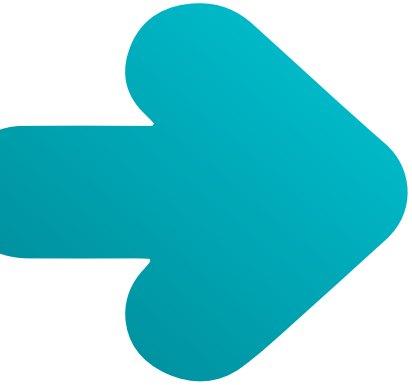

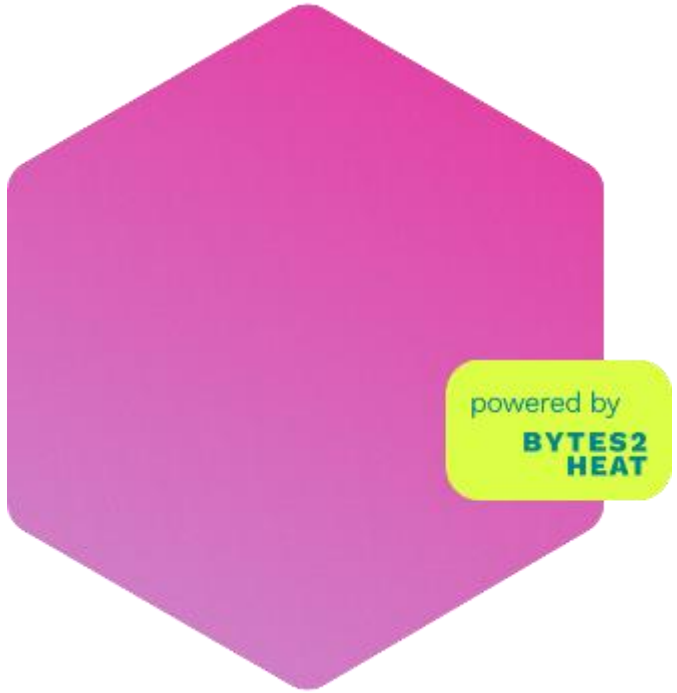

Best-Practice-Overview

Learning from inspiring projects for waste heat recovery from data centers

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DENEFF

Universität Stuttgart
Institut für Energiewirtschaft und Rationelle Energieanwendung (IER)
Institut für Volkswirtschaftslehre und Recht (IVR)

empact

Table of content

Symbol and color definitions

Project summary („Tags“)

- City
- Year of commissioning
- Stakeholders
- IT connection performance
- Data center waste heat temperature
- Waste heat utilization temperature
- Waste heat utilization type
- Technology
- Heat connection
- Distance

Categories

- Technology
- Legal
- Business
- Communication
- Other

Project status

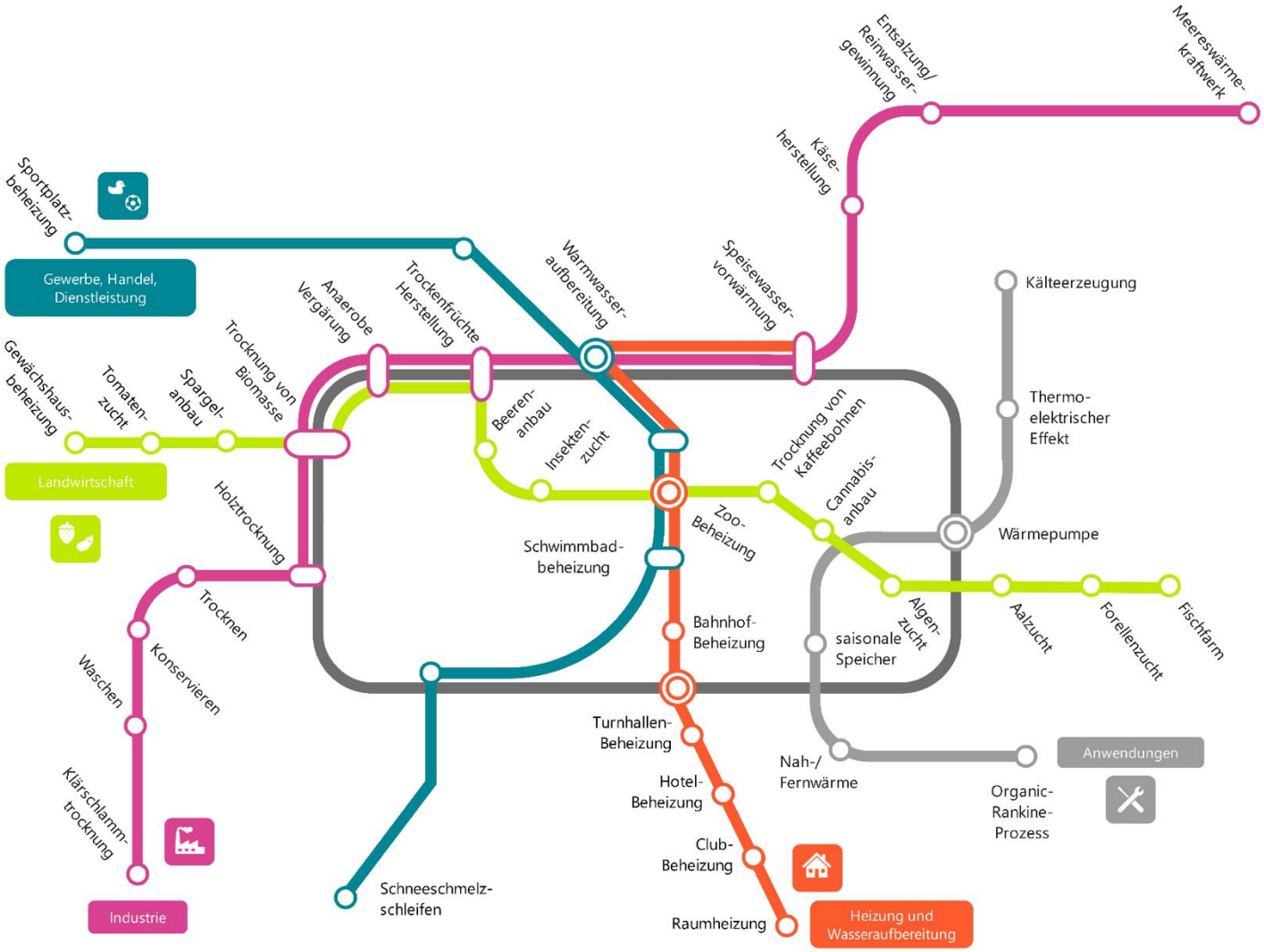
- In operation
- In implementation
- In planning

Disclaimer

The examples of waste heat recovery from data centers contained in this best practice overview are provided for informational purposes only and are intended to serve as suggestions. No warranty is made as to the accuracy or completeness of the information and it is the responsibility of the reader to evaluate and use the information in the context of their individual needs and requirements. We assume no liability for any damages or losses that may result from the use of this information. The use of image material for further purposes must be clarified on an individual basis.

Waste heat utilization map:

Possibilities of waste heat utilization from data centers



Country overview: The Bytes2Heat best practice overview contains 99 examples from 15 countries

Germany

37

Sweden

15

Finland

9

Netherlands

7

Denmark

5

France

5

USA

4

Switzerland

4

Norway

3

Great Britain

3

Canada

2

Ireland

2

Austria

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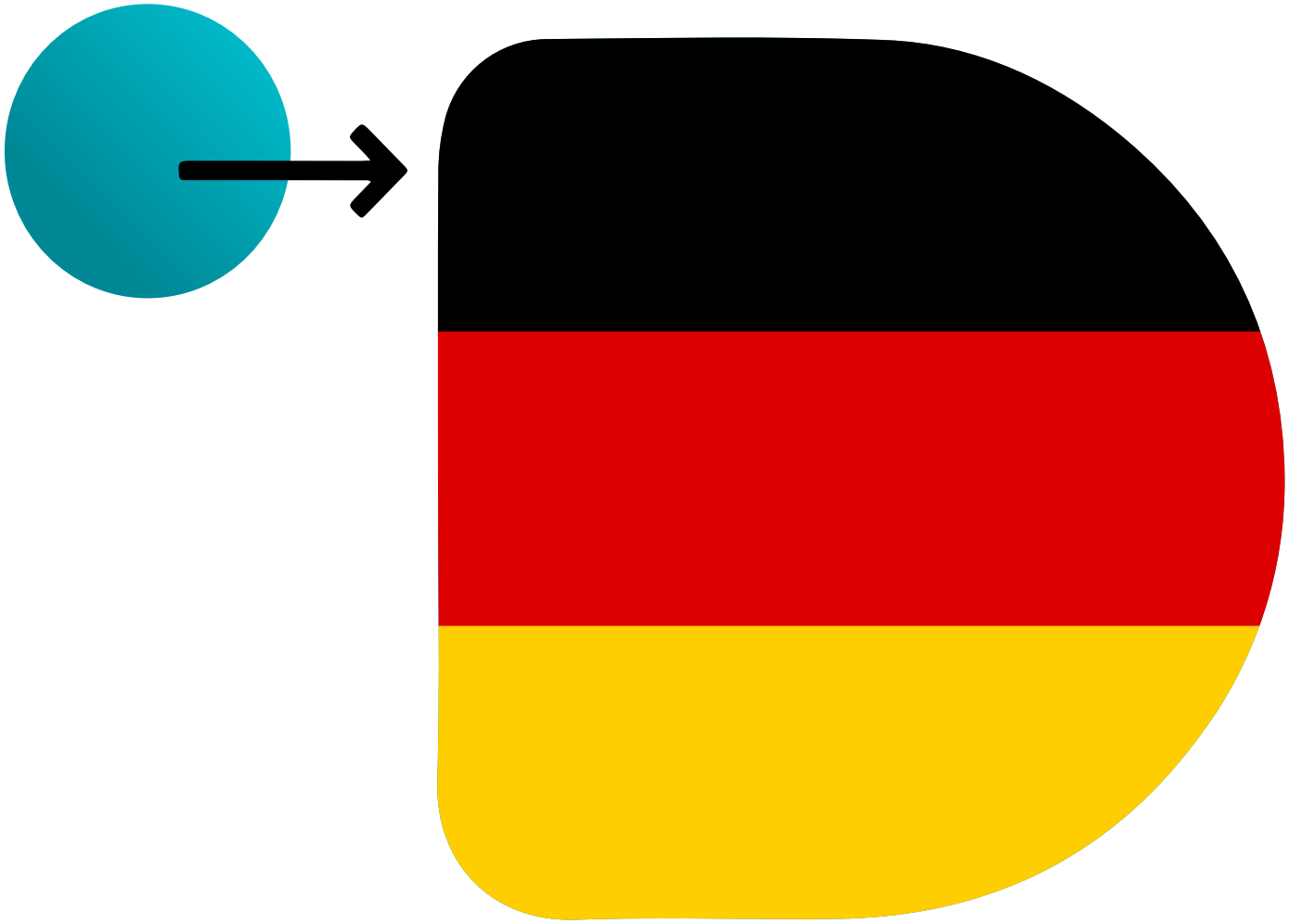
Japan

