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Heat pump application in cluster of buildings and positive energy districts

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Abstract

A new Annex numbered 61 in the Technology Collaboration Programme (TCP) on Heat Pumping Technologies HPT of the International Energy Agency IEA started in September 2022 and deals with heat pump (HP) application in clusters of buildings as well as positive energy neighborhoods and districts (PED). The focus is on smaller clusters of buildings and new built, but there are also contributions to the district level and retrofit situations, where concepts are developed for larger clusters and to move the cluster or district closer to positive energy or a net zero emission balance, respectively. Based on the state-of-the-art of HP in PED the Annex systematically investigates HP concepts in more detail regarding design and control by simulation. The core activities are techno-economic concept analyses accompanied by monitoring of real case studies both for new built and renovation. The Annex delivers recommendations for HP application in cluster of building and districts to increase market shares of HP also in larger buildings and non-residential applications. The paper gives an outline of the Annex and first interim results of the Annex work.

Keywords: positive energy districts; heat pump; system integration; building clusters; monitoring

1. Introduction

Climate protection is presently the largest challenge for the humankind. The global carbon budget for keeping the 1.5 °C target established in the Paris Agreement of 2015 [1] is reached within a time frame of less than 10 years at current CO_2-equivalent emissions [2]. Thus, efforts in all fields to reduce greenhouse gas emissions are urgently required and many cities have already declared a climate emergency in the recent years.

In many countries worldwide, the built environment plays a key role for carbon emission reduction, since in particular the existing building stock has a poor energetic quality. On the other hand, buildings can thereby also contribute to a fast emission reductions. In the EU, for instance, 36% of the carbon emissions are due to buildings, so reaching ambitious climate targets will be strongly facilitated by transforming the building sector. For new buildings, standards have developed to high performance requirements. Furthermore, buildings shall contribute to cover their own demand, leading to the nearly zero energy concepts (nZEB), which has been established in the EU with the recast of the Energy Performance of Buildings Directive (EPBD) [3] and is the current requirement from January 1, 2021 in the EU member states. In addition, the USA and Canada as well as Japan and China have targets to reach Net Zero Energy Buildings (NZEB) in the time frame of 2020 to 2030. Ambitious targets, though, are harder to achieve in existing buildings. However, the latest version of the EPBD of 2018 also requires the member states to develop retrofit strategies to notably enhance the energy performance of the building stock. For new dwellings, also examples to even transcend the nZEB balance and reach a positive energy balance exist with the ability to export parts of on-site energy production to connected grids. This concept can be extended to clusters of buildings and districts deriving a positive energy district.

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However, former work, among others in the HPT Annex 49 on "Design and integration of HP in nZEB" confirmed, that in particular for larger residential and office buildings, reaching a positive energy balance on the individual building level can still be challenging. In this sense, extension to clusters of buildings with different load structures also have potentials to enhance the heat pump (HP) performance and enable to reach ambitious energy targets.

On the other hand, in the Net Zero Roadmap of the International Energy Agency [2], HP are seen as dominating heating systems with a share of 50% globally by 2045.

HP are already establishing as standard heating system in the new built market in many countries, so the integration of heat pumps in the energy system on the large scale is a future task. Application of (larger) HP for the use in cluster of buildings and neighborhoods, though, are not yet as common. Comprehensive recommendations for the best integration of the HP from a purely decentralized use on individual building level to an entirely centralized integration on district level are missing, and performance potentials of HP application in districts depending on load boundary conditions are not obvious. Moreover, further benefits of HP in cluster of buildings regarding storage options and unlocking of energy flexibility as well as economic implications are further investigated to entirely assess potentials and facilitate ambitious energy performance and emission reduction targets.

2. Outline of the Annex

On this background, the new Annex 61 in the Technology Collaboration Programme (TCP) on Heat Pumping Technologies (HPT) of the IEA entitled "Heat Pumps in Positive Energy Districts" studies the application of HP for clusters of buildings and positive energy neighborhoods (PEN) or districts (PED), respectively. A focus is on smaller clusters of buildings and neighborhoods, mainly with residential and office use. While a majority of project contributions concentrates on new built clusters, quite some projects also focus on strategies to increase the energy performance of existing neighborhoods to approach a zero energy/emission balance, which is also in the scope of the Annex. Thereby, renovation strategies include both the improvement of the building envelope and the integration of HP, and optimized concepts of the combination of both approaches to improve the energy performance are to be evaluated.

