comes from waste incineration, around 40% from biomass and 30 % from fossil fuels. Heat pumps cover an insignificant part of it (less than 1%). These data date back from 2010 [10] and according to an update list from 2019 (not published yet) from the Programm “thermal networks” [11] in collaboration with the VFS, the share has significantly moved towards the use of ambient heat with heat pumps. Biomass and waste heat still account for 40% and 30% respectively, but the share of fossil fuels has dropped to about 20 % and heat pumps account for roughly 10 % now. The share of district heating to total heat demand (85 TWh/a) has estimated to increase within the last decade from 6% (5 TWh/a) to about 11% (9 TWh/a). In Switzerland, district heating systems can obtain subsidies from the “Programm Wärmeverbünde” from the Stiftung Klik [12] for each ton of CO_2 saved compared to a reference system. Thank to this program, many wood-based district heating system were realized in the last decade. The subsidy system is secured until 2020 and is likely to renew for several more years.

2 BARRIERS FOR THE INTEGRATION OF HEAT PUMPS

At present, heat pumps are used throughout Europe, primarily for production of domestic hot water (DHW) and space heating for individual heating systems in residential buildings [13]. Heat pumps in district heating networks (e.g. [14], [15]) are emerging in most European countries[2]. For instance, in Sweden about 7% of district heating is provided by heat pumps. In Swedish district heating networks, wastewater, sea and river water as well as industrial waste heat are the main sources for heat pumps. At present, the seasonal performance factor (SFP) is around 4.1 [16]. The motivation to use heat pumps in district heating can be divided into the following areas:

1) usage of low temperature alternative heat sources (e.g. too low temperature level for direct feed-in)
2) enabling other alternative energy sources (e.g. waste heat)
3) link to the power system (e.g. participation in the electricity market, balance of energy domains, reduction of grid bottlenecks through demand side management)
4) reduction of the network temperatures through the (decentralized) use of heat pumps
5) increasing transport capacities (e.g. using the return line as a source, install decentralized units at hydraulic bad connections)

Although heat pumps can be beneficial to DH networks, there are still underrepresented. Implementation barriers were identified and discussed based on stakeholder workshops and literature recherche. Figure 1 gives an overview of aspects and challenges which were considered to address the barriers. The outcomes are summarized into three categories (social-, economical- and technical barriers) and displayed in Figure 2.

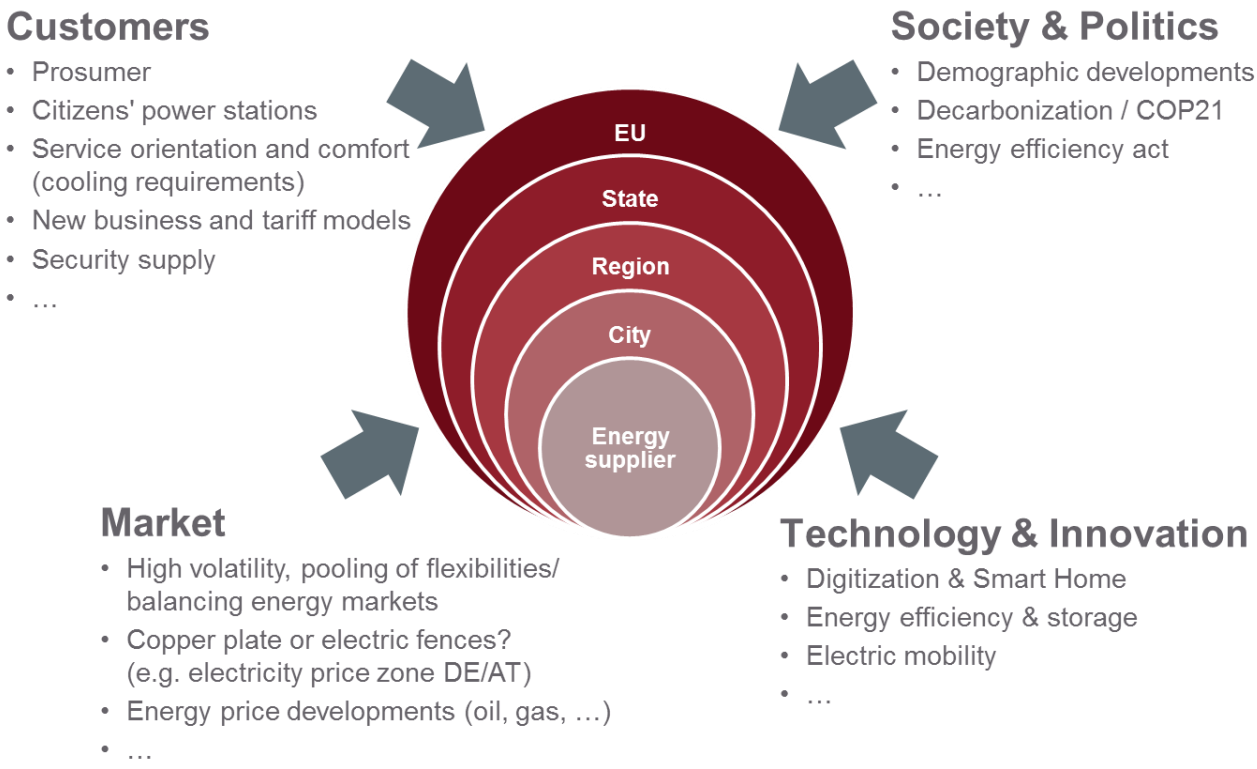

Figure 1: Aspects and challenges for district heating network operators / energy suppliers (Source: AIT)