1

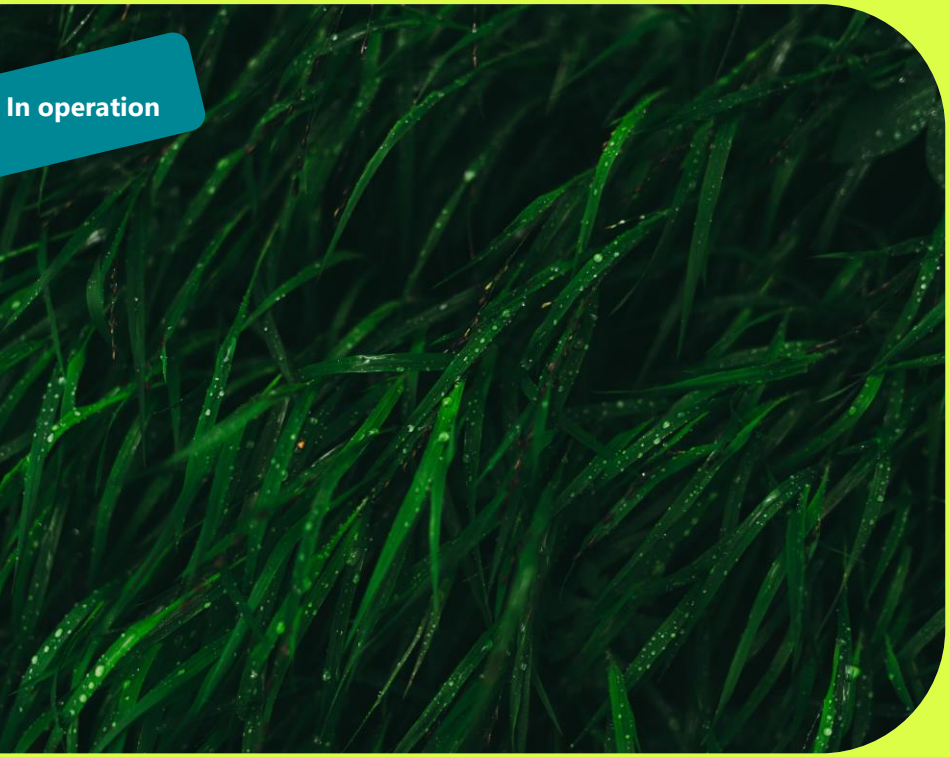
South Korea

1



Germany

Algae farm



Germany	Enge-Sande
35 °C	35 °C
Direct waste heat utilization	60 kW
Windcloud 4.0, Novagreen	Agricultural process heat - Algae farming, Building heating
Hot water circuit	Data center roof

Image source: [1]; Sources: [2–4]

Technology

- Extension building with 24 racks and 60 kW IT power on the Greentec Campus.
- On the roof of the data center is an algae farm (240 m^2), which uses the waste heat directly.
- Waste heat at 35 °C heats the cultivation station and provides the comfortable climate for Chlorella and Spironella.
- Energy for the data center is generated 98% from wind power and the rest from solar and biogas power.
- Data center is certified according to EU standard EN 50600, VK3 and Blue Angel.
- A total of 60 kW of waste heat can be used and fed to the greenhouse above the data center through a flap control system.
- One kilogram of algae "consumes" about 2 kg of carbon dioxide.
- Data center offers co-location and cloud services.

Business

- Production of "Lüttge" nutritional supplements by Evergreen-Food GmbH.
- Novagreen has always looked for synergy opportunities, for example farmers (biogas plants).
- Combination with a data center, which provides just the right temperature, allows the extension of the harvest over the winter.
- With good cooperation, there is the prospect of expanding joint activities and developing additional areas.
- Total cost data center: 550,000 €.

Communication

- Wilfried Ritter: "The biggest challenge was and is to convince everyone that it works."

Campus Lichtwiese, Lichtenberg-Hochleistungsrechner

Technology

- Direct hot water cooling.
- Heat supply to own buildings by coupling the university's own district heating network and a high-performance computer with return temperatures of 60 °C.
- Heat pump is to provide 70 °C on the condenser side for the district heating network and at the same time cool the return water circulating on the evaporator side for server cooling from 60 °C to 50 °C.
- A 4th generation district heating network is to be created on campus.
- Demand for heating energy is to be reduced by 26 % from 2018.

Business

- Funding in the amount of 15 million euros.

Communication

- Data center and heat network have the same carrier.

Germany	Darmstadt
60 °C	70 °C
Direct water cooling, heat pump	Building heating
On the campus	TU Darmstadt, Bund, Land Hessen
District heating network	

Image source: [5]; Sources: [6–12]

ColocationIX Westend

Germany

In-Row-Cooling, Concrete core activation, near-surface geothermal energy

Bremen

Groundwater circulation with integral probes

Consultix

Technology

- Data center location was former nuclear bunker.
- Use of near-surface geothermal energy (borehole up to 400 m deep) for cooling, constant water temperature at 12 °C.
- The patented integral probes use the principle of groundwater circulation. By using groundwater circulation, the ground is transformed into a cold reservoir. The ambient air outside the summer heat period serves as a cold source to regenerate the geothermal system.
- Continuous power 200 kW and peak power 800 kW through four independent circuits. In-row cooling systems are used in the IT rooms.
- At temperatures between 20 and 28 °C, the adiabatic recoolers on the roof step in. For every liter of water nebulized and evaporated, approximately 0.7 kW/h of additional energy is released for cooling. Above 28 °C, the geothermal cooling system then kicks in. If the ambient temperature falls below the threshold of 20 °C, the data center makes use of the free circulating air.
- In addition to air cooling, the building is also cooled and heated (with waste heat) via concrete core activation. Pipe registers are installed in the concrete, in which water circulates and absorbs or releases heat depending on the temperature.
- This energy concept completely eliminates the need for compression cooling and heat pumps.

Image source: [13]; Sources: [14]

Data center at Wallotstraße 1 to 5, Dresden

In operation

Germany

50-60 °C

Hot water cooling, heat pump, buffer storage, district heating

In the building

Hot water circuit

Dresden

Building heating

Cloud&Heat Technologies GmbH, Wohnungs-genossenschaft Aufbau Dresden eG, Stadtwerke Dresden

Technology

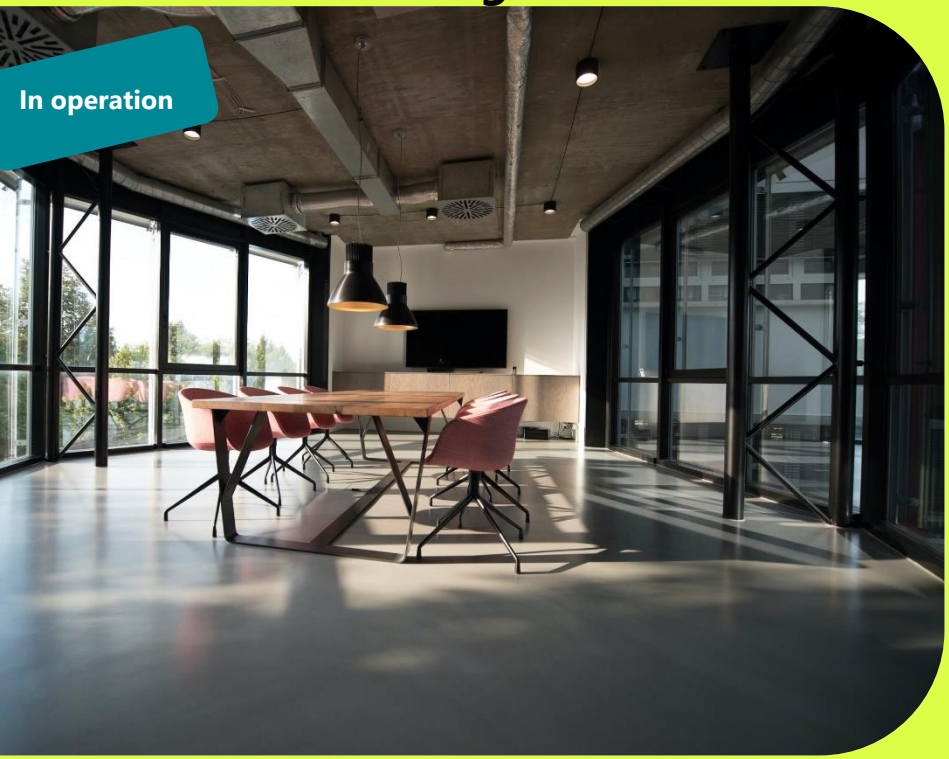
- Liquid cooled (hot water cooling) data center with waste heat extraction.
- Most of the server waste heat is used directly for the hot water circuit.
- Copper pipes run through the server cabinets, through which water flows and heats up. The water heats up to between 50 and 60 °C and then enters a buffer tank. The heat is used for either water heating or heating.
- PUE value of 1.05 and in some cases a partial PUE value of 1.01.
- The "Energy Reuse Effectiveness" (ERE) is 0.62 during the use of heat pumps.
- Saving greenhouse gas emissions by reducing energy consumption and using waste heat to heat residential and commercial complexes. Underfloor heating systems are installed in the apartments.
- 20 server cabinets are located in the basement (underground parking) and heat a building with 56 apartments. The L-shaped new building at Wallotstrasse 1 to 5 extends over five floors and has smaller two- to three-room apartments for seniors and larger four- to five-room apartments for families. The server cabinets are fireproof and theft-proof and are located in a separate room in the underground parking garage.

Business

- The computing and data storage power is sold to companies.
- The waste heat remains in the apartment building. Cloud&Heat sells the resulting heat to DREWAG, which, as the contractual partner and heat supplier of WG Aufbau Dresden, resells the heat to the building's tenants. If the computer waste heat is ever insufficient, the supply is ensured during peak load times via the district heating of the municipal utility.
- The investment starts at €60,000 for customers to switch to this system.

Image source: [15]; Sources: [16–19]

Data Center Cologne



Technology

- Waste heat from the servers and the air-conditioning system is used to heat the offices and to heat water.

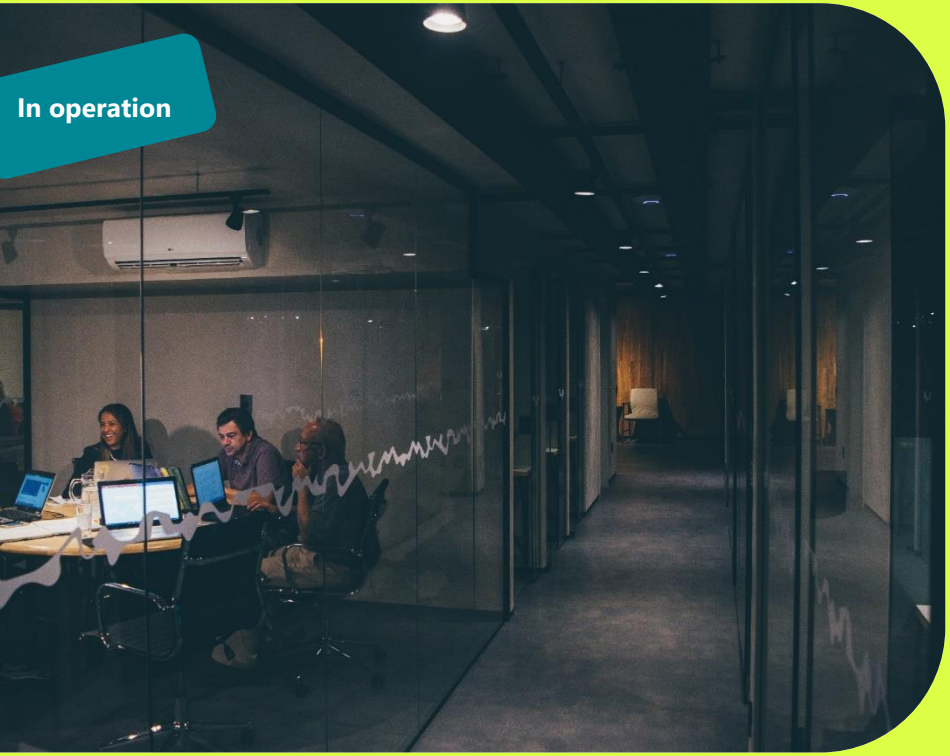
Germany

Cologne

Host Europe GmbH

Image source: [20]; Sources: [21]

Data Center Kelsterbach



Technology

- Heating of company offices.

