EUROHEAT & POWER

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LARGE HEAT PUMPS IN DISTRICT HEATING & COOLING SYSTEMS

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About this report

This report is based on the input from Euroheat & Power's members, mainly from the internal working group on market intelligence and statistics. Additional figures are based on investment forecasts from individual operators. The objective is to shed light on the state of play and expected deployment of large heat-pumps in District Heating and Cooling systems.

The report can be quoted as 'Large heat Pumps in District Heating and Cooling systems, Euroheat & Power, December 2022'.

Author: Market Intelligence Unit, Euroheat & Power

Eloi Piel
Director of Market Intelligence

Crélida Mata
Market Intelligence Analyst

Key points

- In May 2022, the European Commission published a proposal to **REPowerEU**, including concrete measures to phase-out the use of fossil gas in heating and industry. The Commission identified large heat-pumps in combination with heating and cooling networks as a critical solution to decarbonise the European heating market, especially in densely populated areas.

- '**The Future of Heat Pumps'** (IEA November 2022) recognises heating and cooling networks as the energy infrastructure of choice to support the deployment of affordable and sustainable heating, mainly in urban areas.

- Large heat pumps combined with heating and cooling networks allow the harvesting of untapped renewable heating resources such as geothermal, solar thermal, and recovered heat from urban environments (sewage, metros), the tertiary sector (data centres, supermarkets) and public buildings (hospitals). Large heat pumps also maximise the decarbonisation potential of renewable electricity sources (such as wind and solar), converting them into renewable heat. In combination with thermal storage and electric boilers, large heat pumps support system flexibility and security by providing daily, weekly, and seasonal flexibility.

Key points

- Today in the EU, large heat pumps represent an installed capacity of 2.5 GWth in heating and cooling networks, which is around 1% of the total capacity. Existing capacities are primarily located within countries with high shares of electrification, such as Sweden or Denmark. However, the growth potential is significant, building on the fast deployment of renewable electricity sources across EU countries. Based on investment plans of some of the largest heating and cooling networks in Europe, the installed capacity for large heat pumps will increase by at least 80% by 2030, triggering profound changes in the generation portfolio and growth of networks.

- Appropriate measures and incentives will be needed at the EU, national and regional levels to reduce the costs of large heat pumps deployment and support the expansion and modernisation of the underlying heating and cooling network infrastructure.

Why heat pumps?

Large heat-pumps unlock the potential for new heat sources

- Large heat pumps are versatile in their capacity to use a wide range of low-temperature heat sources, enabling energy diversification and accelerating the decarbonisation of heating. They facilitate the phase-in of non-electric renewable heat, and climate-neutral heating sources into the EU's heating mix.

- Heat sources which can be harvested with large heat pumps include:
  - Renewable heat sources (e.g. geothermal, solar thermal and ambient energy)
  - Waste heat from industrial processes
  - Urban excess heat[1] (e.g. from service/residential sectors – supermarkets, underground metro, data centres[2] etc.)
  - Sewage water treatment facilities

- With efficient and intelligent buildings, large heat pumps open the way for high Coefficient of Performance and ultra-efficient heating and cooling networks (also known as 4th Generation District Heating systems).

Why heat pumps?

Building up a more integrated and sustainable energy system

- Combined with large thermal storage, electric boilers, and CHP, heat pumps help reduce the overall electricity demand for heating and cooling by integrating non-electric heat sources into the mix. Amidst the increasing electrification of the EU economy, they will further contribute to freeing up capacity for other sectors such as mobility and industry. The reduction of peak demand will cut down the needs for new investments in grids and peak production capacities.

- In combination with city-scale thermal storage, large heat pumps can absorb excess renewable electricity (for direct or postponed use) and modulate production to ensure grid balancing (thanks to the quick ramp-up/down of generation), and provide weekly and even seasonal flexibility.

- Large heat pumps also enable the decarbonisation of low-and medium-temperature industrial processes, with promising ongoing developments to increase the range of temperatures available. Some installations combined with solar collectors already provide temperature ranges between 120° and 160°, corresponding to over 1000TWh of current energy demand (see below).

