EuroSun2026

Heat pumps in districts – workflow guidelines

Summary

Positive Energy Districts are a key concepts of the urban energy transition and require both technological innovations and integrated planning processes. In order to identify suitable supply concepts, IEA HPT Annex 61 is investigating different heat pump topologies for building clusters with grid solutions. The techno-economic analyses compare centralized, semi-centralized and decentralized solutions for space heating and domestic hot water. The results show that centralized solutions benefit from access to efficient heat sources but cause higher grid investments and heat losses. Decentralized approaches offer higher flexibility and lower infrastructure costs but are heavily dependent on available local sources. The developed planning workflow supports systematic, cost-optimized decision-making and provides a basis for future integrated planning methods in PEDs. It provides important guidance for choosing between centralized, decentralized, and hybrid heat pump concepts.

Keywords: heat pump, district, workflow, guidelines, costs, energy demand

Field of application for the findings: design of energy concepts, heat pumps in districts, supply grids

Addressed audience: owner, municipality, designer and planer, research and development

1. Introduction

Positive Energy Districts (PEDs) support cities in advancing the energy transition by improving technologies and planning processes. IEA HPT Annex 61 examines heat pump (HP) integration in high-performance districts through simulations and monitoring. The project analyzes system designs for neighborhoods, focusing on efficient and economical supply concepts using innovative technologies, planning tools, and optimized building concepts. Planning HP systems for PEDs and dense urban areas is complex due to diverse energy needs for space heating, domestic hot water, and space cooling, as well as varying load profiles and available heat sources. Depending on building type and climate, different district-level HP configurations are possible.

A cost-optimized planning workflow is being developed to support decision-makers in identifying suitable system solutions. While decentralized HPs typically achieve the best performance, centralized systems can be more cost-effective. Combining centralized supply with decentralized booster HPs enables lower distribution temperatures and is beneficial for heterogeneous building structures.

2. Method

The study examines 11 neighborhoods in terms of possible network structure and implementation. The neighborhoods have different structures and sizes. The neighborhoods under consideration comprise between 4 and 22 buildings with a total gross floor area of 4,800 to 168,400 m². The grid lengths vary between 110 and 1,700 m, with heat line densities ranging from 142 to 9,984 kWh/m. The specific heat demand of the districts is between 6 and 105 kWh/(m²a).

Various options are available for the design and integration of HP systems in the PED. The following topologies were used for the analysis:

- Variant 1: Central (one per district) with high grid temperature level (67/40 °C)
- Variant 2a: Mixed - central grid HP for SH, decentral DHW (on building), with mid grid temperature level (35/30 °C)

- Variant 2b: Semi-central - central low temperature HP + decentral booster HP on building or flat level, with mid grid temperature level (20/10 °C)
- Variant 3: Decentral (building-wise HP) with low grid temperature level (0/5 °C)
- Variant 4: Building-wise HP without grid connection

3. Results

Across the analyzed neighborhoods, annual electricity demand ranges from 9.2 to 43.9 kWh/(m²·a) (Fig. 1), mainly influenced by district characteristics and heat losses from varying network lengths; within each district, HP configurations differ only slightly. Total annual costs depend strongly on temperature levels and investments for networks and storage. Lower network temperatures and decentralized heat pump placement significantly reduce heat production costs. Low-temperature grids (Var. 3), the semi-central solution (Var. 2a), and fully decentralized concepts achieve the lowest costs, while high-temperature networks are notably more expensive, with heat production costs ranging from 167 to over 1,000 €/MWh (Fig. 2). Overall, decentralized systems outperform centralized setups. The semi-central configuration (Var. 2a) shows the lowest electricity demand due to high system efficiency, whereas the high-temperature central system (Var. 1) exhibits the highest consumption due to reduced utilization and elevated network temperatures.