Besides the unique performance features of HP and the ability to provide the different building services of space (SH)/domestic hot water (DHW) heating and space cooling (SC)/dehumidification (DH) even at the same time, HP are also a key technology to link the on-site electricity production and heating/cooling demands in districts, respectively. Thus, supposed benefits of the HP integration in districts are manifold.

- the high energy performance of HP enables to reach ambitious energy/emission targets
- the simultaneous operation of HP for different building services enables a waste heat recovery for other building services, e.g. by simultaneous space cooling and DHW heating within the district
- the link of electric and thermal energy allows for load balancing within the district of electric and/or thermal loads as well as on-site electricity production for enhanced self-consumption
- the load balancing can also provide energy flexibility for connected grids, so that the district can provide services for other parts of the city

In order to assess the HP potentials the Annex work follows a 4-step methodology divided into Tasks. Based on the state-of-the-art analysis of HP use in already existing clusters of buildings or PED, a concept analysis for HP in PED is carried out. For promising concepts, a detailed techno-economic analysis is accomplished and backed-up by monitoring of HP operation in PED, which are evaluated in parallel to the concept analysis. Details on the individual Tasks is given in the following

2.1. Task 1: State of the art analysis (September 2022 – June 2023)

Starting from already existing HP systems in cluster of buildings, the state of the art is characterized and boundary conditions for the follow-on tasks are gathered. As Key Performance Indicators (KPI) CO_2-eq.-emissions and further technical and economic KPI are considered. As result of Task 1 an assessment of technically realistic options for PED as well as an economic estimation of reachable ambition levels and the economic handicap could be evaluated. Therefore, standardized load profiles are generated and used for archetype district, e.g. entire residential use, mixed residential and office use etc. These archetype districts are to be characterized by the building quality reflected in the loads, the available renewable sources and the on-site energy production options.

2.2. Task 2: Generic concepts development (January 2023 – June 2024)

Task 1 is followed by Task 2 for the analysis of generic system concepts. On the second Annex meeting a first categorization of the generic system concepts has been discussed and the following top level categories have been derived. Starting from decentralized concepts on individual building level as reference, a stepwise path to an entirely central concept with the different steps have been defined, comprising as second category a purely electric connections, as third category a collective heat source, as fourth category a semi-centralized integration and a fifth category the fully central integration. Semi centralized integration is understood in terms of mixed centralized and decentralized HP, e.g. a central SH HP combined with a decentralized second HP, possibly also as "booster" HP for DHW. The categories are to be further detailed into subsystems in order to derive an overview of different possible configurations. For each of the subsystem, a short technical characterization is to be elaborated. As result, an as far as possible complete overview of generic integration options of the HP in districts with pros and cons and favorable applications as well as recommendations are foreseen.

2.3. Task 3: Techno-economic analysis of concepts (January 2024 – December 2025)

Based on the favorable system concepts derived in Task 2 a more detailed techno-economic analysis is carried out, in particular regarding the design and control as well as integration with storage and other generators to optimize the HP operation regarding performance, renewable energy integration, system cost and energy flexibility. The detailed investigations are carried out by simulations where also modelling aspects of larger heat pumps are a research topic. Task 3 also serves to evaluate optimization potentials of real systems in monitoring in Task 4, which in turn yield operation and performance data to validate the models.

2.4. Task 4: Monitoring and system optimization of the real performance of HP in districts (January 2023 – December 2025)

As mentioned above Task 4 is dedicated to the evaluation of the real performance of HP in district applications and to the identification of typical optimization potentials in the real operation for the different heat pump integration options in monitoring. Moreover, a comparison and verification to simulated values is enabled by the real operational data.