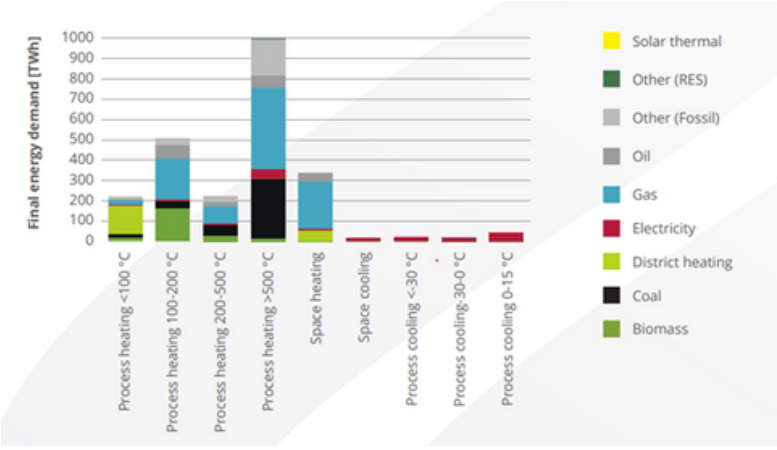

Figure 1 – Potential use of heat pumps in industry by temperature ranges (source: Source: European Heat roadmap, 2019)

Why heat pumps?

Efficiency and Climate Benefits

- Implementing large heat pumps in district heating with a capacity tailored to address urban demands will ensure top performance of installations monitored 24/7 by professionals.

- In terms of environmental impact, operators comply with stringent requirements that ensure the safe monitoring and management of refrigerants used in large installations, which do not apply to small-size individual units.

State of play

- Large heat pumps used in DHC systems are not new. In Sweden, heat pumps coupled with District Heating were installed in the 1980-90s to provide sustainable heat and balance the grid.

- The **IEA HTP project**[3] estimated a total of 1563 MWth installed capacity for large heat pumps in District Heating in Europe (with projects deployed between 1981 and 2016).

- A more recent survey of Euroheat & Power members identified **2.5 GWth (2021) of installed capacity of large heat pumps in DHC systems**, as shown in Figure 2. This represents around 1% of the total DHC installed capacity in Europe.

State of play

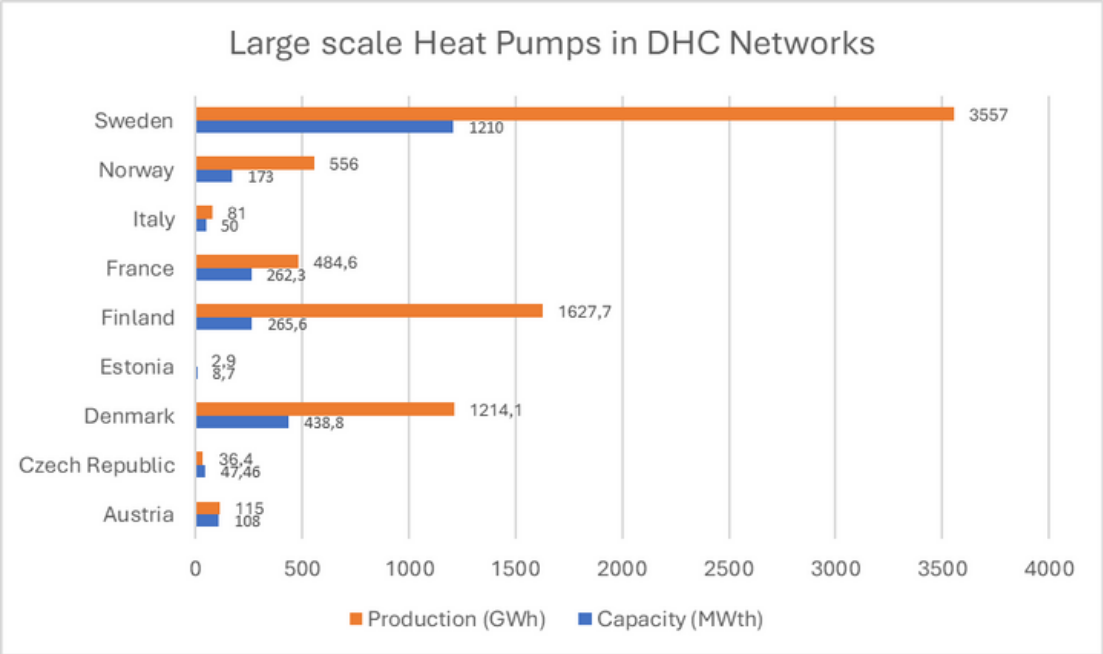

Figure 2 – Large heat pumps in District Heating - state of play (source: EHP members for the EHP Market Intelligence Unit, figures for 2021) [4]