Germany

Kelsterbach

Building heating

Lufthansa

Image source: [22]; Sources: [21]

Green Cube

Germany

Water cooled rack doors

On the campus

Building heating

Darmstadt

GSI Helmholtz Centre for Heavy Ion Research GmbH, Helmholtz Association, Federal Ministry of Education and Research

Technology

- Data center in cube form with a size of 27×30×22 m with six floors and an adjacent technical building incl. cooling towers.
- Up to 12 MW of waste heat can be dissipated via adiabatic cooling using open evaporative cooling towers.
- Circulated server room air is cooled down with water-flow heat exchangers in the rear rack doors, with their water circuit decoupled from the open cooling circuit by a heat exchanger. This eliminates the need for recirculating air cooling.
- Power consumption of the cooling system is less than 7 % of the electrical power of the IT hardware (in conventional systems it is 50 to 100 %).
- Waste heat is also used to heat offices and cafeterias on campus.

Business

- Technical costs € 2.8 million.

Other

- The data center is to serve as a test data center, or a real laboratory or experimental space, which makes it possible to test innovative technologies, products, approaches and services in a real data center environment.
- Furthermore, the possibility is given to test, experiment, collect information and learn under real conditions. This allows research and development to be driven forward, new innovations to emerge and final products and technology to be adapted or developed.

Image source: [23]; Sources: [24–27]

Gym heating

Technology

- Underground colocation data center (RZ-AKQ-HAM-02) with two floors, 200 m² area and space for 63 server cabinets.
- Free cooling is provided when the outside temperature is less than 12 °C.
- On top of the data center in Alsterdorf is a barrier-free three-field gymnasium for the Bugenhagen School. This is heated with part of the waste heat from the data center.
- Alignment of the system and technical rooms according to Green IT principles. PUE value of 1.25 at full load.
- 100% green electricity is sourced from wind and water power, solar radiation, biomass and geothermal energy.
- According to the company, this data center will be the first to use coolwalls instead of conventional recirculating air cooling units, which adapt their operating behavior to the load conditions of the IT rooms.

Communication

- RZ-AKQ-HAM-02 and RZ-AKQ-NOR-01 - form a Twin Data Center in Hamburg and Norderstedt and together meet the TÜViT TSI 4.1 and EN50600 standards.

Germany
Coolwalls
Gym over data center
Direct connection

Hamburg
Building heating
Akquinet, Bugenhagen School

Image source: [28]; Sources: [29–33]

New development area „Heinrich des Löwen“

Germany	Braunschweig-Rautheim
18-25 °C	70 °C
Heat pump	Building heating
3000 m	VW Financial Service, BS I Energy
Low temperature heat network	

Technology

- From the data centre as a heat source, 250 kW of the waste heat with a temperature of 18 - 25 °C is decoupled.
- Spatial proximity to the heat customer (neighboring residential quarter with 400 houses and an expected heat demand of 2100 MWh/a).
- Heat pump (water-water) with 300 kW_{th} and COP of 3.6 for temperature swing and use of carbon dioxide as refrigerant.
- Low temperature heat network with 70 °C.
- Peak load coverage and redundancy via the connection to the existing heating network in the event of a data centre failure.
- Expected primary energy savings of 1284 MWh/a and GHG savings of 304 t CO_2/a.
- Heat network with a length of 3 km, transporting 4.2 GWh/a.

Legal

- "BS|ENERGY built an energy center that includes both a district heating connection and a connection to the cooling water circuit of the data center.

Business

- Funding from the EU project "ReUseHeat".
- Investment costs of € 460,000 without the heat network.
- The turnover generated by the use of waste heat is € 330,000.

Communication

- Volkswagen received the "German Data Center Award" in 2019 for this idea.

Other

- Company wants to assume ecological responsibility → own environmental policy "goTOzero".

Image source: [34]; Sources: [35–42]

Heinrich-Böll-Foundation

Germany

Berlin

30 °C

30 °C

High-performance heat exchangers, cool racks

Heinrich Böll Foundation, Basler & Hofmann

In the building

Building heating

Technology

- Energy consumption undercuts statutory values by half.
- Primary energy consumption after one year of adjustment of approx. 44 kWh/m²*a.
- Ventilation via atrium, cooling by water evaporation, heating with server waste heat, optimal insulation.
- Photovoltaic system on the roof with 53,000 kWh primary energy contribution per year.
- In all offices, along the window fronts, there are so-called parapet units. They contain a high-performance heat exchanger. The parapet units only require a supply temperature of 28 °C for heating.
- Cool racks allow servers to be integrated into building technology and waste heat to be used directly; water with a temperature of 23 °C flows through the racks.
- Servers heat water to approx. 30 °C, which is fed into the heating system and heats office rooms.
- Cooling of servers in summer via adiabatic recooler.
- Natural ventilation through atrium inside the building, ventilation of the courtyard through the open atrium roof in summer. In winter, ventilation unit with heat recovery provides fresh air supply in the atrium. Waste heat is used as exhaust air to warm up the fresh air.

Business

- Reduction of operating costs by approx. 18 %.
- Construction costs at approx. € 10.5 million with approx. 7,000 m2 gross floor area.

Other

- GeenCIO Award for cooling/heating concept.

Image source: [43]; Sources: [44]

High-rise building Eurotheum

Germany	Frankfurt
60 °C	60 °C
Direct hot water cooling, pumps	0,6 MW
Same building	Building heating
Hot water circuit	Cloud & Heat

Technology

- Original building from 1999 (former ECB data center) with a modernization of Cloud&Heat 2017/2018 to a Tier 3+ data center with the Cloud&Heat OpenStack public cloud infrastructure.
- Direct hot water cooling (50 to 60 °C) for GPUs and CPUs for a data center on 2 floors in the final expansion with 250 kW IT power/waste heat each. 90% of the waste heat from the data center can theoretically be used. Practically, due to the high drinking water temperatures in summer and the lack of heating load, 2/3 of it is delivered to the high-rise building (with a total of 31 floors) for space heating (Hotel Melía, hotel bar 22nd Lounge e& Bar and Bistro in the foyer, local office and conference rooms, hotel and gastronomy) and hot water, 1/3 goes unused via the façade to the surroundings).
- Existing ventilation systems with mechanical refrigeration (circulating air coolers) are available in the existing building, which take over the remaining 10 % air cooling. In addition, free cooling of the existing refrigeration systems can be used under suitable ambient conditions.
- In the first step, the heat is decoupled for heating purposes and, if there is a further cooling requirement, the free cooling is used first and then, if necessary, the mechanical chiller. For water cooling, however, 100 % free cooling is possible through a newly installed ventilation system with façade flaps, due to the temperatures of 60/50 °C even all year round and with small dry coolers and glass louvre façade openings.

Business

- Cost savings in cooling of around €95,000 and €65,000 heating cost savings of 557 tonnes of CO_2 per year.
- Reduce operational costs by up to 50%.
- PUE of 1.014 according to its own data.
- According to Tech Tour, Cloud&Heat is among the 50 fastest-growing technology companies that are financed with venture capital, which makes it easier to finance.

Other

- "Master Plan 100% Climate Protection" (BMU), Frankfurt is one of the largest of the first 19 municipalities and is interested in creating a waste heat register in order to enable local usage concepts for waste heat.

Image source: [45]; Source: [46–50]

Horeka - High performance computer Karlsruhe

In operation

Technology

- Performance: 17 PFLOPS (FP64) with 22.4 GigaFlops/Watt.
- Computer system and energy-efficient hot water cooling comes from Lenovo and is based on Lenovo Neptune Direct Water Cooling (DWC) technology.
- Hot water cooling (cooling water throughput: 90,000 l/h), allowing year-round cooling with minimal energy use.
- In cold seasons, office rooms can also be heated with the waste heat.

Business

- 15 million € supercomputer.

Communication

- Dr. Jennifer Schröter, head of High Performance Computing at SCC, says, "Our technical requirements were demanding, but the bidding process was deliberately kept open to technology in order to solicit bidders' expertise and obtain the most powerful overall system."

Germany	Karlsruhe
Hot water cooling	Building heating
In the building	Karlsruhe Institute of Technology, Lenovo

Image source: [51] ; Sources: [52–54]

Location Hannover

Germany

Hannover

Cold and hot aisle containment

Building heating

In the building, neighborhood

Hostway

Technology

- Waste heat from the data center is used to heat the surrounding office space, as well as commercial space in the neighborhood.
- 4,000 m^2 data center. Power supply of 4,000 W/m^2. Data transmission per rack at several 100 megabits per second. No more than 4 kW of waste heat generated per rack.
- Location connected via Germany-wide fiber optic backbone ring and via own 2 Gigabit connection to branch offices in Frankfurt, Great Britain and Bucharest.
- Power supply via 10 kV system with 5 MW, 1,000 kVA transformer.
- UPS system with 720 kVA, two diesel generators with 1,000 kVA each.
- Room temperature of the data center regulated to 21 °C (± 2 K).
- Free cooling at low outside temperatures, chillers only switch on at certain outside temperatures.
- Plant pressurized floor air-conditioned.
- Racks are installed on raised floors in rows and according to the front-to-front principle, cold air with a supply temperature of 22 °C is fed in from the front via perforated raised floor panels and cabinet doors, warm air is extracted again behind racks via ceilings, cold air aisles and warm air aisles are clearly separated from each other.

Communication

- Commissioning of the newest data center plant in 2007, constant adaptation to increasing requirements.
- Fifth data center under construction (as of 2008), principle of cold and hot air aisles is being consistently further developed, high-pressure cold air presses are not used.

Image source: [55]; Sources: [21, 56, 57]

LRZ

In operation

Germany

60 °C

Hot water-cooling circuit, adsorption chiller

3000 m

Water circuit

München - Garching

60 °C

Building heating, adsorption cooling

Free State of Bavaria, Federal Government, German Research Foundation, Lenovo Germany, Fahrenheit

Technology

- Cooling capacity (hot water cooling) of 4 MW for cooling the SuperMUC-NG high-performance computers.
- Purely free cooling can be used all year round by means of water cooling.
- Waste heat can be used for building heating in cold seasons.
- Use of waste heat (1.1 MW) in warm seasons to generate process cooling with a Fahrenheit cascaded adsorption chiller (600 kW cooling capacity). This allows a total cooling capacity of 1.7 MW to be achieved.
- Cooling production by the adsorption chiller is used to cool the plate storage tanks.
- Direct hot water cooling is supplied by Lenovo (input: approx. 50 °C, output: approx. 60 °C).
- The first CoolMUC (since 2011) still required a heat pump.
- The new building, which was handed over in 2005, had the so-called building core temperature control for the institute and lecture hall building as the only after-use concept for computer waste heat. At least, the so-called static heating by district heating via radiators in the offices could be largely dispensed with, because the temperature control with > 21 °C in winter in the screed generally generates enough office heat.

Communication

- Close cooperation between Fahrenheit and Lenovo Germany.

Image source: [58]; Sources: [59–64]

Munich 2

Germany

Building heating

Munich

NTT Global Data Centers

Technology

- The heat generated in the data center is also used at the Munich 2 site to operate the underfloor heating, for example, in offices, in the entrance area or in the stairwell for heating.