[2] The Task 2 (Description of existing DHC systems and demonstration and R&D projects with heat pumps) report summarizes national demo sites. Available under: https://heatpumpingtechnologies.org/annex47/publications/

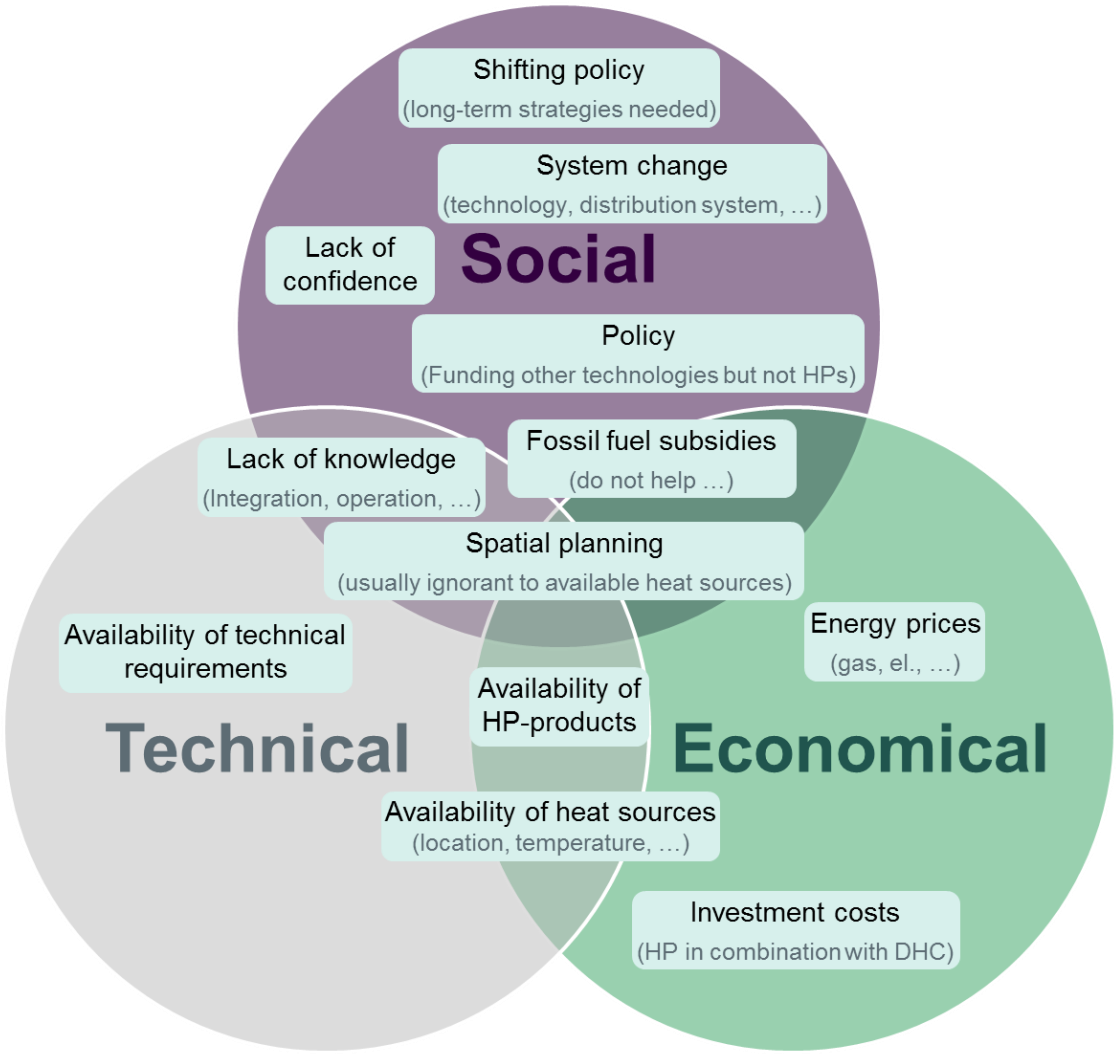

Figure 2: Social-, economical- and technical barriers for heat pump integration into district heating networks (Source: AIT)

Shifting policy *(long-term strategies needed)*
Current legal framework conditions are not suitable for a significant share increase of HPs in DH networks. Changing governments mostly develop their own climate and energy strategies with changing funding schemes, which gives low planning reliability for cost-intensive projects for the long-term.