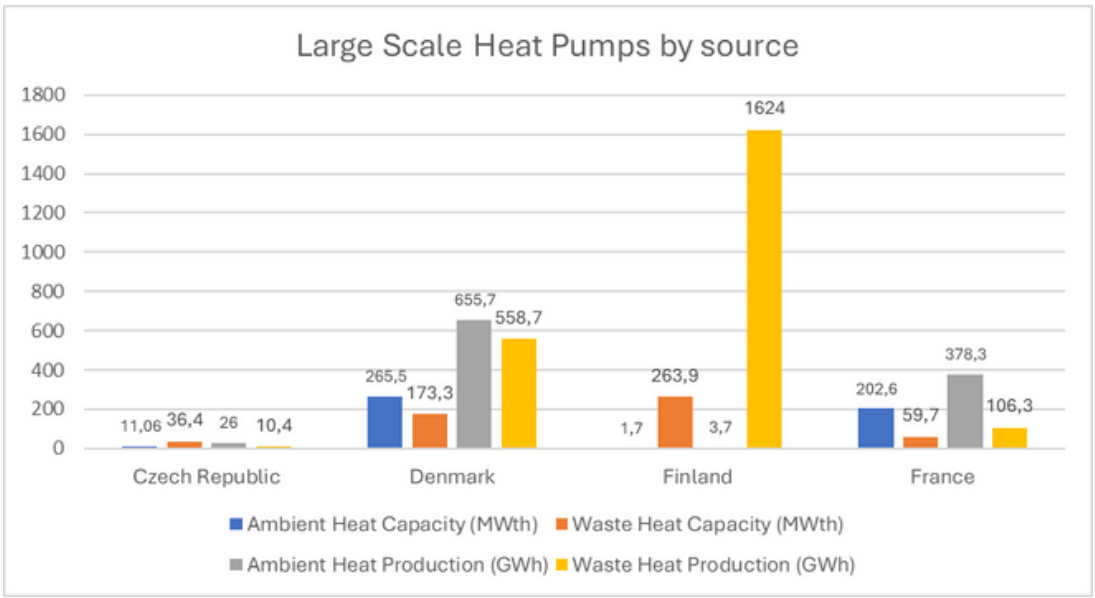

Figure 3 – Breakdown between ambient and waste heat in markets for which information is available (2021)

Outlook for large heat pumps

Several market reports and EU projects anticipate a crucial role for large heat pumps in the perspective of a growing and changing District Heating and cooling sector. It will be instrumental to decarbonise Europe's heat markets in line with Green Deal objectives.

- The **Heat Roadmap Europe**[5] project estimates a potential 50% market share for District Heating by 2050 in Europe, with approximately 25-30% of installed capacity based on large electric heat pumps. If these large heat pumps were operating at total load capacity half of the year, their share would reach 38% of the total DH production. The HRE 2050 scenario only refers to large electric compressor heat pumps with an output temperature of 80-100 °C. The use of low-temperature excess heat sources (5-40 °C), which would require an upgrade of heat pumps, was not analysed in the study, as it would have required a more detailed mapping of available sources at local levels. Additionally, the potential estimated by HRE does not factor in any expected technology improvements and increased digitalisation that will create new potentials.

- The **DHC Transition Pathways 2050** (Euroheat & Power, June 2022) highlights national pathways for the decarbonisation of the heat sector. The various pathways have shown the key role assigned to District Heating to decarbonise the heat market. Large heat pumps are expected to play a prominent role in all markets. For instance, in Germany, the sector forecasts that the output from heat pumps could represent 29% before 2050; in Austria, heat pumps combined with geothermal will represent 19,8% of the district heating mix by 2040-50.

Outlook for large heat pumps

- The **ReUseHeat project** has assessed the potential for urban waste heat sources in Europe. These sources, which are typically low-temperature, cover waste heat from a wide range of sectors such as data centres, food production facilities, food retail stores, metro stations, residential sector buildings, service sector buildings and wastewater treatment plants; they require a heat pump so that the output temperature is suited to supply demands from the residential and service sectors. The project has defined both the available and accessible potentials (to be understood as a respective resource and utilisation potentials) which District Heating could use. With a default utilisation potential to capture sources within a 2-kilometre radius from existing District Heating areas, the project estimates over 1.4 EJ per year of excess heat qualifying as 'accessible volume' which could be supplied to the heat market, representing over 10% of the total heat market (EU 27+UK).