Table 1. Overview of possible contributions of participating and interested institutions to the IEA HPT Annex 61

Country	Institutions	Contributions
AT	UIBK, AIT, AEE-INTEC	• Concept analysis in 7 equal multi-family houses (MFH) by simulation/monitoring • Evaluation of HP in clusters of buildings (decentral, semi-central, central) • Investigation of new built district regarding integration option by simulation/monitoring
BE	ULB, KU Leuven, Swecobelgium, vito	• Design and monitoring of clusters of offices/neighbourhoods with sewage water heat source • Development of models and a testing framework for district concepts • Test of different HP technology options in a living lab of a district retrofitted to PED
CA	Concordia	• Model development and case studies of PED by simulation
CH	IET OST	• Simulation and monitoring of PED with centrally integrated heat pumps • Design of larger heat pumps for MFH and clusters of buildings
DE	THN, SIZ energieplus	• Model predictive control of a cluster 8 single family plus energy houses for energy flexibility • (Retrofit) concepts for MFHs/neighborhood by simulation and monitoring
IT	Univ. Firenze	• Monitoring and simulation of neighborhood with seasonal thermal storage, HP and solar collectors/troughs
JP	Univ. Nagoya	• Evaluation of contribution of HP in positive energy district to reach climate protection targets • Case studies of simulation and monitoring of HP in districts
NL	RVO	• Investigation of decentralized and centralized system concepts for HP in new built and retrofit application
NO	SINTEF, NTNU, COWI AS	• Case studies of heat pump application in clusters of buildings by monitoring • Integration of heat sources for clusters of residential buildings and districts
SE	RISE	• HP modelling and development for the use in thermal grids • Control of HP flexibility in thermal grids and large-scale control of HP
US	NIST, ORNL, EPRI	• Simulation, testing and monitoring of high performance ground source integrated HP with different ground-source systems (horizontal/borehole)

2.5. Task 5: Dissemination of interim results (September 2022 – December 2025)

All task are accompanied by dissemination activities like workshops, articles, website information and presentations, which are summarized in an overarching Task 5.

3. Overview of selected contributions and interim results

The IEA HPT Annex 61is still in the starting phase since it officially started in September 2022. However, two meeting have been held, where first definitions and results have been discussed. Thus, in the following, a more detailed description of Annex contributions along the single Annex Tasks linked to first interim results are summarized to give better impression of intended and ongoing Annex work.

3.1. State of the art results in Task 1

First results on the state of the art are given in terms of PED definitions and an evaluation of realized PEDs concepts in Germany and Switzerland.

3.1.1. International and national definitions of PED

Even though the concept of PED is developed since 2015, there is no uniform definition up to now. In Seifried et al. [4] a detailed evaluation of applied definitions is provided by the analysis of five EU programs and nine prominent PED project and common items and differences are analyzed. In Figure 1 left, the PED framework developed by Joint Programming Initiative of Urban Europe (JPI UE) which seeks to create a uniform vision for PED and states PED as "energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero GHG emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability." While this definition has a focus on the operational phase, a Swiss definition of a "*2000 W Areal*" is based on the SIA 2040 efficiency path [5], which takes into account the whole life cycle incorporating also the embodied energy for the construction and demolition phase and the building induced mobility linked to the site as basic energy boundary. However, as can be seen in Figure 2 on the left, also other criteria like management and communication processes, surrounding and use are contained.

A characteristic, though, which is contained in several definitions, is besides the efficiency and the on-site energy generation the requirement for energy flexibility in order to manage the local or regional energy flows also in conjunction with connected local or regional grids.