System change *(technology, distribution system, …)*
HPs represent a competitive situation to biomass
While biomass boilers focus on heat generation, HPs are increasingly focusing on electricity (high connected loads, etc.). Services such as participation in the energy balancing market could generate additional income, but from the point of view of the small biomass operators this is too expensive or the knowledge about this "new business" too low and thus the risk too great.
Comparison with biomass boilers
It is often more economical to use a biomass boiler for new heating networks. If the capacity within a heating network is increased, retrofitting with a heat pump can be interesting, especially in combination with flue gas condensation. Another positive factor is the greater flexibility / diversification in generation (optimization according to biomass and electricity prices).
Risk for standard business
"Standard technologies" such as gas-fired boilers, biomass boilers and CHP plants characterize the generation of DH. "Novel" technologies such as HP are still regarded as innovations in the DH sector. Since

the generation concept is of a different value, it is a risk for conventional business. Above all because changes in the value-added/production chain are imminent (established and functioning processes such as fuel procurement/logistics are changing).

Lack of confidence

No standard heat generation unit in DH systems

The technology has existed for decades (keyword refrigerator) and in many Scandinavian countries there is also some experience. However, the HP is not yet established as standard technology in European heating networks. This gives rise to a certain amount of skepticism regarding integration, operating characteristics and long-term experience.

Competitive concepts (including solutions) are missing

From the point of view of the workshop participants, competitive concepts for the HP integration are still missing or there is not yet sufficient standardization. Each integration or large heat pump is still a "special design" with special requirements. As a result, there is currently still a lack of confidence, especially in the operating mode after commissioning.

Sensibility - especially in winter regarding exergy

From the thermodynamic aspect, the sense of heat pumps is questioned. The use of electricity for heating purposes is criticized, especially in winter, when the COP is lower (higher network temperature and a lower source temperature depending on the heat source).

Policy *(Funding other technologies but not HPs)*

Lack of coordination of subsidies at federal and state level, for example for green electricity (heat pumps), resulting in non-utilization of synergies (e.g. storage). Lack of financing incentives for large-volume infrastructure investments such as long-term storage or large-scale HPs. While for other renewables subsidies exist, incentives for HPs are still missing. Legal requirements for the prevention of Legionella are in some countries more restrictive (e.g. Austria) than in other countries (e.g. Sweden) which makes standardization of technical concepts more difficult.

Fossil fuel subsidies *(do not help …)*

As long as there are still subsidies for fossil energy sources, there will be high entry barriers for alternative energy sources. Fossil subsidies should be gradually reduced and replaced by renewable sources.

Lack of knowledge *(Integration and operation)*

HPs are not yet an established technology in the DH networks. There is a lack of both internal and external (planners, suppliers, etc.) know-how. Furthermore, integration into existing networks, including producers, is not yet state-of-the-art. While large network operators can use external companies (national, international), it is difficult to integrate HPs into existing networks (lack of personnel, capital, etc.), especially for the large number of small biomass networks. In addition, biomass technology is widespread (e.g. Austria) and can look back on many years of reliable partners and manufacturers. The operators are familiar with the technology. Smaller repairs can be done by themselves.

New domain (heat and electricity)

The addition of a new domain (electricity in addition to heat) brings with it additional requirements/regulations or requires new/further know-how (technical, organizational, regulatory, etc.). This creates additional hurdles, especially for rural heating network operators (corresponding resources required).

Spatial planning *(usually ignorant to available heat sources)*

Intelligent energy planning should avoid the emergence or continued existence of double infrastructures (e.g. DH and gas network at one site). These could also be DH preferential areas, for example. For example, there are no holistic tools existing, giving overview of development areas and possible heat sources.

Availability of technical requirements *(high-temperature applications)*

Demand is seen above all for high-temperature heat pumps. From some point of view, the current heat pump cannot yet fully meet technical requirements. Market readiness is viewed critically.

Availability of HP-products *(missing overall database)*

There is no satisfactory databases of product/technology and market overview of established manufacturers, their offers and implemented projects available[3]. There are some suppliers of large HPs, but only a handful of manufacturers are producing these systems. In addition, large HPs in the MW-range have several months of production/delivery times. Regarding product, technology and market assessment, independent institutions are regarded as trustworthy and necessary.

Availability of heat sources (location, temperature, temporal …)

(Waste) heat source(s)

A high availability of the heat source is required to achieve a high operational hours and thus low heat generation costs. However, the availability of the heat source does not always match the demands (e.g. certain sources are smaller, especially in winter, where they are most needed). Availability of waste heat from industries depends very much on the process and on the economic situation. A major barrier is the uncertainty of the economic situation of companies. The time horizon for economic considerations and budget plans is usually 2-3 years, whereas heat suppliers plan with periods of 10-20 years. The different time periods are mentioned as the main barrier for the implementation of waste heat feed-in in DH networks (e.g. even if the economic efficiency can be proven, this can be a no-go criterion).

It should be noted that an increasing feed-in of waste heat and decentralized heat sources, higher interaction with the electricity grid via heat pumps and possible new market players, such as storage providers, require an increased need for coordination in the planning, design, implementation, operation and renovation of networks.

Temperature levels

Often the ratio between heat source (especially at ambient heat) and heat sink (DH network temperature) does not match to achieve sufficient COPs and thus corresponding economic efficiency. The usage of two-stage HPs helps to achieve higher COPs, but the investment costs are quite high compared to the efficiency gain.