Excess heat source	Recovery Type	Temperature range °C	Temporality (seasonal)	Heat Pump Conversion Type
Data centre	Server room air cooling systems	25-35	Principally constant	Air to water
Metro stations	Platform ventilation exhaust air	5-35	Variable	Air to water
Food production facilities	Rejected heat from the refrigeration process	20-40	Principally constant	Liquid to water
Food retail stores	Rejected heat from the refrigeration process	40-70	Principally constant	
Service sector Buildings	Central cooling devices	30-40	Variable	Liquid to water
Residential sector buildings	Central cooling devices	30-40	Variable	Liquid to water
Wastewater treatment plants	Post-treatment sewage water	8-15	Principally constant	Water to water

Figure 4 - Examples of typical recovery types, temperature ranges and temporality for different types of heat sources (source: ReUseheat Project)

Outlook for large heat pumps

- Planned investments in large DHC networks confirm the dynamism of the market. **The largest European networks have investment projects representing an increase of over 80% of the existing capacity by 2030.** Figure 5 below, is based on planned investments for a few large networks to upgrade the generation portfolio and supply additional demands; it is very likely an underestimation of investment plans across Europe and covers exclusively large heat pumps.[6] It can be anticipated that the consensus at the European level to fasten the pace of the energy transition (REPowerEU) and the engagement of cities to propose better heating for citizens will trigger much larger volumes of new investments.

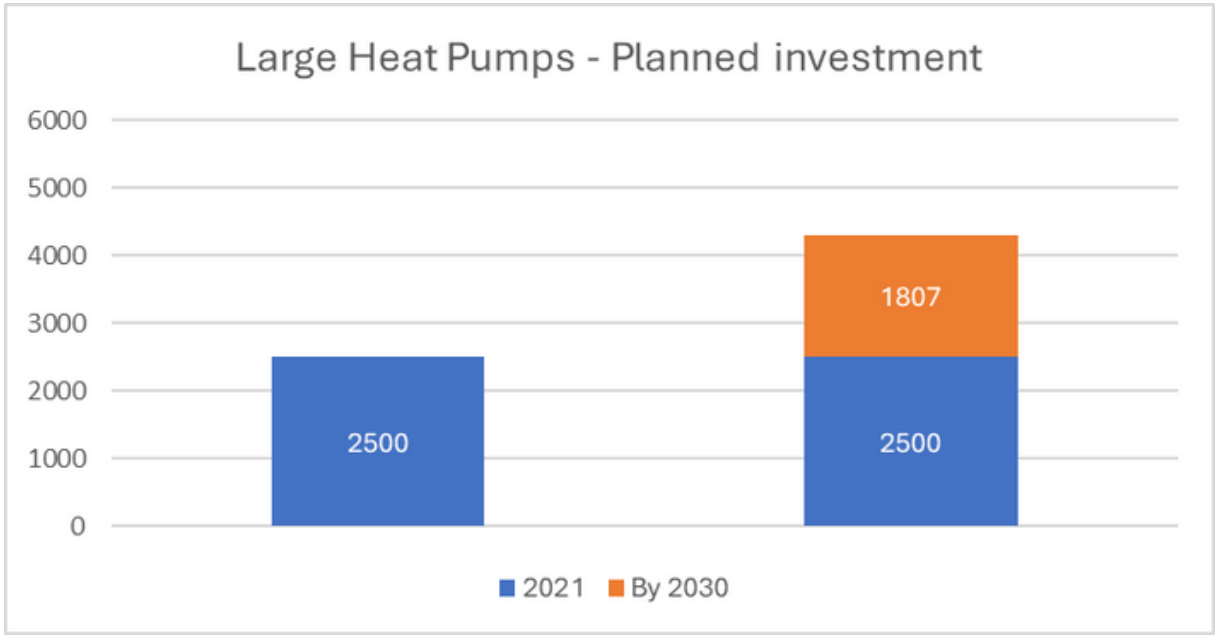

Figure 5 – Planned investments for large DHC systems in Europe by 2030, based on forecasts from large EU DHC systems