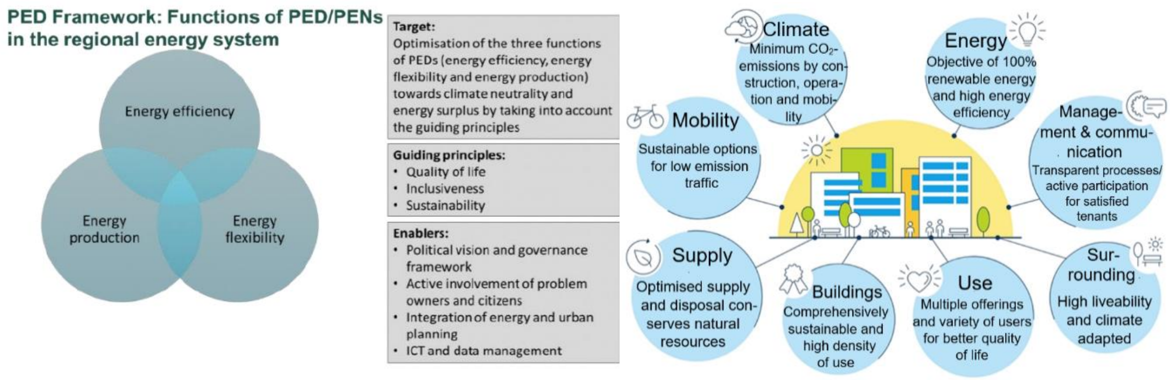

Fig. 1: PED Framework definition according to JPI UE (left) [6] and Swiss definition of 2000 W Areal (www.2000watt.swiss)

Seifried et al. [4] conclude from their evaluation that there are still a lot of differences, among other on the PED boundary, the calculation method of the energy balance and the scope for non-energy matters. An important fact is defining the fundamental purpose and application, which can lead to a universal framework.

3.1.2. Interim results on the evaluation of existing PED in Germany and Switzerland

At the Steinbeis Innovation Center (SIZ) EnergiePlus, a first review of existing PED in Germany with a particular focus on heat pump operation has been compiled and is summarized in the following.

The overall number of PED found adds up to 42 documented projects, of which 2/3 are in realization or already realized, while the remaining 1/3 is still in the planning phase or will not be realized. Thereby, projects are not evenly spread in Germany, but most of the projects are located in just two federal states "Baden-Württemberg" and "Hessen". Based on available data, only 16 of the total of 42 have been evaluated. Regarding the energy system, all PED are equipped with PV-systems, while installed solar thermal systems are below 20%. HP are with 60% the most applied heating system followed by combined heat and power (CHP) with 40%. Further energy generators are small wind turbines as well as district heating.

With respect to the HP, eight of them are centrally integrated, while two are decentral. The CHP is mainly linked to thermal grids within the PED, and only two transcend the PED physical boundary. The size of the PED are quite different in the range of 16 – 480 flats. However, most of the PED have above 50 and below 200 flats, also including the districts in planning.

In Switzerland, PED are currently dominated by the *2000 W districts*, counting 44 projects, which, however, are also differentiated to projects in realization (25%), in planning and in transition (together 75%). Projects in transition are related to transform existing districts to the requirements of a *2000 W district*.

The term 2000 W district is based on a budget approach developed at the Swiss Federal Institute of Technology ETH stating that a continuous global power consumption of 2000 W/P/year (corresponding to 17500 kWh/P/year) for all energy services including transport and industry sector is sustainable. It developed as long-term vision for the Swiss energy consumption. However, due to the newer results on climate change the objectives of the 2000 W vision have been significantly tighten in order to comply with the net zero targets by 2050 [7]. Furthermore, the 2000 W district certification is currently linked to the efficiency label MINERGIE [8] and to the sustainability label SNBS [9], which may also change the name of the certification.

Only 4 projects are listed as so-called "plus energy district", which is a different initiative to document high performance districts with a positive energy balance. For this certification, only operational energy is taken into account for the balance. The 2000 W projects are more evenly spread in 13 of the 26 federal states, but only five federals states have projects in use. Heat pumps are the dominating heat generator besides district heating, with shares in the range of 90%, often combined with PV, which also reaches fractions above 90%. More than half of the projects use heating grids, and about 30% use the ground as heat source. Also almost all projects plan to import certified green electricity. Regarding the use of the districts, the majority has a mixed use with a range of 200 to 1500 workplaces. These districts include also offices, restaurants, hotels etc. 9 districts are only for residential use without any workplace and commercial or retail areas. The number of buildings reaches from one to 53, whereby the total area reaches from 4'500 m^2 to 900'000 m^2. The number of flats reach up to 1500, while the smallest contains just 81. Regarding the supply systems, nearly all districts incorporate heat pumps and PV production partly combined with other heat generators. Imported green electricity is often found, as well, and one district uses a river hydro power plant to generate electricity in the district. The heat production is mostly local, i.e. there is still potential for the extension of heating grids. Some districts use biogas to dampen peak load. One district also produces its own biogas.