Energy prices (*Electricity and fuel prices)*

The economic decision for integration of heat pumps is very depending on the energy prices. When gas is cheap and electricity expensive, heat pumps do not pay off.

Investment costs (*Costs and geographical proximity for the development of heat sources)*

The investment costs (CAPEX) of heat pumps are significantly higher compared to conventional heat generators. On the other hand, the operational costs (OPEX) are much lower. Due to low COPs, air is hardly considered as a heat source and deep drillings have high costs. The development of waste heat sources is seen most favorably (however, other points are to be considered here as described above). Water bodies or cooling water from power plants are another option. For all sources, the closer, the cheaper the connection and the better the economy.

[3] An overview of manufacturers and products (no guarantee of completeness) is given in Task 3 of the Annex. Task 2 extracts some best practice examples on a country base.

3 POSSIBLE SOLUTIONS

For the integration of heat pumps in district heating networks, general solution options were developed within the project and described below (see subchapters). These possible solutions could also necessitate innovative business models (see chapter 4). Within stakeholder workshops possible solutions were discussed. The outcomes are summarized into the same categories as the barriers and displayed in Figure 3.

Figure 3: Possible solutions and aspects that could promote heat pump integration into district heating networks (Source: AIT)

3.1 Holistic heat supply strategies

The optimum combination of heat generation plants in DH network depends on the most varied parameters and is correspondingly individual for each network. In the following, a method for the development of sustainable heat supply concepts for district heating networks integrated in the overall energy system in the target triangle of supply security, sustainability and economic efficiency is presented and the respective tools are explained. One focus is on the integration of alternative heat sources (e.g. HPs). The following approach is divided into the three phases:

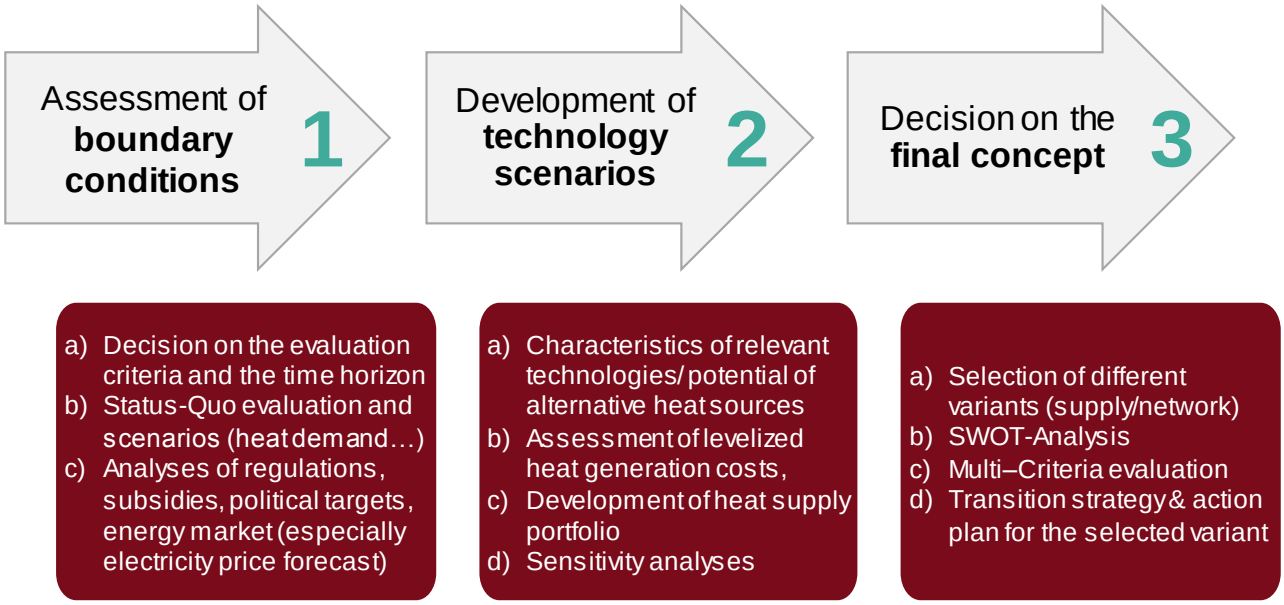

Figure 4: 3 phases for the development of a heat supply strategy (Source: AIT)

3.1.1 Assessment of boundary conditions

The first phase creates basic principles for the further considerations in phases 2 and 3 and includes the following aspects [2]:

a) Coordination of the **evaluation criteria** (including the calculation methodology and parameters; e.g. share of renewables) and the time horizon to be considered (e.g. 2030/50) with the stakeholders involved to achieve a high degree of acceptance of the heat supply concept.
b) **Status quo evaluation** and **scenarios**: Evaluation of the existing generation plants of the network infrastructure and the consumers regarding the status quo according to the above-mentioned evaluation criteria and elaboration of perspectives in the required time horizon. The creation of scenarios for the development of heat demand and network temperatures as well as the analysis of hydraulic restrictions in the network is important.
c) **Analysis** of **energy** and **climate policy framework conditions**: Focus on forecasting electricity and fuel prices. This also includes the consideration of current or foreseeable developments or (binding) objectives on the part of the city/community, the (federal) government and the EU as well as socio-political objectives, including relevant taxes and subsidies.