Drivers and potential barriers

- Targets applying to the energy and climate policies will significantly drive the market, i.e. the priorities to phase out imported fossil fuels and implement the Green Deal objectives. In such a setting, measures applying more broadly to the deployment of district energy projects (heat planning, aid for infrastructure deployment, building standards, accelerating permitting procedures etc..) will impact the roll-out of large heat pumps. Markets where a ban on fossil boilers was introduced will likely provide high-growth areas.[7]

- Electricity prices, as well as taxation applying to electricity, will impact future developments. Energy taxation should be reviewed to stop favouring gas and oil heating. The tax cuts for electricity implemented in some markets to adapt surcharge on electricity for large heat pumps are helpful measures.

- The smooth deployment of new projects will also rely on the ability of manufacturers to overcome recent challenges that affected production (increasing prices for materials, shortages of critical components and skilled labour). Recent announcements of new investments from key leading companies in the heat pump sector are encouraging signs of trust in future market developments.

- Appropriate measures and incentives will be needed at the EU, National and Regional level to bring down the costs of large heat pumps deployment, and support the expansion and modernisation of the underlying heating and cooling network infrastructure.

References

[1] The ReUseHeat project estimates that urban waste heat sources could cover about 10% of the EU heat demand.

[2] As the world becomes increasingly digitalised, data centres and transmission networks are emerging as an essential source of energy demand. According to the IEA (September 2022), data centres account for 1-1.5% of global electricity use. In Europe, data centres tend to locate in places where data transmission networks are most performant. These installations are increasingly seen also as potential partners for waste heat projects.

[3] IEA Technology Collaboration Programme on Heat Pump Technologies, Annex 47: Heat Pumps in District Heating and Cooling systems, Final report, October 2019.

[4] For Germany, values are upper-level estimates from AGFW.

[5] Heat Roadmap Europe: large-scale electric heat pumps in DH systems by Andrei David, Brian Vad Mathiesen, Helge Averfalk, Sven Werner and Henrik Lund (2017).

[6] Investments in heat pumps are typically a part of a strategy that includes other elements such as e-boilers – e.g. Vattenfall investments in Berlin (120 MW recently commissioned) and Amsterdam (150 MW to be built in 2023).

[7] Nine European countries have announced or implemented national bans on gas and oil boilers, while four others have only announced bans for oil boilers. (The Future of Heat Pumps, IEA, 2022).

Annex 1 Overview of existing support schemes for large heat pumps

	Investment aid	Operating aid	Others	Comments
Czechia	v	X	-	Investment aid for large-scale heat pumps in the heating industry is limited to one program within the Modernisation Fund, the HEAT program.
Denmark	v	X	CO2 taxation applying to the heat market and heat zoning	Investment aid is provided to operators to establish heat pumps or solar heating systems. District heating companies, where a minimum of 5% of the current heat production is based on coal, oil or natural gas, are eligible.
Estonia	v	X	–	Support will be continued under funding from EU structural funds to support fuel-switch, including large heat pumps.
Hungary	X	X	-	No scheme dedicated to District Heating. The only incentives for heat pumps target small-size units in the form of a reduced price for electricity for end-users during the heating season.
Italy	X	X	-	There is an indirect mechanism linked to the white certificate schemes: the deployment of Efficient DHC systems can be rewarded with certificates proportionally to the amount of heat delivered to final customers, and heat pumps can be part of an efficient DHC system. But this aid is not sufficient to stimulate the market. According to calculations made by the Italian DH association, the aid would represent no more than 5% of total investment costs.
Finland	v	v	CO2 taxation applying to the heat market	Investment support from July 2022, electricity to both heat pumps and electric boilers in district heating are included within tax class 2 (i.e. set to the EU minimum)
France	v	X	CO2 taxation applying to the heat market	The heat fund targets the development of renewable and waste heat projects, including Capex for DH deployment, and applies to large heat pumps projects.
Germany	v	v	Scheme that establishes a CO2 price signal on the heat market, complementary to ETS (large installations)	Both investment and operating aid (for thermal energy) are available under BEW, which aims to develop new DH schemes and upgrade existing ones, with a budget of Euro 3 billion until 2026. Operating aid is granted for the first 10 years of operation. Additionally, the iKWK (innovative CHP) provides operating aid for heat pumps in conjunction with CHP units.
Poland	v	X	–	Aid can be provided for heat pumps fuelled by renewable energy sources or in combination with CHP.
Norway	v	X	CO2 taxation applying to the heat market Fossil heating phase-out	–
Sweden	v	X	CO2 tax applying to the heat market	Reduced energy tax for electricity used for heat pumps for district heat supplies to industry or cooling sold to large IT-infrastructure industries (i.e. data centres for the digital sector or other industries).