3.2. Generic system concepts in Task 2

Based on the outline in chap. 2.2 the different categories are depicted in direction of increasing integration of the heat pump into the district in Figure 2.

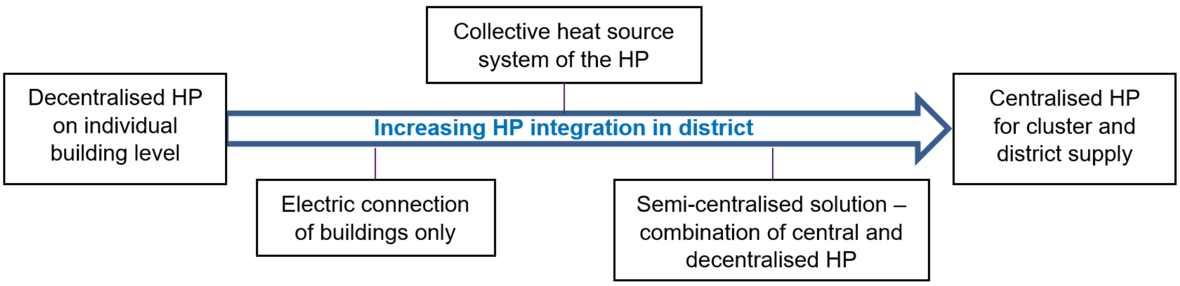

Fig. 2: HP integration categories defined in Task 2 in the direction of increasing HP integration

Currently, the subsystems are gathered and a template is elaborated for the compilation of system characteristics.

3.3. Techno-economic analysis of promising cluster concepts by simulation in Task 3

Task 3 has not yet started, but is dedicated to the in-depth techno-economic analysis for favourable concepts identified in Task 2

3.4. Monitoring of HP application in clusters and districts in Task 4

Monitoring of HP is an important feedback of the real performance, on the one hand for the energy assessment, on the other hand for simulation validation. In turn, simulation in Task 3 are used to identify optimization potentials in order to improve the real operation.

In the following, an outline of four different clusters and districts, respectively are given, which also visualize the different categories of generic concepts for the heat pumps integration in Task 2, see chapter 2.2.

3.4.1. Cluster of eight terraced plus energy single family houses Herzo Base in Herzogenaurach, Germany

The cluster of eight terraced houses is located in Herzogenaurach, Germany in the new district Herzo Base and built in 2017. The buildings were designed as an "all electric buildings", which means that the only source of energy is electricity. A PV-system (88 kW_p) on the roofs delivers an annual surplus of energy. The idea of small neighbourhoods creating an energy community and share energy systems enables higher potential to increase the PV self-consumption. Furthermore, synergies between different electrical loads lead to a more even electrical profile and reduces electrical load peaks. The terraced houses share a central heat pump system of two modulating HP (MHPs) of each 17 kW_{th}, with geothermal heat source as well as a battery system with a capacity of 40 kWh_{el}. The supply of domestic hot water is decentralized in each terraced house by a domestic hot water-HP (Booster), which use the heating buffer storage units as heat source. All eight terraced houses are equipped with floor heating and decentralized ventilation devices. The objectives of the field monitoring is the evaluation of the plus energy balance and PV self-consumption. Another aspect is the field test and evaluation of advanced control strategies in order to increase PV self-consumption and reduce energy costs. Figure 3 shows the building cluster and its position in the district.

Fig. 3: Building cluster Herzo Base, Herzogenaurach, DE

3.4.2. Clusters of multi-family buildings in Konstanz and Wolfsburg, Germany

The planning and implementation of a completely renewable energy supply for a block of residential buildings in an urban structure presents a challenge. This was achieved in the two projects by providing heat using a ground- coupled HP. The multi-family houses in Konstanz and Wolfsburg were completed in 2016 and supply a net floor area of 1140 and 9500 m².