3.1.2 Development of technology scenarios

In the second phase, different technology scenarios and generation portfolios are developed and evaluated as the basis for decision-making in phase 3 [2]:

d) **Characteristics** of generating plants/potentials of alternative heat sources: Research and consolidation of the techno-economic characteristics of relevant new plants, in particular (partial load) efficiencies as well as investment (CAPEX) and operating costs (OPEX). Estimation of the available or technical potentials of the relevant heat sources (heat pumps, biomass and waste, solar thermal energy, deep geothermal energy, waste heat, etc.)
e) Calculation of **heat generation costs** based on full-load hours of the relevant generation technologies. This allows a rough overview with the help of simple assumptions for economic efficiency calculation and efficiency of the technologies.
f) **Development** of **generation portfolios** for different years based on the respective heat demand curves and considering heat generation costs and, where applicable, existing plants.
g) **Sensitivity analysis** with the aid of application and operational optimization for different external boundary conditions from phase 1 (electricity and fuel prices, heat demand and investment costs). In this way, the robustness of the individual scenarios against future changes is tested.

3.1.3 Decision on the final heat supply concept

The final concept development in phase 3 summarizes the results from phase 2 and compares all scenarios [2]:

a) **Selection** of **different scenarios** (generation/grid): Consideration of the compatibility of generation and, if applicable, heat grid options and testing of grid hydraulics.
b) **SWOT analysis** of the individual production technologies considering qualitative criteria from phase 1.
c) **Multi-criteria evaluation** using a standardized, weighted decision matrix for all meaningful generation portfolios. Where possible, individual portfolios are valued based on quantitative data (economic and ecological parameters) and the results of the SWOT analysis (technical and other criteria). Weighting criteria with each other as well as the respective sub criteria with each other.
d) **Transition scenarios** and **action plan** for the selected variant: derivation of necessary implementation measures and a reasonable time schedule for transformation of existing plants and installation of new plants.

3.2 Sector coupling/ hybrid energy systems

This is the concept of joint planning and design as well as joint operation of different energy domains, e.g. power-, gas- and heating/cooling systems. Since these energy domains are usually individually optimized, the integration of various coupling points between the domains and thus an examination of the interactions beyond the traditional domain boundaries makes it possible to optimize the entire energy system.

Figure 5 represents the universal structure of a hybrid network, consisting of different energy domains. In addition, a hydrogen network is shown here as a possible future energy domain. Using coupling points such as CHP processes, power-to-heat and power-to-gas technologies, energy can be transformed from one domain to another and then directly consumed or stored. In view of CHP plants, it can be stated that parts of a hybrid network already exist. In a fully developed hybrid network, however, all centralized and decentralized coupling technologies (e.g. generation units, storages, …) are fully integrated [17].

In hybrid energy systems, for example, the following significant synergies result: the use of heat pumps/ e-boilers at times of favorable electricity prices can i) increase the share of renewable energy sources and the security of supply in the heating grid, ii) increase the capacity and own consumption in areas with a high degree of local electricity production from PV and wind energy and iii) hydraulic bottlenecks in the heating network can be avoided/reduced.

Key challenges of hybrid energy systems are:

- high technical complexity, whereby a dynamic behavior on different time scales must be considered.
- considering mutual interactions and dependencies of the respective networks at different time constants, from fractions of a second in the power network to hours and days in the heating and gas network.

Such systems are still the subject of research, including the associated business models and the necessary changes in the boundary conditions.