Annex 2 Case studies

Odense

Figure 6 – Integration of waste heat (data centre) within an existing DH system (Fjernvarme Fyn)

The project was integrated into the strategy to decarbonise the District Heating system and relies on the waste heat from a data centre operated by Meta. The excess heat from the data center is upgraded via the means of a large heat pump from 27°C to 70°C, enabling the delivery of hot water and space heating to nearby homes at a suitable temperature.

Key figures:

- Project led by Fjernvarme Fyn and Meta
- Source: Data centre supplied with renewable electricity
- Capacity: 42 MWth – electric heat pump
- Production: recovery of surplus heat to produce 160.000 MWh of district heating/year, supplying the equivalent of 11,000 households

Brno

The SAKO Brno project uses excess heat from both the generator cooling and the oil system from the steam turbine located in the EfW facility. The heat recovery uses a heat pump based on the absorption principle with LiBr/water, while the driving energy is obtained from the 11bar extraction. The heat from both streams is then delivered into the existing District Heating network at a temperature level of 80-87°C. The SAKO Brno company developed the conceptual design to increase the overall efficiency of the power plant by approx. 1,2%.

Key facts and figures:

- Project led by SAKO Brno
- Source: the heat pump is powered by steam from the existing turbine
- Capacity: Nominal Heat Pump capacity up to 4,5 MW delivering up to 87°C
- Production of either 29 TJ (thermally optimised operation) or 2,4 GWh (electrically optimised operation)
- Provides simultaneous cooling and heating within the same process

Figure 7 - The facilities at Sako, in Brno (Sako).

Annex 2 Case studies

Berlin

The Berlin Qwark3 project combines heating, power and cooling supplies via heat pumps. It will start operations at the end of 2022. This project is part of the scheme to fully decarbonise the heat supply in Berlin with renewable electricity combined with electric boilers and thermal storage, waste heat and CHP.

Figure 8 - Heat pump at Postdamer Platz (Vattenfall).

Key figures:

- Project led by Vattenfall
- The cooling plant at Potsdamer Platz has been providing cooling and heating to about 12,000 offices, 1,000 housing units, and numerous cultural facilities since 1997. Unused waste heat was previously rejected into the surrounding air via cooling towers. It produces 55 GWh of heat per year.
- Source: installation of an 8 MW heat pump that uses waste heat generated in the refrigeration centre and upgrades it to a suitable temperature of 85-120°C. The heat pumps are powered by renewable electricity and will provide fully decarbonised heat to the city.
- Capacity: It will supply hot water to around 30,000 Berlin households in summer and heating and hot water to 3,000 households in winter.

Vienna

- The installation of heat pumps in Austria is on the rise, driven by the need to phase out fossil fuels and the energy crisis in the wake of the war in Ukraine. For instance, in 2021 alone, 56 large heat pumps were installed in the high-temperature application/industrial sector.

- The most powerful large heat pump in Europe is currently being built in Vienna. As early as mid-2023, this large unit, with a capacity of 55 MWth, is expected to supply heat to up to 56,000 households in Vienna. A complete full-scale expansion with a capacity of 110 MWth is planned by 2027.

Figure 9 - The site of future heat pump installations in Vienna (WienEnergie).

Annex 2 Case studies

Paris region

The District Heating scheme provides green heating to Arcueil and Gentilly in France and substitutes individual gas boilers. The renewable share of this heating and cooling network averages the 60%. This project is led by Engie and started operations in 2021.

Figure 10 – The geothermal plant at Arcueil/Gentilly (Engie)

Key figures:

- Source: deep geothermal (1800 m)
- Installed capacity: 50 MW
- Heat supply: 61 GWh
- Heat pump capacity: 15 MW with 18 MW make-up boilers and 6 decentralised backup boilers
- Avoided CO2 emissions/y: 15 k tonnes
- 120 Energy substations
- 18 km network infrastructure

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CONTACT US ep@euroheat.org