Image source: [65]; Sources: [66]

New building data centre

Technology

- All requirements of the Energy Saving Ordinance (ENEV) were implemented.
- Use of waste heat from the computer building for the seminar and administration building section (100 percent share from waste heat).
- In case of excess waste heat, supply of the neighboring research building Center for Functional Genomics of Microbes (CFGM) with "local heat" (waste heat) via a newly laid underground line (25 percent share from waste heat).
- Two-part cooling system: 1. indirect free cooling with adiabatic spray humidification, 2. direct water cooling of the CPU and feeding of the waste heat (approx. 340 kW) into a low-temperature local heating network.
- Surface heating in the buildings to be heated.
- PV system and rainwater utilization system to increase sustainability.

Business

- Total costs of approx. 12.1 million euros.

Germany

Greifswald

Direct water cooling

Building heating

One building, neighboring building

State of Mecklenburg-Western Pomerania, HWP Planungs-gesellschaft GmbH, GTB Berlin, dc-ce Berlin-Brandenburg GmbH, IBK Ingenieurbüro Küchler GmbH, European Union

Low-temperature local heating network

Image source: [67]; Sources: [68, 69]

University of Hamburg

Technology

- Savings of 3,500 MWh of thermal energy and 1,000 tons of CO_2 per year.
- Cooling data center with water, heated water is led through pipe system via shaft and basement into Bundesstraße 45.
- Use of heat exchangers that transfer heat from water to supply air.
- Supply air is subsequently fed to university laboratories to heat rooms.
- Optimizations to controls planned for second year of operation to achieve 4,000 MWh of thermal energy saved.

Business

- Financing by climate fund of the city of Hamburg and financing model "Interacting".
- Funding from the Department of Energy, Climate and Agriculture.
- Money saved through lower electricity costs flows into funds through which new measures are financed (participation of the University of Hamburg since 2017).

Germany	Hamburg
Heat exchanger, Ventilation system	Building heating
0-500 m	University of Hamburg, German Climate Computing Center (DKRZ)
Pipe system	

Image source: [70]; Sources: [71]

University of Stuttgart – High-Performance Computing Center Stuttgart (HLRS)

Germany

35 °C

Two heat pumps

In the building

Heat network

Building heating

3,5 MW

Stuttgart

70 °C

Stuttgart and Hohenheim University Construction Office, Ministry for the Environment, Climate and Energy Management Baden-Württemberg, Pfaffenwald cogeneration plant

Technology

- HPE Apollo (Hwak): Flagship supercomputer (CPU and GPU) of the Stuttgart High Performance Computing Center and one of the fastest computing systems in Europe (26 petaflops).
- Power consumption: max. power consumption per rack: ~90 kW; power consumption during normal operation; ~3.5 MW; power consumption LinPack operation: ~4.1 MW.
- Cooling: 6 distribution units for cooling (CDUs); water inlet temperature: 25 °C; water return temperature: 35 °C; water inlet temperature (ARCS cooling towers): 16 °C; water evaporation for wet cooling towers: ~9 m^3/h.
- Since 2012, own buildings have been heated with two electricity-based heat pumps (heating capacity of 55 kWth each), which raise the temperature level of waste heat to a level that can be used for heating purposes. Approx. 96 % of the heat required for heating the HLRS buildings is covered by waste heat from the maximum power computer (max. 100 kW in winter). Approximately 270 MWh of heat is generated by this annually. The part of the waste heat that cannot be used is dissipated by free cooling. In high summer, district cooling is also used.

Law

- Certified: ISO 14001, 50001, EMAS, Blue Angel for energy efficient data center operations.
- Introduced environmental management system systematizes sustainability efforts and makes it an integrated part of the center

Business

- A comprehensive study has determined that the use of waste heat from HLRS to supply heat to the university campus is ecologically necessary and economically feasible.
- In the course of planning, possible variants will be further specified and prepared for implementation. The expansion of the infrastructure with supply channel and heat network, the further planning of the new construction project HLRS III and the buildings suitable for the use of waste heat will also be considered.

Image source [72]; Sources: [73–78]

Unterfränkische Überlandzentrale Lülsfeld

Technology

- Recirculating air cooling units extract waste heat from the data center.
- NOVELAN brine-to-water heat pump with a heat pump capacity of 50 kW_{th} at 22 °C heat source temperature.
- COP of 7.0 at 22 °C heat source temperature and 35 °C flow temperature.
- Heating of the company's own rooms (offices and workshop via heated ceiling), a total of 500 m^2 of heated floor space.
- Return flow from the cooling brine system flows into a 1,000-liter buffer tank. This serves as a heat source for the heat pump.
- There is a primary and secondary cooling loop to increase unit run time and prevent cycling of the chiller.
- A 2,000-liter buffer tank is integrated into the secondary circuit.
- Annual performance factor is 4.48 at a maximum system temperature of 55/45 °C.

Business

- With an electricity price of 18 cents per kWh, this results in a heat work price of 4 cents per kWh; significantly cheaper than standard heating operation of the overland center using natural gas condensing boilers.
- Natural gas savings of 100,00 kWh per year; saves 25 tons of CO_2 annually when using natural electricity.

Germany	Lülsfeld
22 °C	35 °C
Heat pump, heat buffer tank	NOVELAN, unterfränkische Überlandzentrale
In the building	Building heating
Direct connection cooling circuits	

Image source: [79]; Sources: [80–82]

Züblin Z3

In operation

Germany

Stuttgart

34 °C

29 °C

Chillers (heating and cooling operation), buffer storage, heating ceiling, passive house standard, underground car park access heating

Ed. Züblin AG, zafh.net, Biberach University of Applied Sciences, Fraunhofer Institute IBP, Federal Ministry for Economic Affairs and Energy

On the buidling

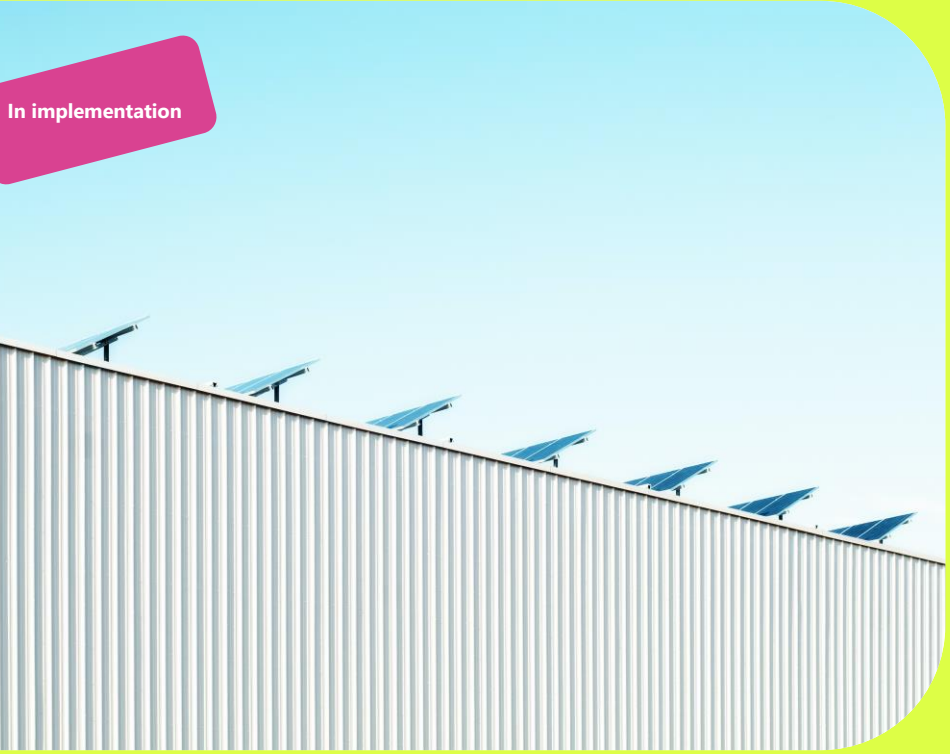
Building heating, Process heat - snow melting loop

Image source: [83]; Sources: [84–87]

Technology

- Waste heat from the data center is used for the complete heating of the office building in combination with a facade in passive house quality (0.4 W/m²K). Energy transfer takes place in the office and meeting rooms by means of heating/cooling ceilings and in the stairwell with an underfloor heating system.
- Heat demand (4.30 kWh/m²a) of the building is so low that the waste heat is sufficient to keep the access road to the underground car park (approx. 200 W/m²) ice-free in winter.
- Data center has a cooling demand of about 200 MWh/a, which is mainly covered by free cooling. 2 chillers are available, one designed for heat pump operation and the other for cooling operation. In winter, the heat pump and the waste heat from the data center are used to heat the office building and completely cover the cooling demand of the data center. In the summer months, both chillers operate in tandem.
- Cold and hot aisle for server cooling. An electronic control system controls and monitors all the necessary components for refrigeration. The supply temperature in the refrigeration circuit is 19 °C, so that the air conditioning units can supply air at 20 to 22 °C directly to the racks. The existing warm aisle results in a warm air temperature of approx. 34 °C.
- CHP for peak load.
- Buffer storage for low-temperature heating (heat pump) to achieve high annual performance factors.
- Heating/cooling ceiling has a supply temperature of 29 °C and contributes to the high annual performance factor.

25 MVA Data center



Germany

District heating network

Schwalbach am Taunus

25 MVA

Data Castle

Technology

- First "Green Data Center" from Data Castle in Schwalbach with a capacity of 25 MVA.
- Co-location data center.
- Use of exclusively renewable energies and waste heat is fed directly into the district heating network.
- Installation of solar panels for power generation on the site.
  Planned PUE value of 1.25.

Business

- Construction work to start in 2023.
- Completion of first construction phase and move-in of first customers planned for second half of 2024.

Communication

- Property convinces with necessary infrastructure, waste heat concept can be realized.
  The site belongs to the Frankfurt Availability Zone.

Image source: [88]; Sources: [89]

Audi IN CAMPUS

Germany

22-30 °C

3000 m

2023

Low-Ex network, reversible heat pumps, thermal storage, surface heating

Cold local heating network

Ingolstadt

Max. 45 °C

2 MW

Building heating

AUDI Plant Planning/ Planning Energy and Building Technology, Audi AG, Drees & Sommer, City of Ingolstadt, Ingolstadt Municipal Utilities, Ingolstadt University of Applied Sciences, Fraunhofer Institute Magdeburg, incampus GmbH

Image source: [90]; Sources: [91–93]

Technology

- Waste heat (approx. 2 MW, in the final stage 20 MW) from around 8,000 servers (Group data center) is used as heating energy.
- The waste heat from the IT servers is transferred via heat exchangers to the cooling water system, which serves as a heat source for waste heat utilization. If no waste heat is used, the data center independently cools the cooling water circuit to the required temperatures.
- Heat is extracted via a valve in the water circuit (between 22 and 30 °C). Excess waste heat is dissipated via air conditioning units and hybrid coolers.
- The Low-Ex network (DN800 - DN600, pipeline length 3,000 m (9,100 in final construction), water capacity 1,220,000 l) consists of combined piping open in both energetic directions. The temperature ranges between 5 - 30 °C.
- Reversible heat pumps (flow temperature: max. 45 °C) in connection with surface cooling heating systems and supporting radiators are provided in the buildings.
- Heat pumps are designed to provide only 50 % of the necessary heating capacity (cover 80 to 90 % of the annual demand). The district heating network of Stadtwerke Ingolstadt is used to cover the peak load.
- With a capacity of 3,000 m^3, both heat and cold are stored in the sprinkler extinguishing water tanks. In addition, the earth storage tanks with a capacity of 28,779 m^3 serve as heat storage.

Business

- Planned commissioning in the course of 2023.
- Joint venture between AUDI and the city of Ingolstadt.
- The development of the INCampus focuses on future-proof and sustainable concepts - both in the construction of the buildings and in the energy supply of the technology park. The research campus serves as a trial for Audi to advance the energy transition worldwide.