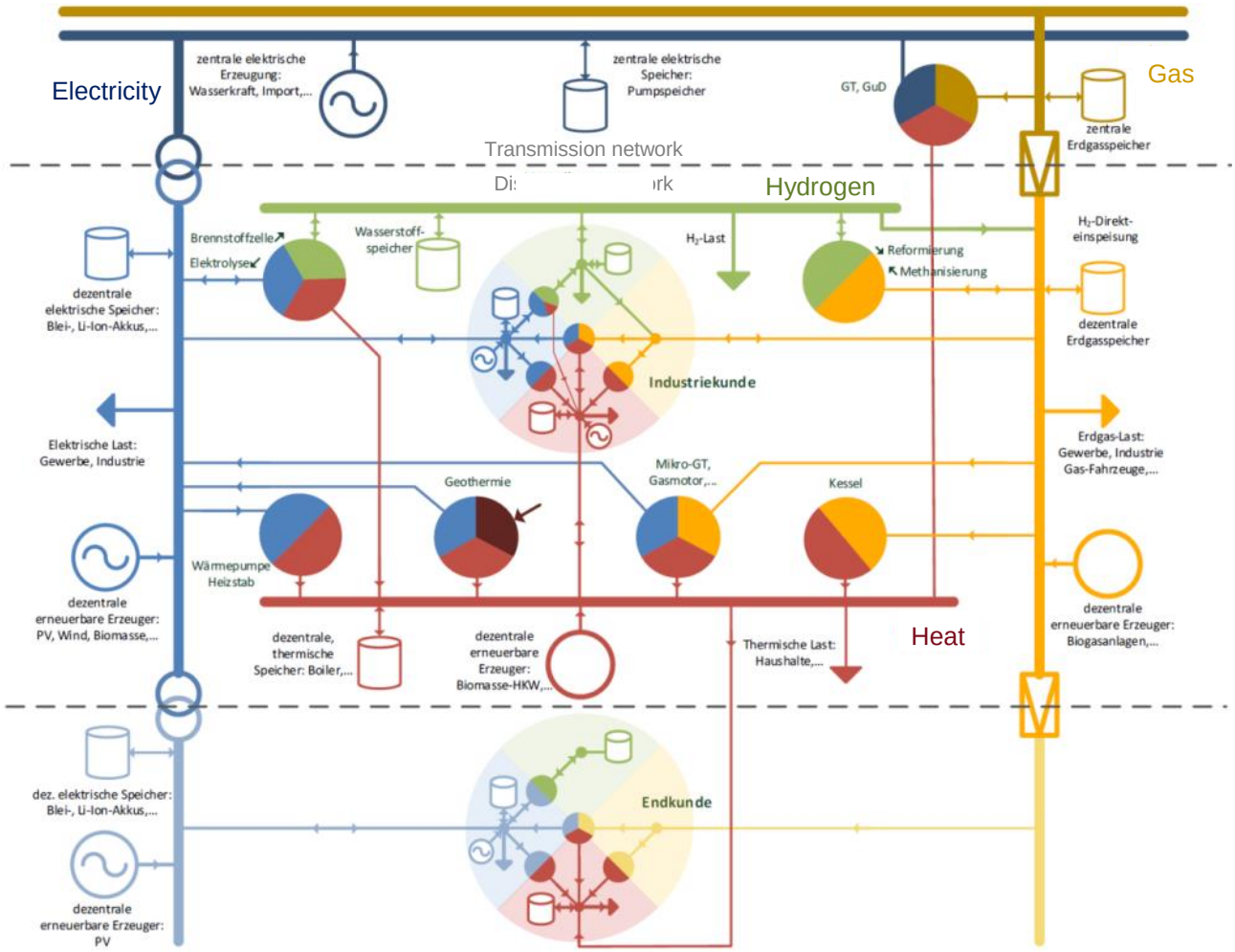

Figure 5: Visualization of a hybrid energy system (adapted according to [17])

3.3 Further supporting measures / success factors

In addition to the solution options, following measures were mentioned in stakeholder workshops to foster heat pump integration in DH networks:

- **Strong partners** (companies, institutes, start-ups, etc.): Competent and reliable partners who support and advise heat suppliers and stakeholders in planning, project planning, implementation, commissioning and ongoing operation. These are: reliable manufacturers, but also research institutes that provide neutral advice / inputs and support with monitoring and optimization measures. Start-ups are also seen as important with innovative solutions.

- **Projects** (demo, best practice, experiences, motivation): Currently there are some efforts ongoing to establish HP in DH networks (see task 2 of this project). According to the WS participants, it requires concrete implementation examples to pass on "lessons learned". These can come from the national as well as international environment. Support platforms/ blogs where experiences (positive as well as negative) can be shared. Above all, the question of motivation, i.e. why a HP was installed, represents a significant added value for the community. If the reasons for such investment decisions are shared and the benefits of using HPs are clearly explained, this can also motivate other actors.

- **Learning by doing**: Every new or innovative technology requires pioneers who are willing to "pay its dues" as a newcomer and share experiences to avoid future failures. Since small heat suppliers

hardly have large budgets, they expect a "pioneering role" from larger suppliers who show a certain willingness to take risks in research and development.

- **Energy planning** (localizing waste heat, avoiding double infrastructure): Politicians are calling for holistic measures for energy spatial planning. This ranges from support for innovative projects (subsidies, mediation, data provision, etc.) to the provision of tools (such as identification of waste heat potential, calculation tools for HP) as well as guarantees for long-term planning security and appropriate commitments. Intelligent energy planning should avoid the emergence or continued existence of double infrastructures (e.g. DH and gas network at one site).

4 BUSINESS MODELS

To establish alternative heat sources in heating networks, new players will emerge (or old ones will be replaced) and innovative business models will be necessary. In addition to stakeholder discussions, the findings from coaching sessions of the EU project "STRATEGO" [18] and the project "heat_portfolio" [2] were used as a basis for outlining possible innovative approaches for new business models. The experiences from these two projects are described using the nine elements of the "Business Model Canvas" in Figure 6. The evaluation should provide an ability to generalize how "typical" business models of heating networks can look like. Innovative elements of the business model are underlined in red.