Fig. 4: Cluster of multi-family buildings in Konstanz (left) [source: WOBAK] and Wolfsburg (right), DE

Figure 4 shows the building cluster in Konstanz (two buildings) and Wolfsburg (four buildings). The energy concepts of the residential buildings are based on heat supply via HP.

The generated heat is temporarily stored in buffer tanks and delivered to the low-temperature heating systems. The DHW is heated via fresh water stations or storage tank charging systems. Decentralized exhaust air systems or central ventilation systems ensure a constant air exchange. Natural ventilation via the windows is possible in all properties. Photovoltaic systems are installed to cover the electrical energy needs of the system technology and the connected households. The system technology is optimized for so-called "PV self-consumption", which means direct use of the photovoltaic yields.

Electrical energy from the PV systems that cannot be directly consumed or stored is fed into the public electricity grid. The comparison of the multi-family buildings refers to their efficiency, ecology and economy, with the overall balance and thus the total consumption of electrical energy serving as the basis for evaluation.

The consumption of the buildings is made-up of the electricity consumption of HP and circulation pumps, general electricity (lift, staircase, garage, etc.) and the user electricity of the individual flats (appliances).

Table 2. Key data of the building and supply concept

	Konstanz	Wolfsburg
Building	2 buildings (2016) with 12 apartments in total; 3 floors each; Net Floor Area (NFA) 1140 m² (total)	4 buildings (2016) with 68 apartments in total; 4 floors each; Net floor Area (NFA) 9500 m² (total)
PV-system	59.2 kWp on the roof; roof slope 10° to west and east	27.4 kWp on the roof of house A; Roof slope 45° to south (possible PV size ~160 kWp)
Heat pump	2x brine-to-water-HP (30 + 27 kW)	2x brine-to-water-HP (90 + 50 kW) and 4x air-to-water-HP (each 14 kW)

3.4.3. New built district Campagne, Innsbruck, Austria

A new low-energy residential district is being built in Innsbruck, Austria. The building owners (social housing companies) had to make decisions with respect to the energy quality of the buildings and the heating system with respect to the energy and environmental impact. The district will be composed of 16 buildings grouped in four blocks, see Figure 5. The main part of the buildings is residential and will consist of approximately 1100 new apartments for a total surface of 78027 m^2. Moreover, sport facilities, cafes, schools and kindergartens will be constructed. In the planning phase, a cooperative process was carried out, involving neighboring residents and local associations.

Fig. 5: Building cluster of Campagne, Innsbruck, AT (source: ibkinfo.at; stadtteilzentrum-reichenau.at, Bogenfeld Architekten)

The buildings are built according to Passive House standard (space heating demand lower than 15 kWh/ (m^2yr)). The space heating demand is supplied by a groundwater HP and the emission system is floor heating. The domestic hot water is provided by the district heating network, which accounts for a high proportion of heat by renewable sources, industrial waste and bioenergy. The shares of renewable sources and industrial waste heat of the district heating of Innsbruck are higher than other cities in Austria and it is foreseen that these shares are going to increase in the future. Photovoltaic panels are installed on the roof of the buildings to cover the electrical demand of auxiliaries. Moreover, sustainable mobility solutions are planned to enhance the electric mobility. System simulations have already been performed, while also monitoring of the buildings is intended.

3.4.4. Papieri district, Cham, Switzerland

The Papieri district in Cham, CH, is an old estate of the Paper industry, which is rebuild to a comprehensive new neighborhood in six phases over the next years for 1000 inhabitants and 1000 additional workplaces in the final development. Figure 6 left shows a picture of the district, the first development phase is depicted in Figure 6 middle, and the energy concept of the borehole fields connected to the central HP heating and cooling is shown in Figure 6 on the right.

The neighborhood consists of industrial heritage buildings of the paper industry which are preserved and retrofitted for a new use and are amended by new buildings, which create a mix of about 30% of existing and 70% of new buildings. In the first phase depicted in Figure 6 middle, 105 freehold apartments and 160 rental apartments together with 4400 m^2 floor area of commercial and office use will be commissioned by the end of 2022.