Communication

- Vision of a zero-energy campus.
- External consulting by IBM and minimizing the number of interfaces between the local heating network and the data center have contributed to a high level of acceptance among IT managers.

Data center campus heated night club

Germany

High temperature heat pumps

0-500 m

Local heating network

2024

Frankfurt Seckbach

30 MW

Building heating, heat grid feed-in

Mainova Webhouse GmbH & Co. KG, Mainova AG, Batschkapp Cultural Center

Technology

- Data center area with 10,500 m² and an IT load of about 30 MW.
- High energy efficiency and supply exclusively with green electricity.
- Own photovoltaic systems on site.
- Greening of facade and exterior to contribute to sophisticated appearance, insulation and cooling.
- Use of waste heat from the data center to supply heat to the campus and nearby buildings.
- "Buildings feature optimal use of space for high computing power per square meter as well as ecological construction," says Mainova CEO Dr. Constantin H. Alsheimer.
- Two high-temperature heat pumps. Flow temperature of 75 °C.
- Dismantling of the original gas heating system and hydraulic connection with Batschkapp via a connecting line as an emergency supply.
- Heat demand of around 300 MWh/a.
- Simultaneous construction of a 110 m long pipeline.

Law

- Meeting the sustainability goals of customers

Communication

- Fulfillment of the company's own sustainability goals

Other

- No noise / odor emission nuisance
- Batschkapp customer converts heat supply on its own premises.
- Savings of 35 tons of CO_2 per year

Image source: [94]; Sources: [95–99]

Equinix FR 4, FR 6 and FR 8

Germany

Frankfurt - Griesheim

Heat exchanger, Low temperature network, heat pumps

Equinix, AS Enterprise Engineering GmbH

2000 m

Building heating

Local heating network

56 MW

Technology

- A low-temperature network is being planned. Within four phases, starting from the north, the center and the east of Griesheim are to be developed.
- Extraction of waste heat through heat exchangers and pumps in the network to consumers, current distance of two kilometers.
- Heating of buildings via local water pumps.
- In the final stage, data center should be able to supply around 56 MW of waste heat for a heat demand of 35-45 MW.

Law

- Contract guaranteeing free provision of waste heat for at least 20 years, with option for extension.

Business

- No investment costs incurred, as start-up assumes costs.
- Possible long-term binding heat price of 15 cents per kilowatt hour, which could also be "significantly reduced" after completion of the implementation planning.

Communication

- Start-up wants to design and implement low-temperature heating networks for urban heating in the city and region of Frankfurt am Main.
- Reason for idea is operator Equinix's many data centers on Lärchenstrasse.
- Idea also relevant for homeowners and tenants because of current concerns about energy and heat supply.

Others

- Three data centers already in place (FR4, FR6, FR8 (still under construction)) and more in the planning stage.

Image source: [100]; Sources: [101, 102]

FRANKY

Germany

30 °C

Large heat pump, buffer storage, district heating network

500 m

35 MW

2025

Frankfurt, Gallus district

70 °C

Local heating network

Building heating

Telehouse Deutschland GmbH, Mainova AG, Instone Real Estate, Bayerische Versorgungskammer

Image source: [103, 104]; Sources: [105–114]

Technology

- IT power approx. 35 MW, but continuous increase due to expansion on campus. Actual power consumption at approx. 20 MW, of which approx. 2/3 is pure IT power (approx. 14 MW).
- Spatial proximity of data center - residential quarter (new building), construction of waste heat line from data center of Telehouse to main technical center: approx. 500 meters, expansion of district heating line: approx. 260 meters along Rebstöcker Straße, construction of local heating network in residential quarter: approx. 580 meters.
- Temperatures of local heating network: 70/40 °C, 2 large heat pumps with 320 kW_{th} each, heat load and output of the district heating station of 3,210 kW_{th}, annual demand 4,000 MWh/a of 1,300 new apartments, 3 kindergartens and commercial units; of which at least 2,400 MWh/a are to be covered by waste heat.
- Combination of data center waste heat (min. 60 %) and district heating (max. 40 %, generated among other things by waste incineration in the MHKW Frankfurt). The waste heat temperature is about 30 °C. In addition, there is a small buffer storage.
- Coupling of local and district heating network to ensure heat supply at peak load times. Max. Heating load residential quartier Westville 3.2 MW. Mainova heat purchase from Telehouse in winter approx. 500 kW plus 140 kW_{el} for heat pumps results in max. 640 kW_{th}. In summer, a heat demand of approx. 100 to 200 kW_{th}, which means that the district heating network is not used at all.

Law

- Mainova contracting, 15-year contract term, Mainova plans and builds the technical systems, Telehouse commits to Mainova to supply this waste heat for 15 years.
- The energy supplier was granted access by the data center operator "to everything they install". Contract Telehouse - Mainova and Mainova - Instone is signed.

Business

- Willingness to cooperate with data center (security and free waste heat). Currently only profitable because the waste heat from the data center is provided free of charge.
- Completion of the overall project: 2025, phase 1 and first heat supply: 2023.

Communication

- Openness and interest of the developers/investors as well as the data center operator.
- First project of this type and size in Germany.
- Savings of 440 t CO_2 per year compared to conventional heat generation.

Other

- Mainova has a sustainability strategy in its 2028 corporate strategy.
- Telehouse was extremely cooperative and signaled a willingness to decouple heat at an early stage.

JH-Computers

Germany

30 °C

Water-cooled rack doors, adsorption chiller, CHP, Fresh water stations, buffer tank

Local heating network

1 MW

Stödtlen

95 °C

Building heating, Warm water

JH-Computers GmbH

Image source: [115]; Sources: [116, 117]

Technology

- "Cumulus Computing" with 1 MW IT power and a PUE of 1.05.
- Power density of 40 - 60 kW per cabinet with 50 cabinets on 220 m².
- Water-cooled rack doors.
- Use of PV on the roof, which is designed for maximum possible power. In addition, building shape is designed to achieve maximum PV yield and other PV systems are located on surrounding buildings. Remaining electricity demand is covered by biogas and PPAs for wind and solar. Thus, the data center is operated 100 % CO_2-free.
- Use of several combined heat and power plants, operated with biogas from the balance sheet, which on the one hand supplies electrical power for the data center operation and on the other hand uses the thermal power to drive n+2 redundant and modular adsorption chillers, which in turn cool down the chilled water. This results in a CHP system. In the maximum expansion, 3 to 5 CHP units are to be used.
- The adsorption machine has a heat pump operation. With the data center waste heat (30 to 40 % share) and the CHP heat, heat can be extracted at a temperature level of up to 95 °C.
- The room air temperature is a constant 22 °C for all servers. The return temperature of the cold water is between 23 and 26 °C.
- In addition, the waste heat generated will be decoupled and fed into a local heating network to be set up (construction to begin in 2023).
- In Stödtlen, with a population of around 2000, heating oil used to be the most important fuel for heat supply. Now the changeover to a warm local heating network is taking place and the initial connection rate is 60 %. Fresh water stations with small buffer tanks are installed in the households.

Business

- A separate company is founded for the local heating network, in which the residents can also become shareholders.
- Compared to a "classic standard data center ", the annual operating costs can be reduced by about 66 %.

Communication

- Most residents were convinced by the project, which is also evident from the high initial connection rate.

MU4

Germany

Aquifer Thermal Storage (ATES) System

Munich

Equinix

Technology

- First $90 million phase provides more than 2,250 sq. ft. of colocation space and more than 825 cabinets of capacity.
- Install Aquifer Thermal Energy Storage (ATES) system in next phase of construction for heat recovery.

Communication

- "At the local level, we are engaging with operators, policymakers and energy providers to address the long-term challenges of sustainable digitization for the benefit of the surrounding area. This includes design aspects such as the use of green facades as well as possible measures to support the energy transition such as the use of waste heat." Jens-Peter Feidner, Managing Director Germany at Equinix.

Other

- Data center is powered by an expected 100% renewable energy sourced through a green power certificate from local supplier Mainova.
- International Business Exchange (IBX) facility.

Image source: [118]; Sources: [119, 120]

nLighten Data Center

Germany

District heating network

Building heating, swimming pool heating

800 m

Eschborn

2,4 MW

nLighten, City of Eschborn, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)

Technology

- Use of heat from plant with 2.4 MW_{el} capacity for district heating supply of GIZ-owned properties in Eschborn and the Wiesenbad of the city of Eschborn.
- Construction of 800 m long supply pipeline for connection between Edge-data center and Wiesenbad for transmission of hot water.

Law

- Signing of Memorandum of Understanding for the reuse of waste heat from the data center.

Communication

- GIZ aims to use the project not only to reduce its energy costs, but also to promote sustainability initiatives.
- nLighten is also looking into heat recovery at its other ten German sites and says it is "already in discussions with municipal authorities and local stakeholders."

Other

- "The ongoing digitization of the economy and the accompanying energy transition are creating an exciting opportunity to integrate data centers with local energy infrastructure," said Chad McCarthy, CTO at nLighten.

Image source: [121]; Sources: [122, 123]

Voltastraße, Hattersheim

Germany

Building heating

Hattersheim

NTT Global Data Centers

Technology

- Five NTT data centers on the Voltastraßen are to provide their waste heat to heat 460 apartments in a new residential area.
- The waste heat is sufficient to cover around 80 % of the buildings' energy needs.

Image source: [124]; Sources: [125]

ZIH TU Dresden

Germany

Heating pumps

District heating network

2024

Dresden

Building heating

Staatsbetrieb Sächsisches Immobilien- und Baumanagement (SIB), SachsenEnergie, TU Dresden

Technology

- Processing of the surplus waste heat (24,000 MWh) from the high-performance computer of the ZIH with three heat pumps.
- Use of waste heat in the district heating network of SachsenEnergie.
- Theoretically, an average of 3,100 households can be heated.
- Avoidance of 2,700 tons of CO_2.
- Construction of technical building with heat pumps west of the Lehmann Center data center.
- Use of waste heat for feeding into the grid, in winter heat is already used for heating surrounding university buildings and is to be increased.

Business

- Total costs of around €1.6 million.
- Construction measure is co-financed by tax funds on the basis of the budget passed by the Saxon state parliament.
- Investment by SachsenEnergie of around €3.2 million in plant, with financial support from the German Federal Ministry of Economics and Climate Protection as part of the National Climate Protection Initiative.

Other

- Future user SachsenEnergie will provide technical equipment for the technical building.

Image source: [126]; Sources: [127, 128]

80-MW-Hyperscale-Datacenter

Germany

Residential area on site

Stack Infrastructure

Taunus community Liederbach

80 MW

Building heating

Technology

- 80 MW data center campus with a size of 70,000 m^2.
- Campus is focused on energy efficiency and sustainability.
- Houses four facilities.
- Facilities will contribute to a circular economy, such as through the use of innovative green technologies, including rainwater harvesting and providing surplus heat for on-site residential development planning.

Communication

- Work closely with CCEP DE and collaborate with Liederbach community to foster local relationships and shared vision for modern data center campus.

Other

- "We know there is overwhelming demand in Frankfurt for fast, flexible, resilient and efficient data center infrastructure. That's why we answered the call to deliver exactly what our customers expect." John Eland CEO of Stack EMEA.
- Eva Söllner is the mayor of Liederbach, a community of 8728 inhabitants. She points out, "The community of Liederbach is looking forward to opening its first on-site data center campus and contributing to an increasingly connected world." She expects positive effects, such as short-term and long-term benefits and new perspectives.