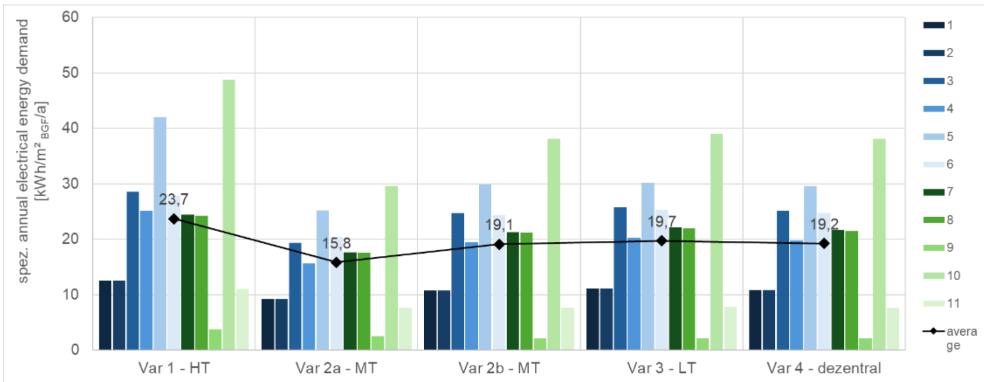

Fig. 1: Specific annual electrical energy demand of the various heat pump systems

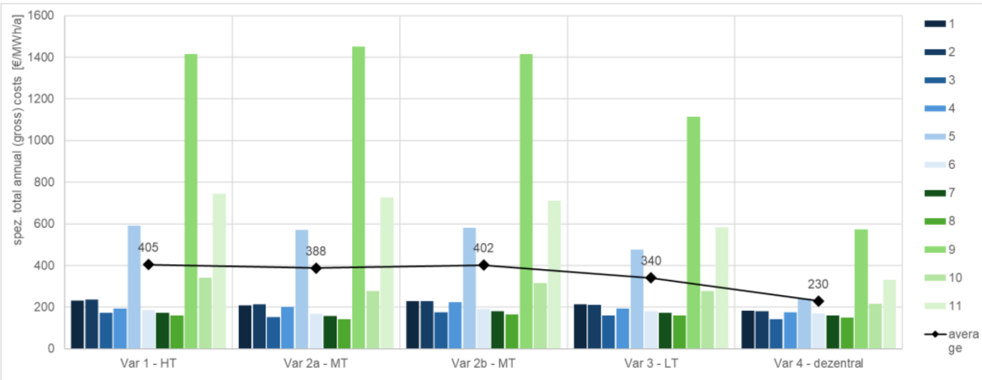

Fig. 2: Specific total annual (gross) costs of the various heat pump systems in relation to heat demand – heat production costs

4. Workflow and Design Guidelines

For a design workflow for HP systems for districts, local boundary conditions such as source availability and temperature level of the heating networks, as well as the energy requirements of the individual buildings and the possible heat pump topologies, must be developed and taken into account. Depending on the function of the building type (residential, non-residential), the layout, and the availability of heat sources onsite (or nearby), various options are available.

The following proposed workflow guidelines can support decision-making and can serve as a basis for a future integral planning approach for PEDs. Based on the results of the network study and analysis of the different topologies, as well as the evaluation of the monitoring areas in the annex, the following conclusions can be drawn for planning guidelines:

- Basis of the design: specification of boundary conditions
- Optimization of buildings: high efficiency standards with low-temperature distribution systems and maximum PV yield
- Preference for decentralized or semi-centralized heat pump concepts: decentralized heat pumps with minimal distribution losses and maximum performance.
- Minimization of grid temperatures: design of grid for the lowest possible temperatures that are still compatible with the requirements of the buildings.
- Placement of the source: restrictions on the choice of heat source for the heat pump in decentralized solutions without a grid. More options and easier connections of sources with network topologies.
- Cold local heating grids enable buildings to be cooled in summer within the framework of a network/system.
- Simultaneous operation of heat pumps for various building requirements enables waste heat recovery for other functions.
- Limitation of network size and complexity: compact neighborhoods with corresponding grid are more economical and energy-efficient than widely scattered buildings and large neighborhoods.
- High energy efficiency of heat pumps and systems makes it possible to achieve ambitious energy/emission targets.
- The topology of the heat pump system determines its efficiency!
- Annuity method for calculating total annual costs
- Safety aspects to be considered with natural refrigerants are becoming more relevant from a centralized to a decentralized perspective.

5. Conclusion

The cost-optimal integration of heat pump systems in emerging Positive Energy Districts requires highly efficient buildings, simulation-based planning, and techno-economic evaluation. Results show that decentralized heat pump solutions consistently deliver higher performance than centralized systems, particularly in heterogeneous districts and low-temperature concepts. Centralized thermal networks become economically viable only at high heat densities, which are uncommon in PEDs. Overall, system topology influences district-level performance more strongly than the efficiency of individual heat pumps, highlighting the importance of selecting low-temperature, decentralized configurations in PED planning.

6. References

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