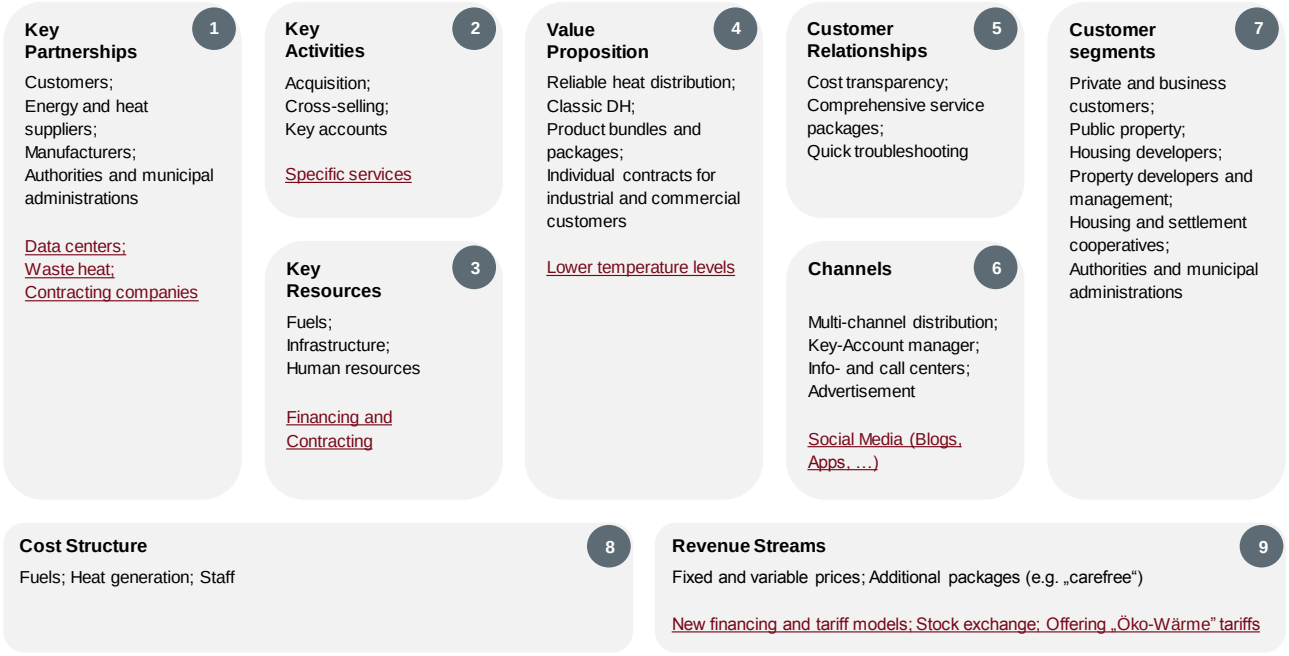

Figure 6: Exemplary business model of a district heating network operator (according to: Business Model Canvas); new elements of the business model are underlined in red (Source: AIT)

The following innovative elements can be mentioned:
Regionality: highlighting socio-economic indicators like value (added) creation, jobs, avoided CO_2 emissions, "regional factor", etc.

Fuel substitution (replacing scarce resources): Increasing the renewable share in DH networkds. Heat production through "environmentally friendly" electricity from renewable sources (PV, wind, geothermal energy, etc.) and substitution of fossil fuels. Offer an eco-heating tariff (like the eco-electricity tariff).

Holistic system concept: Application of sector coupling and offering of several services. Like providing electricity additional to heat, telecommunications (fiber optics), mobility. Addressing "green" overall concepts to customers and establishment as a regional and "visible" local supplier.

Usage of **waste heat/cooling energy** (three positive effects can result from the use of HPs): Offering heat, cold and electricity (energy balancing market). An example would be the provision of cooling for data centers and production of heat feeding into DH networks. Additional energy savings result through replacing cooling towers. Decentralized contractor solutions would also be possible. This means additional sources of income which can have a positive effect on investment decisions and economic considerations. This results in additional usable applications for new urban development areas that are unfavorably distant from existing heating networks. These could be supplied by micro-networks with utilization of local waste heat sources. This requires intelligent urban/city planning to make the best possible use of synergies. Contracting companies could play a key role here.

Specific services: For the largest or most energy-intensive customers, special services such as analysis of heat consumption (load profile), energy saving measures, reducing return/system temperatures, shading/shifting peak loads for smoothing the load profile etc. could be offered. Especially for larger heat consumers such as industrial customers, hotels, swimming pools, etc., the potential for load shifting is huge. Demand Side Management (DSM) would enable intelligent network operation by remote control of loads. Customers who actively contribute to load management could benefit from financial incentives. With additional capacities created, additional customers could be connected cost-effectively.

Financing and contracting: The conversion or upgrading of an energy supply system involves high investment costs. New financing models such as contracting, external financing (crowdfunding, -investing, -lending), leasing, factoring, but also customer and supplier participations should be considered to avoid risks. Best practice examples can be found in Denmark. Many of the solar heating networks are operated or financed by the customers themselves, whereby the focus is on minimizing heat generation costs. Another form of financing could be investment participation by key component manufacturers. Using "Big Solar Graz" as an example, this could be equipment providers [19]. On the one hand, this would reduce the investment risk for heat suppliers, which has a positive effect on investment decisions, and on the other hand, manufacturers can benefit from product sale and further long-term business relationships (warranty, maintenance, insurance, etc.).