Image source: [129]; Sources: [130]

Data center campus at the ICE train station

Germany	Limburg
30 °C	35 MW
Patented water-cooling systems, floor heating	OVHcloud, PowerRZ GmbH & Co. KG, Limburg Energy Supply (EVL)
In the Building	Building heating
Water circuit	Q2 2023

Technology

- Data center with a server capacity of 35,000 servers on an area of 10,330 m² at the Limburg ICE train station. The building occupies a gross area of around 4,500 m².
- Commissioning is scheduled for Q2 2023.
- The data center will exclusively use water cooling systems developed and patented by OVHcloud itself, which combine high reliability with high energy efficiency. To increase redundancy and thus resilience, each server rack has its own double-redundant mini water loop system.
- With 2017 technology status, the water blocks can dissipate 200 W at a water temperature of 30 °C. Using the latest technology with laser-welded metallic base plates and covers, screws and glue can be avoided and the risk of leakage minimized.
- Electricity is sourced from the regional provider Energieversorgung Limburg (EVL) from 100 percent renewable sources.
- The data center is being built on a "greenfield" site, allowing the new facility to be tailored to OHVcloud's requirements from the outset.
- PowerRZ GmbH & Co. KG will take over the planning of the data center. Direct water cooling will not only be used to increase energy efficiency, but also for waste heat recovery. For the new building, the return flow from the server room cooling is used to heat the offices via underfloor heating. A green facade and a green roof are also used to compensate for sealed surfaces.

Business

- OVHcloud plans to invest an amount of around 100 million euros in the new data center over a period of five years.
- 25 new jobs will be created directly and an additional 20 indirect jobs.

Image source: [131]; Sources: [132–136]

Digital Park Fechenheim (former Neckermann site)

Germany

Large heat pump

Local and district heating network

Digital Reality Mainova

Frankfurt Fechenheim

Building heating, feed into the district heating network

Technology

- When fully developed, 20 MW of waste heat for district heating supply, heating energy for around 3,600 households.
- In addition, waste heat utilization for local heating network is planned for around 18,000 m^2 of own office and storage space.
- Installation of several large industrial heat pumps in the listed boiler house on the Digital Park Fechenheim site to raise waste heat from the data center to the required temperature level for feeding into the district heating system.
- Construction of a new district heating line in the immediate vicinity of the Digital Park for connection to the grid.

Law

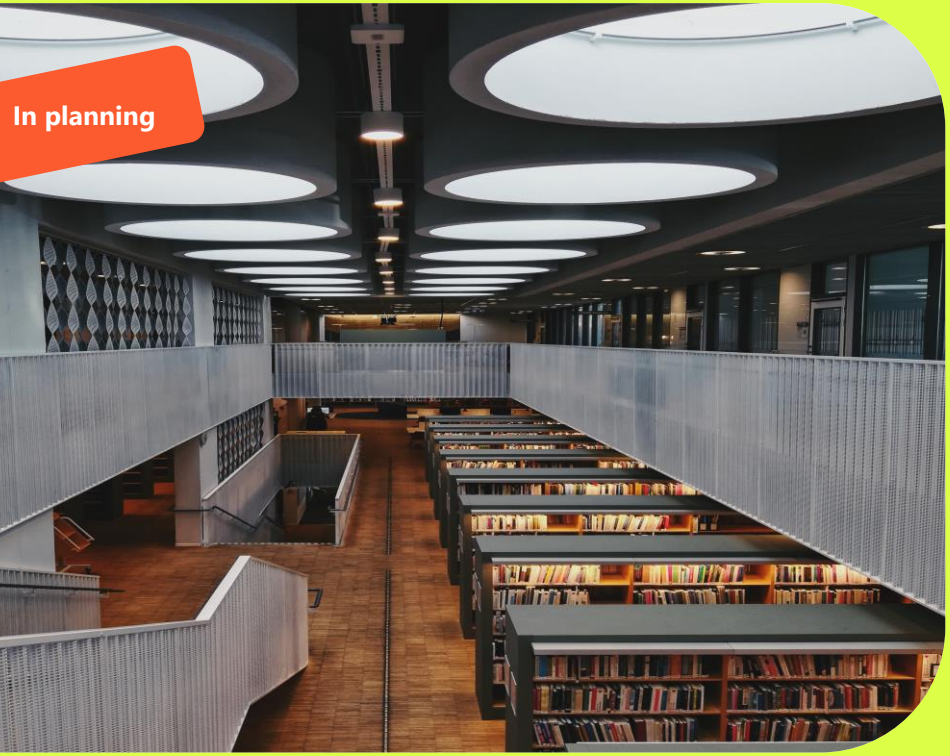
- Signing of a memorandum of understanding for a joint project on the sustainable use of waste heat from data centers.

Communication

- Construction of data center campus with eleven new data centers.
- Feasibility study to examine whether waste heat from a data center can be fed into Mainova district heating network.
- "The cooperation with our partner Digital Realty will enable us to integrate data center waste heat into our district heating system for the first time in the future," says Mainova Chief Technology Officer Martin Giehl.
- First data center "FRA17" with state-of-the-art infrastructure already completed and handed over to operations.
- FRA18 is already under construction and will be completed in the coming winter of 2023. Construction of FRA27 will begin and will also be completed in the winter of 2023.

Image source: [137]; Sources: [138]

heiCOMACS



Germany

Heidelberg

State Government of Baden-Württemberg, Klaus Tschira Foundation, University of Heidelberg

Technology

- Waste heat from the data center is to be made usable for building operation via a heat recovery system.

Betriebswirtschaft

- Total investment of around 15 million euros.

Image source: [139]; Sources: [140]

Ingelheimer Aue

Germany

Large heat pump

District heating network

Ingelheimer Aue in Mainz

54 MW

Kraftwerke Mainz-Wiesbaden AG (KMW), Green Mountain

Technology

- Site area of 25,000 m^2, successively three buildings with a total IT capacity of 54 MW.
- Waste heat of up to 60 MW is fed into the Mainz district heating network via large heat pumps.
- Cooling water is drawn from the Rhine.

Communication

- As Markus Blüm, Managing Director of Green Mountain KMW Data Center GmbH, explains, this is "a beacon project for the industry, as the combination of secure, emission-free power supply, sustainable heat utilization and efficient cooling is unique for a data center of this size."

Other

- Construction of first building to begin in fall 2023.
- KMW says it is using synergies at the site to sustainably supply the buildings and is responsible for subsequent maintenance.
- KMW's operating site on the Ingelheimer Aue offers several advantages, such as power supply from KMW's renewable energy portfolio and good grid connections.
- Surrounding KMW power plants secure the emergency power supply.

Image source: [141]; Sources: [142, 143]

JUPITER Project

In planning

Germany	Jülich
Water cooling	15 MW
In the Building	Building heating
Low temperature network	Forschungszentrum Jülich, European High Performance Computing Joint Undertaking
2023	

Technology

- The computer, called "Jupiter", which stands for "Joint Undertaking Pioneer for Innovative and Transformative Exascale Research", will be installed in a purpose-built building on the campus of Forschungszentrum Jülich from 2023. The Jülich Supercomputing Centre (JSC), whose supercomputers "Juwels" and "Jureca" are currently already among the most powerful supercomputers in the world, is planned as the operator.
- A major challenge is the energy required for such a large computing power. The expected average power is up to 15 MW.
- However, the future operators say that Jupiter is designed as a "green" computer and will be powered by green electricity.
- The planned hot-water cooling is intended to help the supercomputer achieve high efficiency values. At the same time, the cooling technology opens up the possibility of making intelligent use of the waste heat generated, for example by connecting Jupiter to the new low-temperature network on the campus of Forschungszentrum Jülich, just like its predecessor system Juwels. Other possible uses for Jupiter's waste heat are currently being investigated by Forschungszentrum Jülich.

Business

- The total cost of the system is 500 million euros.
- 250 million euros will be provided by the European supercomputing initiative EuroHPC JU and the other half by the Federal Ministry of Education and Research (BMBF) and the Ministry of Culture and Science of the State of North Rhine-Westphalia (MKW NRW).

Image source: [144]; Sources: [145]

Residential area „An den Eichen“

Germany

Local heating network

2024

Offenbach

Building heating

Cloud HQ

Technology

- A non-evaporative heat rejection system was planned, with a PUE < 1.25.
  Waste heat from the Evo data center is to be fed into the company's own district heating network, with an additional 9 MW of heat from new data centers to heat 1200 two-person households from 2024.

Business

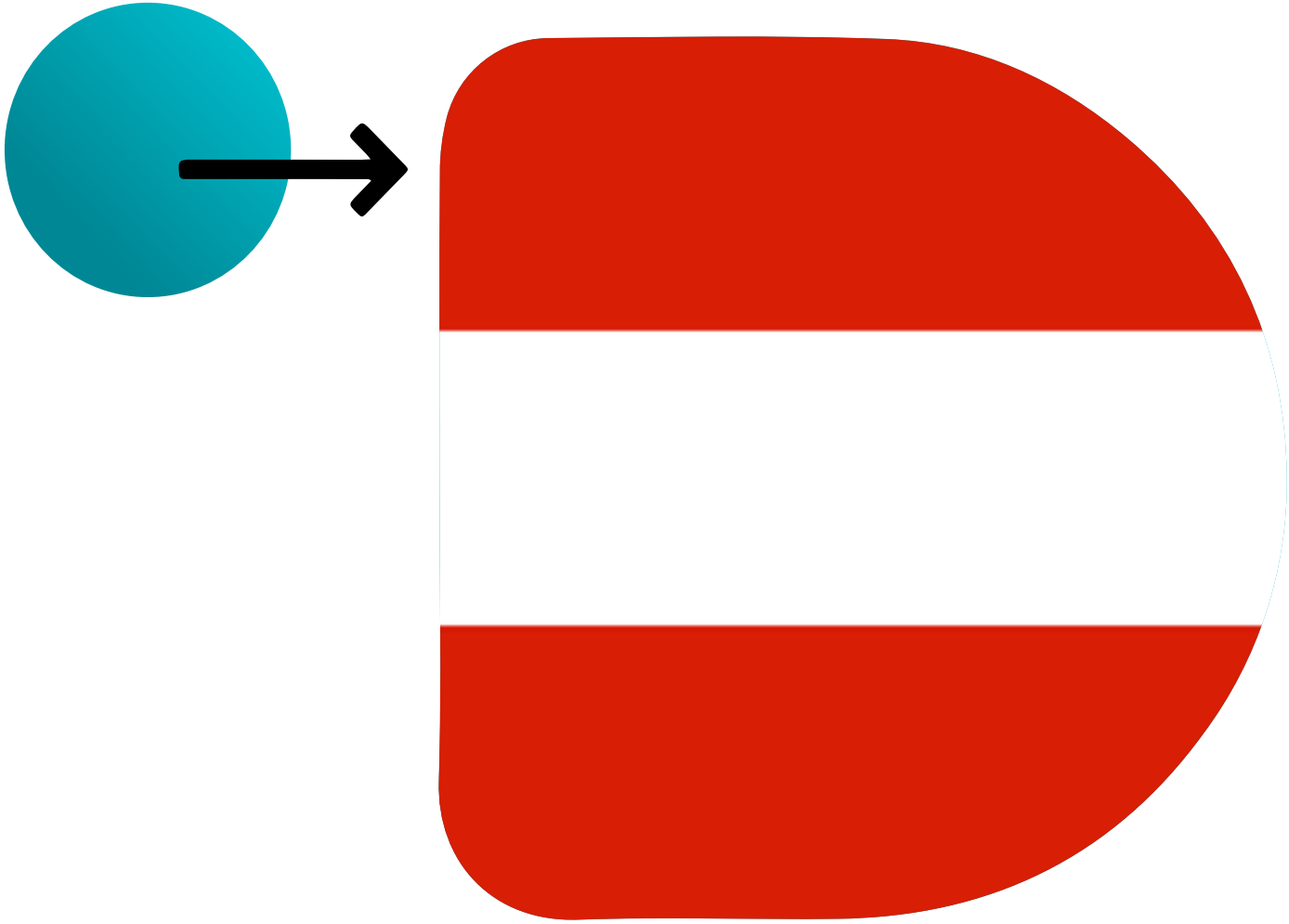
- 500 million euros total cost.