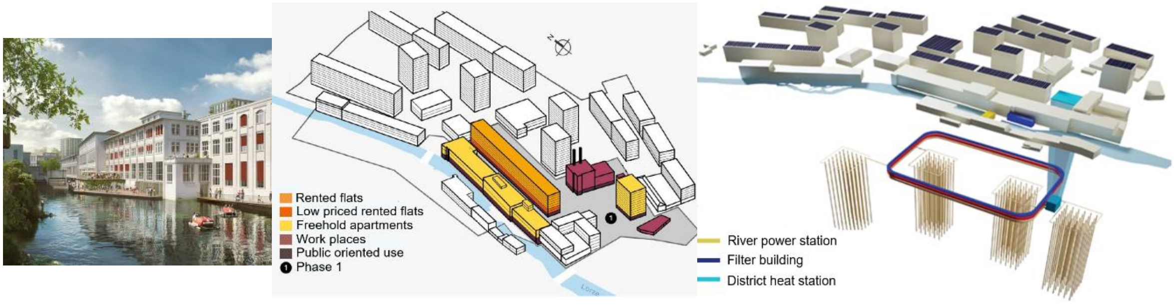

Fig. 6: Papieri neighborhood, Cham, CH, with neighborhood view from the river (left), buildings of the first phase (middle), and the energy concept (right) source: www.papieri-cham.ch, AWIAG, Cham group)

The estate development is designed in a way that all building services of heating, cooling and domestic hot water are entirely supplied by renewable energy. About 40% of the electricity use in the district is generated on-site. The electricity is generated by a 6500 m^2 PV-system of an installed peak capacity of 1.27 MW_p and an estimated annual electricity production of 1.1 GWh, which is installed on the roof of the new buildings. As second electricity generator, a hydro power plant with an installed capacity of 240 kW and a calculated annual production of 1.25 GWh is installed in the river Lorze, which run through the district. The remaining electricity is imported as certified green electricity from the utility in order to reach a zero emission balance.

The space heating and cooling as well as the DHW production is supplied entirely renewable by four central ammonia HP of a total capacity of 4 MW, which use borehole fields of totally 192 ground probes of 320 m depth as heat source. As second heat source, the river water of the Lorze is used either directly as heat source or as regeneration source for the borehole fields. The comfort cooling for the residential and office use is planned to be operated primarily by freecooling from the boreholes. Active cooling by the HP in chiller operation is only provided for peak load cooling, whereby all the recooling (waste) heat from the active chiller operation is to be recovered for other uses like DHW production or for the regeneration of the borehole fields.

Since neither the modelling and simulation nor the monitoring has started, yet, only the above-mentioned energy concept and design data are available of the neighborhood. The HP system will be modelled, simulated and monitored in order to optimize the first operation years and retrieve on-site information for the further development of the neighborhood in the later project phases. The evaluation includes the verification of the system performance of the centralized HP and the zero emission balance.

A special focus of the simulation and the monitoring is a more detailed analysis of the operation and the energy balance of the borehole fields for combined space heating, DHW and cooling operation. Moreover, the options for the interaction of the two heat sources of the borehole fields and the river water is investigated. Performance potentials are seen in the use of the source with most favorable temperature level, the regeneration of the borehole field for space heating and the simultaneous operation of the HP for heating and cooling in combination with high free-cooling shares. Thus, the objective for the system operation is the maximize the system performance of the HP by an optimized management of the borehole field as heat source and (free-) cooling heat sink and the integration of the ground and river water heat source.

3.4.5. Summary of monitoring projects and link to other tasks

The selected monitoring concepts combine both different sizes of the cluster for smaller groups of 2 and 3 buildings to larger neighbourhoods of up to 1000 flats in 16 buildings. Figure 7 depicts the outlined monitoring projects as contributions to the IEA HPT in the categories of the Task 2.