Reducing system temperatures: The structure of the current heat supply contracts or technical connection conditions with long-term orientation hardly permits reducing system temperatures, since high supply temperatures (barrier for HPs) - for historical reasons - have been contractually agreed and this is difficult to change retrospectively. In order to reduce system temperatures in renovated buildings, heat supply contracts must be renegotiated. For properties with many customers this means an enormous administrative effort. Optimization often fails because heat suppliers are not even informed about renovation measures. Therefore, appropriate communication interfaces and adapted rules and regulations are required. In addition, the consumer is one of the most important instruments for achieving low return temperatures. This requires consumer information and the conscious observance of the prescribed return flow temperatures or the achievement of these must be monitored more closely.

Corporate appearances: Strategic communication and presence in the most important channels and platforms are necessary to strengthen customer relationships: Social media, communities, blogs, apps, etc. provide the opportunity to interact with customers. These communication channels should be used for a holistic corporate strategy regarding various interests such as sales, product placement, market observations, but also opinion polls, customer feedback and entertainment.

System optimization: High system temperatures result in inefficient operation and pose a major problem for heating networks, especially in combination with decentralized generation units (HPs, etc.). The causes are usually due to errors at the customer substations as well as unsuitable heating systems and operating modes. Planners and installers are often not aware of the requirements for customer installations or the effects of non-compliance. Therefore, workshops and training should be offered to various stakeholders to get them on board right from the start and to show them the importance of customer installations for overall efficiency. In addition, cooperation between the individual heat network operators should be expanded. Knowledge transfer of best practice examples and solutions should promote the multiplication and implementation of efficiency and optimization potentials on other networks. Additional revenues could be generated by offering additional services such as system assessments, system analyses and optimization of customer heating systems.

Digitization (new opportunities, more cooling capacity, smart heat meters, etc.): Digitization is generally seen as an enabler for alternative heat sources. On the one hand, new opportunities arise for generation, network and customers with the potential for global optimum (smart heat meters send real-time data whereby continuous optimization regarding pricing, flexibility, DSM etc.). On the other hand, more digitization

also means more computing power and thus more cooling capacity. This also results in new lines of business such as the simultaneous supply of heat and cold mentioned above.

The introduction of new tariff systems can be another way of promoting the integration of heat pumps:
Low return temperatures are an important feature of future district heating networks. Wherever users have the possibility of adapting their heating system (especially in single-family homes), suitable tariff systems can be an incentive for users to take measures to reduce system temperatures.
A possible structure of such an incentive system could be as follows: Customers who achieve an average spread between supply and return temperature of over 35 K ($\Delta T=T_S-T_R$) receives a discount (bonus). In the case of an average spread below 30 K, however, a fee (penalty) must be paid. The billing (of the energy price in whole or in part) via the volume flow rate has a comparable effect [20], [21]. However, it should be noted that (most) currently installed heat meters do not permit such tariffs, since they are calibrated only to the energy quantity[4] and accordingly no billing may take place. It should also be noted that many users do not have access to the heating system to make necessary changes themselves.

Flexible tariff models or "**district heating exchange**" can become relevant in district heating as soon as the share of volatile generation units becomes dominant. Furthermore, it is possible to design district heating tariffs in such a way that high working prices are charged during peak load periods. This means that loads such as space heating or storage charging can be shifted to times with low prices. In Sweden for example, there are already heat suppliers (e.g. Göteborg Energi AB, Öresundskraft AB) who offer their customers flexible tariffs. These are subject to seasonal or daily fluctuations and are partly offered on an hourly basis at different prices. This type of "district heating exchange" is intended to offer customers financial incentives so that they can actively participate in load shifts towards times of cheaper heat [21]. This pricing model can be attractive to all consumers, not only to private households, which have little or no opportunity to structure their demand for space heating over time. This depends on the regulated daily routine (with demand peaks mainly in morning and late afternoon times) and above all on the outside temperature, building age and type as well as the location of the buildings. However, such incentive systems can may lead to reduced user comfort and financial burdens, especially for low-income households, where energy costs is a relevant factor.

[4] That means to the product ($Q. = m. * c_p * \Delta T$) and not to the temperatures or volume/mass flow itself.

5 CONCLUSION

District heating networks are essential for future energy system, especially in conurbations. 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. At present, heat pumps play a minor role in European district heating networks.

Barriers to the large-scale integration of heat pumps are, among other things, the lack of heat sources (often only available in small decentralized quantities) or 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).

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. One promising application is the use of flue gas condensation in thermal combustion systems in combination with heat pumps.

To achieve a sustainable heat supply that includes a significant proportion of alternative heat sources, the implementation of further demo 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)

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8 LIST OF ABBREVIATIONS

CAPEX	Capital expenditure
CHP	Combined Heat and Power
COP	Coefficient of Performance (ratio of useful heating or cooling provided to work required)
COP 21	Nations Framework Convention on Climate Change, 21st Conference of the Parties
DH	District Heating
DHC	District Heating and Cooling
DHW	Domestic Hot Water
DSM	Demand Side Management
FFG	Austrian Research Promotion Agency
HoB	Heat only Boiler
HP	Heat Pump
OPEX	Operational expenditure
PV	Photovoltaic
SPF	Seasonal Performance Factor (average COP of a heat pump over the full heating/cooling season)
SWOT	Strengths, Weaknesses, Opportunities and Threats

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