Communication

- The residential area "An den Eichen" was completed and connected to the local heating network before the data center. For a connection, the data center would have had to be built earlier. Possibly a swimming pool could be built nearby. A connection to Bürgel-Ost is considered realistic by some partners.
- Potential customer for the waste heat of the private data center: Samson Werk, since large demand for heat, but rather unlikely.
- Criticism of Cloud HQ data center because of land sealing, unused waste heat, large environmental impact from diesel generators for emergency power.
- Criticism led to better exchange between Cloud HQ and local agenda.

Image source: [146]; Sources: [147–151]

AUSTRIA



Waste heat recovery in a Viennese hospital

Austria	Vienna
26 °C	82 °C
Heat pumps, heat exchangers	40 MW
A few hundred meters	Building heating
Heat network	Interxion, Floridsdorf Hospital, Wien Energie, Austrian Government
2023	

Image source: [152]; Sources: [153–157]

Technology

- The Interxion Campus consists of about 120,000 servers on an area of 22,000 m² with an IT connection capacity of up to 40 MW.
- From 2023, the Floridsdorf hospital will be heated by water heated by the Interxion data center with the help of heat pumps. Two heat exchangers in the technical center connect Interxion's cooling circuits with Wien Energie's waste heat recovery system. This is expected to save 4,000 tons/year of CO_2.
- The hospital already has a heating circuit system with a pipe length of 90,000 m. Per year, 73,000 m³ of hot water is used.
- The hospital should be able to meet 50-70 % of its heating needs with waste heat.
- The servers are cooled with air, which causes the cooling water to leave the server rooms at a temperature of about 26 °C. For the hospital, heat pumps are then used to raise the temperature level to as high as 82 °C. The temperature of the heat pump return is 16 °C on average and can be used for cooling the data center.
- The energy supply company Wien Energie installs three heat pumps (COP ≈ 4, output of 1 MW each) in the hospital's energy center. There, heat is taken from the cooling circuit of the data center and supplied to the heating circuit of the hospital with the help of the heat pumps. The heat is used in the hospital, while the cooled water is returned to the data center.
- The electrical energy requirements of the heat pump are covered, among other things, by an on-site wind turbine.

Business

- The Austrian government is paying EUR 3.5 million from the Environmental Fund for technical infrastructure between Interxion's data center in Louis-Häfliger-Gasse and the Floridsdorf hospital, which is located next door in Brünner Straße.

Communication

- Austrian Environment Minister Leonore Gewessler stressed that the project is part of the country's efforts to meet its energy needs through local production. She pointed out that a good way to do this is to use energy that is already produced in the country but is subsequently wasted.

Other

- Project was chosen as the project of the month of environmental promotion in the country.

SWITZERLAND

Data Center Eastern Switzerland (RZO)

In operation

Switzerland	Gais
20 °C	100 °C
Heat exchangers, high temperature heat pumps	Process heat for pasteurization, building heating
neighboring	St. Gallisch-Appenzellische Kraftwerke AG (SAK), St. Galler Stadtwerke, Bergkäserei Gais
1,5 MW	
Local heating network	

Image source [158]; Sources: [159–162]

Technology

- Data center with 1.5 MW IT connection capacity and a PUE of 1.15.
- Facade and roof surfaces equipped with photovoltaic system, generates 230,000 kWh of electricity annually for data center.
- Adiabatic cooling (ServeCool units from Hoval) requires no mechanical chillers and operates in a climate-friendly manner through free cooling.
- Location 920 m above sea level saves cooling capacity due to colder environment.
- Rainwater collection for adiabatic cooling in Gais.
- Cross-flow plate heat exchanger with side length of 1.20 meters, size allows above-average heat recovery. The heat exchanger area amounts to 1,200 square meters per ServeCool.
- Waste heat utilization in the local heating network through connection by means of a water circuit.
- Water is heated to 20 °C by waste heat, cheese dairy extracts energy, water cools down to 14 °C and flows back again. The neighboring mountain cheese dairy in Gais draws around 1.5 GWh of waste heat annually (decoupled waste heat output up to approx. 800 kW). Around 18 million liters of milk are heated annually with waste heat.
- High-temperature heat pumps still have to raise the temperature for cheese-making (up to 100 °C). Waste heat is also used for heating the building.

Business

- Hochverfügbarer, energieeffizienter Kommunikationshub, gleichzeitig auch Solar- und Wärmekraftwerk.

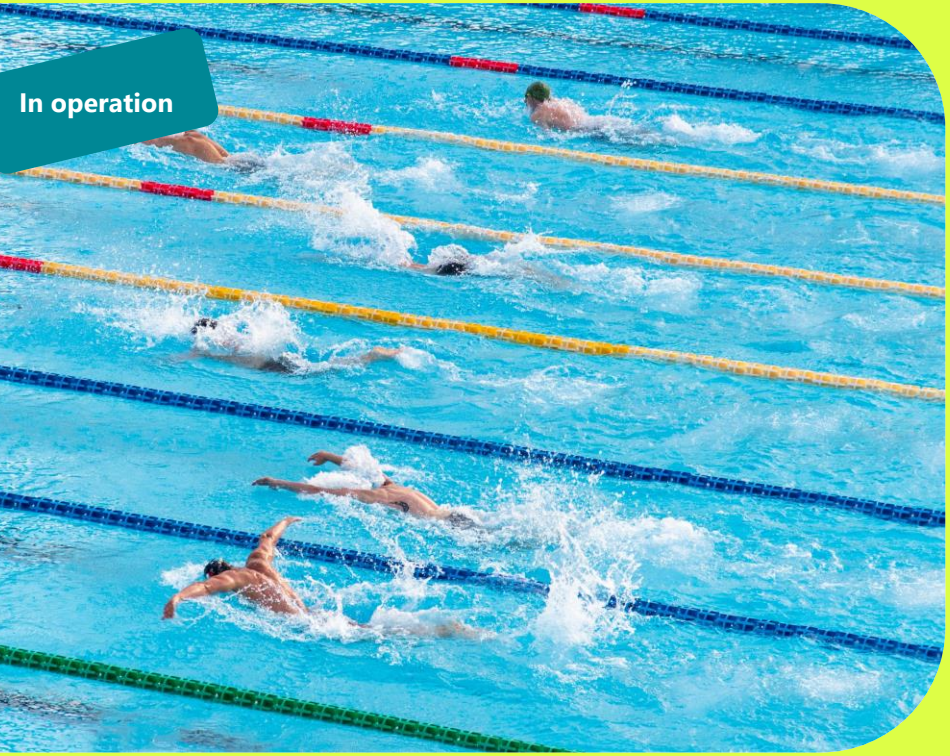
Communication

- Pre-construction contact with neighbors in the upstream industrial area of the municipality and cantonal offices for close cooperation.
- Project met with great approval.
- In the next six years, 270 racks are to be rented out, utilization of approx. 90 % (as of March 2019).

Other

- Data center has been certified at TIER IV level.

Data center of GIB-Services (IBM) near Zurich for heating an indoor swimming pool



Technology

- Underground data center that can accommodate 300-500 customer servers on 200 m² at full capacity.
- According to IBM, it generates up to 2800 MWh of waste heat annually; at 8760 hours per year, this corresponds to just under 320 kW of continuous power.
- Use of heat exchangers to provide waste heat to a swimming pool.
- Excess heat is collected in a storage area, water is heated with it and directed to heat exchangers in the swimming pool.
- Heated water warms the pool water.
- Up to 130 tons of CO_2 per year are said to be saved here.

Business

- Provision of waste heat free of charge.
- Municipality assumed part of the connection costs.

Other

- Former military bunker used.
- Opened for colocation customers since May 2008.

Switzerland	Uitikon
Heat exchanger	320 kW
IBM, GIB-Services	Process heat - indoor swimming pool

Image source: [163]; Sources: [10, 164, 165]

ECO-Qube

Switzerland

Heat pump

Medium and low temperature network

Dübendorf

Building heating

NEST, Lande, SDIA

Technology

- The "ECO-Qube" data center in NEST is simultaneously part of the IT infrastructure and part of the building technology.
- A field test with micro data centers in the NEST research building at Empa and at two other locations in Turkey and the Netherlands aims to explore the potential of heating buildings.
- Sensor data from individual IT components is accumulated in Big Data structures, helping to ensure that heat distribution within the facility is accurately recorded at all times. Artificial intelligence combines this data with airflow simulations so that cooling can be highly targeted. At the same time, the computing loads in the three test data centers in Switzerland, Turkey and the Netherlands are distributed so that all three facilities can be operated as energy-efficiently as possible.
- The three data centers will be integrated directly into the energy systems of the surrounding neighborhoods and will be powered by renewable energy wherever possible.
- For the data center in NEST, the electricity for operation comes from the photovoltaic systems of the NEST units and the mobility demonstrator move, among others.
- The waste heat from the data center is fed into the existing medium- or low-temperature network. In winter, it directly feeds the building's heating system and, throughout the year, also serves as a source for a heat pump that provides domestic hot water.

Business

- Server system is part of the EU research project "ECO-Qube", which investigates the integration of data centers into building systems and their energy-efficient operation.

Communication

- The project, called "ECO-Qube," is supported by the EU's Horizon 2020 funding program and brings together research and industry partners from Switzerland, Turkey, Spain, Germany, the Netherlands and Sweden.
- The project will last about three years. Once completed, the team aims to be able to provide guidelines for planners and building operators to help them integrate data centers into buildings and neighborhoods in an energy-efficient way.

Image source: [166]; Sources: [167, 168]

Airport City energy network

Switzerland

Large heating pump

Energy network (pipeline networks)

Zürich

Building heating, cooling, hot water production

InterXion, EBL (Genossenschaft Elektra Baselland), Energie Opfikon AG

Technology

- Heating and cooling are generated in a climate-friendly energy network.
- The primary energy source is waste heat from data centers, which is processed and made usable by large heat pumps.
- Supply to customers via piping networks for heating, water heating or cooling.