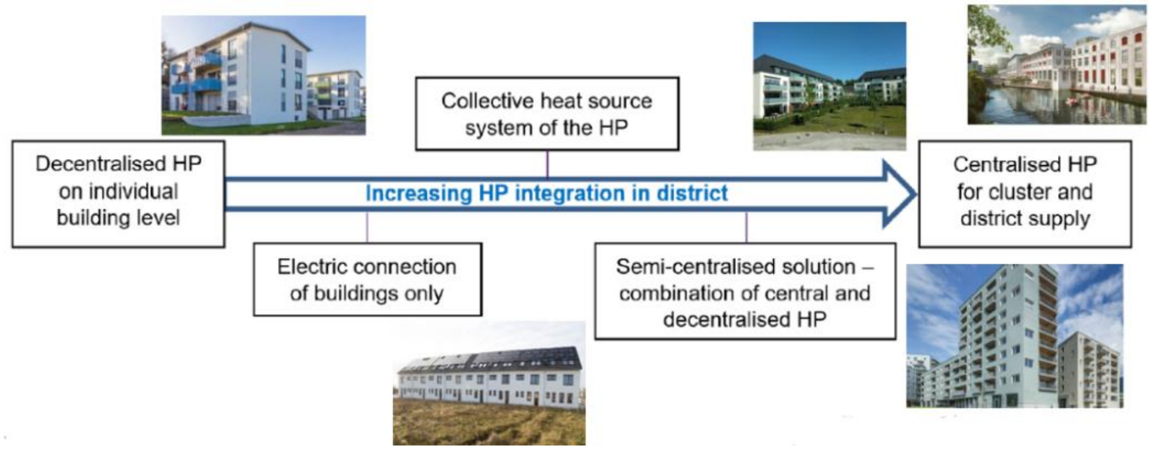

Fig. 7: Presented monitoring project in the categories of Task 2 between central and decentralized integration

Moreover, the uses range from smaller residential to larger multi-family, combined also with commercial and office use in the district. Even though for this selection, the focus is on new built there is also monitoring projects for retrofit concepts, even a variety of concept in 7 nearly identical buildings, which enables a direct concept comparison as well as larger districts build-up of retrofit and new built. By the chosen monitoring projects, it also becomes clear, that the different integration options according to the categories in Task 2 followed by the in-depth analysis in Task 3 can be well covered.

4. Conclusions and outlook

Positive energy districts are an ambitious concept, which is currently promoted in order to enhance a high energy performance and on-site energy production as part of the transition of the urban energy systems. Extending the system boundary from the individual building to clusters of buildings and neighbourhoods offers the combination of different load structures, which can unlock opportunities to increase on-site self-consumption of the produced electricity in the cluster by load balancing and to enhance the performance by waste heat recovery from one building service for another. Heat pumps can play an important role in positive energy district concepts, since they facilitate to reach ambitious energy targets by their high energy performance and can link both electric and thermal loads as well as different thermal uses like heating and cooling. As further aspect, sector coupling within the district and with connected grids can provide energy flexibility within and over the boundaries of the district.

The upcoming Annex 61 in the Technology Collaboration Programme on Heat Pumping Technologies TCP of the IEA investigate heat pump concepts for building cluster and positive energy districts. Starting with decentralized solutions on the individual building level, higher integration of the HP in the districts up to entirely centralized solutions and integration with other energy generators/supply like district heating is evaluated technically and economically. Based on generic concepts a detailed techno-economic analysis shall deliver favorable applications of HP in positive energy districts and recommendations for the integration, design and control of the HP systems.

As insight to the national contributions, the paper presents four case studies with different degree of integration of the heat pump in the cluster or district. Already existing results of the case studies confirm that reaching a positive energy balance is a challenge, which requires high building performance to limit the loads, high performance generators for efficient energy supply and vast energy production with the cluster or district, in particular for larger buildings and non-residential use.

Higher integration of the heat pump can create opportunities of higher on-site energy consumption and waste heat recovery for different building services in the cluster, which may further increase the energy performance and flexibility, but may also increase the cost and losses due to necessary grid connections. Both technical and economic trade-offs with be analyzed in the Annex 61.

Results of the case studies underline that HP reach high performance values in the application in clusters and can facilitate to reach ambitious objectives of zero or plus energy neighbourhoods or districts due to its unique features of even simultaneous provision of different building services with high performance. Furthermore, HP offer energy flexibility for higher PV self-consumption and reduced grid interactions. The upcoming Annex will derive favorable HP concepts for districts by simulation and monitoring in different case studies.

Acknowledgements

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