Business

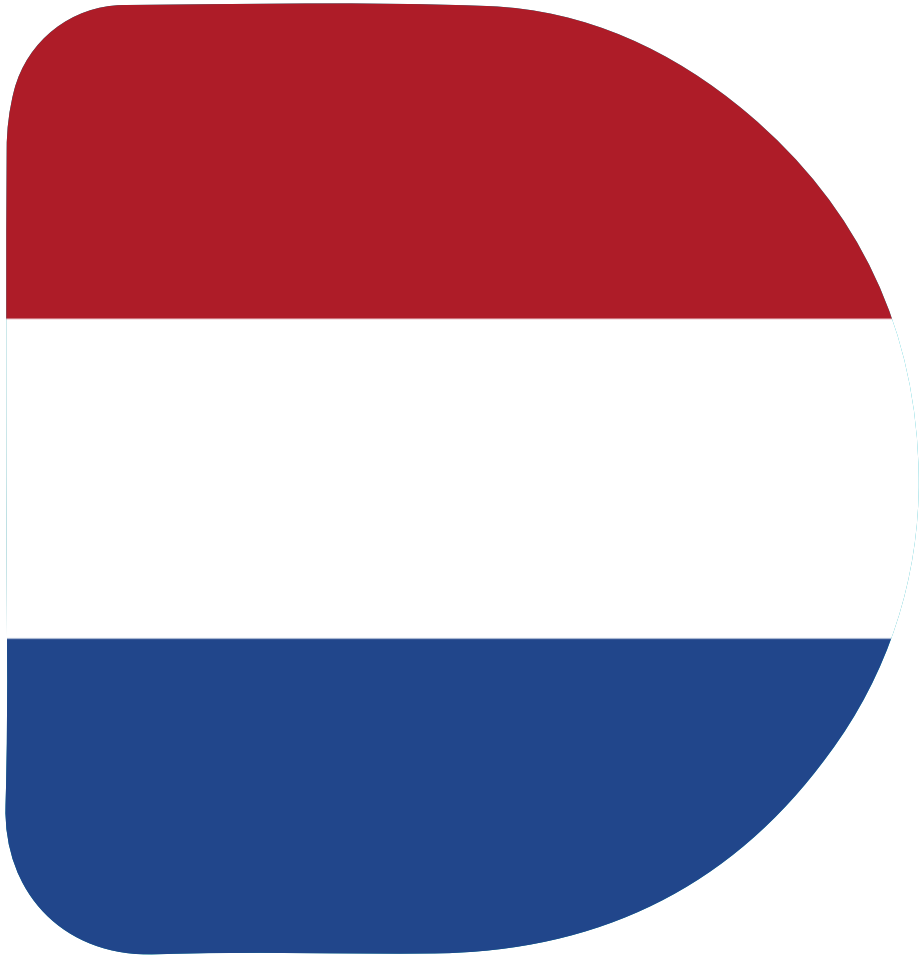
- Construction of an energy network with the aim of generating minimum emissions for heating and cooling and using unused waste heat from the data center in the energy network.
- High energy density and demand in the area between Glattbrugg station and Balsberg for heating and cooling.
- Energy network for district heating and cooling is worthwhile.
- Waste heat is used in summer by the energy center to generate heat.
- Customers also require heat in summer for operational processes, among other things.

Other

- No noise / odor emission nuisance

Image source: [169]; Sources: [170]

NETHERLANDS



BlockHeating

Netherlands

65 °C

Liquid cooling

Venlo

200 kW

Agricultural use

EcoDataCenter, WA3RM

Technology

- All-in-one data centers in containers with 200 kW IT power.
- Technology to heat greenhouses of 2 hectares in summer, in winter the heat is sufficient for half a hectare.
- 60-kW pilot plant saving 22,000 m^3 of gas and 40 t of CO_2, pilot operation ran until mid-2020 in Venlo.
- Liquid cooling, heated water (65 °C) is fed through pipes into the greenhouse.
- Sesame rack computing and storage systems from ITRenew, consisting of Open Compute Project hardware (recycled from hyperscale companies like Facebook).

Communication

- "Greenhouses have continuous heat needs, and gardeners are very innovative and eager to adopt new techniques," says the startup's co-founder Burks.
- "A lot of parties don't want to put their data with big parties like Google and Amazon. That's where we get interesting. And for gardeners, our technology is a good alternative to geothermal and biofermentation because we have minimal impact on the soil and the environment," Burks asserts.

Image source: [171]; Sources: [172, 173]

Equinix AM3

Netherlands	Amsterdam
30 °C	20 °C
ATES, heat pumps	14 MW
nearby	Building heating
Underground river	Equinix, Universiteit van Amsterdam

Image source: [174]; Sources: [175, 176]

Technology

- Data center with 14 MW, which is utilized to 80 % all year round (PUE 1.19).
- Air cooling: inlet temperature 24 °C, server outlet temperature 34 °C, cooling water of approx. 18 °C. The cooling water heats up to approx. 30 C and is available for waste heat recovery. There are 4 independent ATES (Aquifer Thermal Energy Storage) systems installed, each with a cooling capacity of 2.5 MW.
- Cooling system: < 16 °C outside temperature: free cooling; > 16 °C: water atomization of the hybrid cooler; > 22 °C: ATES system is used. In summer, only the ATES system is normally in operation and in winter, free cooling is used as standard. Mechanical cooling machines are available for emergencies. In total, the operating hours of the ATES are about 2,000 h per year.
- At a depth of about 180 m there is an underground river which flows into the North Sea. The water has a temperature of 10 °C and is used for cooling purposes by the ATES system in summer. As a result of waste heat dissipation, the temperature in the hot well rises to 20 °C. There is a distance of about 200 m between the cold and hot wells. The water consumption of the ATES system is about 1,000 m^3/h during operation.
- A nearby university campus of the Universiteit van Amsterdam uses heat pumps for heating the buildings, which in winter use as a heat source the water of the underground river heated to 20 °C by the data center. Due to the very low flow velocity of the water, it can be used as a seasonal heat reservoir.

Law

- There is an agreement between the data center operator and the university to use the waste heat. However, there are no obligations on either side. If the ATES were to fail, the temperature of the university's heat source would be only 10 °C in winter instead of 20 °C. This case should not occur, however, as any problems with the ATES can be fixed within a few hours.

Business

- The waste heat is provided free of charge.
- This system is used in the same city at the AM4, AM5 and AM6 sites. In addition, the new MU4 data center in Munich will also have an ATES system.

Communication

- The company, which carried out the installation of the electrical components of the data center during its construction, is in parallel also responsible for the maintenance of the university's electrical systems.

Switch Datacenters

Netherlands

40-60 °C

Direct water cooling

Woerden

Building heating

Switch Datacenters

Technology

- Planned upgrade of switch data center in Woerden enables waste heat with temperatures of 40 to 60 degrees Celsius.
- Instead of cooling the servers with traditional room coolers like CRAH units, the cooling is done as close to the server as possible to get the highest possible waste heat temperature from the servers.
- DLC provides a much higher cooling capacity, which in most cases allows for higher power density in a much smaller footprint. This is advantageous for data centers in urban areas.

Business

- The cooling water is heated by the servers to temperatures between 40 and 60 °C and can be used immediately to heat offices or homes. Customers who opt for DLC cooling receive a financial incentive of 20 to 30 % of their electricity costs.
- The more usable heat produced, the higher the financial compensation.

Communication

- First data center in Europe to financially compensate its data center customers for waste heat recovery by using existing Direct Liquid Cooling (DLC) technologies to cool servers.
- Switch Datacenters believes that large cloud providers may be motivated by the financial incentive to switch to DLC or other high-temperature cooling. The company also wants to be an example for other data centers adopting the same strategy, which could also be very beneficial for the data center industry as a whole.

Image source: [177]; Sources: [178]

Aalsmeer Energy Hub

Netherlands	Aalsmeer
25 °C	22 °C
Heat exchanger, cold local heat	4 MW
1400 m	Building heating, process heat
Water circuit	NorthC
2024	

Image source: [179]; Sources: [180]

Technology

- 4 MW data center.
- The data center is cooled with outside air as long as the temperature is below 18 ˚C, otherwise chilled water is used. The air is heated to about 25 ˚C and discharged.
- - Waste heat is extracted and reused, and about 20 % of it goes to the IKC Triad school, the Fertiplant plant nursery, a swimming pool and a gymnasium called The Waterlelie.
- More waste heat could be used elsewhere, but the distance to other potential customers would make that difficult, Reinders said.
- The water is piped through a 1,400-m-long pipe (up to 25 m underground) and reaches customers at a temperature of 22 °C. Apparently, the project opted for deep drilling and horizontal directional drilling (HDD) because of the risk of encountering other pipes and possibly World War II munitions. Two non-insulated pipes (HDPE) with a diameter of 160 mm are used.
- After the water has given up its heat to the customers, it returns to the data center at a temperature of 12 °C, where it is used again for cooling. The pipe does not need to be insulated, which would have driven up costs because the water flows at a high speed of 1.5 m/s, Jeroen Roos of energy transmission company Infinitus told Reinders.

Law

- There is a residential area nearby that could potentially use the waste heat from the data center, but this has not yet happened. Apparently, under the Dutch Heat Act, NorthC would have to fulfill supply obligations to supply residential consumers.

Business

- Aalsmeer Energy Hub transports hot water from the NorthC data center to customers such as a swimming pool, school, and nursery, which then use heat pumps to efficiently bring the water to higher temperatures.
- Fertiplant uses hot water year-round to heat its offices and planting areas and to clean plant roots. The company initially held on to its gas boiler as a backup but has since abandoned it.

Data Center Bytesnet

Netherlands

Immersion cooling

Bytesnet Boston Ltd., WarmteStad

District Groningen

200 kW

Building heating

Technology

- The energy from the waste heat emitted by the servers and IT equipment is said to be sufficient to heat more than 10,000 homes and businesses.
- According to Boston, the IT infrastructure consists of Supermicro server nodes combined with large DDN storage systems connected via Mellanox networks. The software layer uses vScaler, an HPC platform based on OpenStack that provides monitoring, management, job scheduling and message passing, and can automate processes to reduce management overhead and lower costs for Bytesnet.
- Cooling technology from Asperitas, specifically the AIC24 solution for 21-inch servers.
- Mainboards of the servers completely immersed in a dielectric fluid, dissipates heat by convection and keeps the system cool.

Business

- Dutch data center company Bytesnet collaborates with computer manufacturer Boston Ltd.
- "This approach, developed by Boston, enables us to achieve unprecedented energy efficiency and significant savings in our upfront and operational costs - all while delivering a higher quality of service to meet the increased demands of data-driven businesses," said Jan-Joris van Dijk, managing director of Bytesnet.

Image source: [181]; Sources: [182]

Interxion-Rechenzentrum AMS5

Netherlands

nearby

Heating network

Schiphol-Rijk

Heat supply for industrial estates

Interxion, Polderwarmte

Technology

- Since AMS5 is located in the immediate vicinity of RichPort and Starpark, and these industrial estates are striving to become more sustainable, it is possible for Interxion and Polderwarmte to efficiently tap the heat for them.
- Supplying residual heat to industrial estates in Schiphol-Rijk in the Amsterdam area.

Business

- Estimated 45,000 GJ of waste heat for businesses.
- Savings of approximately 1.5 million m^3 of gas at project start-up, may increase to 75,000 GJ of waste heat and 2.5 million m^3 of gas savings five years after start-up.
- Interxion uses 100% green electricity, therefore a saving of 2,500 tons of CO_2 per year at the start of the project, increasing to 4,200 tons of CO_2 per year within 5 years

Communication

- In addition to the Interxion AMS5, Polderwarmte also plans to connect other data centers to the heating network, thus supplying heat to various buildings in Schiphol-Rijk.

Others

- This makes Interxion the first data center company in the Netherlands to supply waste heat on a large scale to business parks in the vicinity of its AMS5 data center.

Image source: [183]; Sources: [184, 185]

QTS-Datacenter

Netherlands

Heat pumps

Heat network

2026

Groningen District

Building heating

QTS Data Centers, WarmteStad

Technology

- Use of 100 % of waste heat.
- Heat pumps, powered by renewable energy, supply hot water via the existing underground heating network installed in Zernike, Paddepoel and Selwerd.
- Heat generation for more than 10,000 households, buildings and knowledge institutions by 2026.

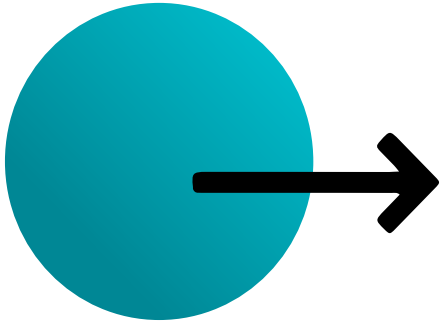
Business

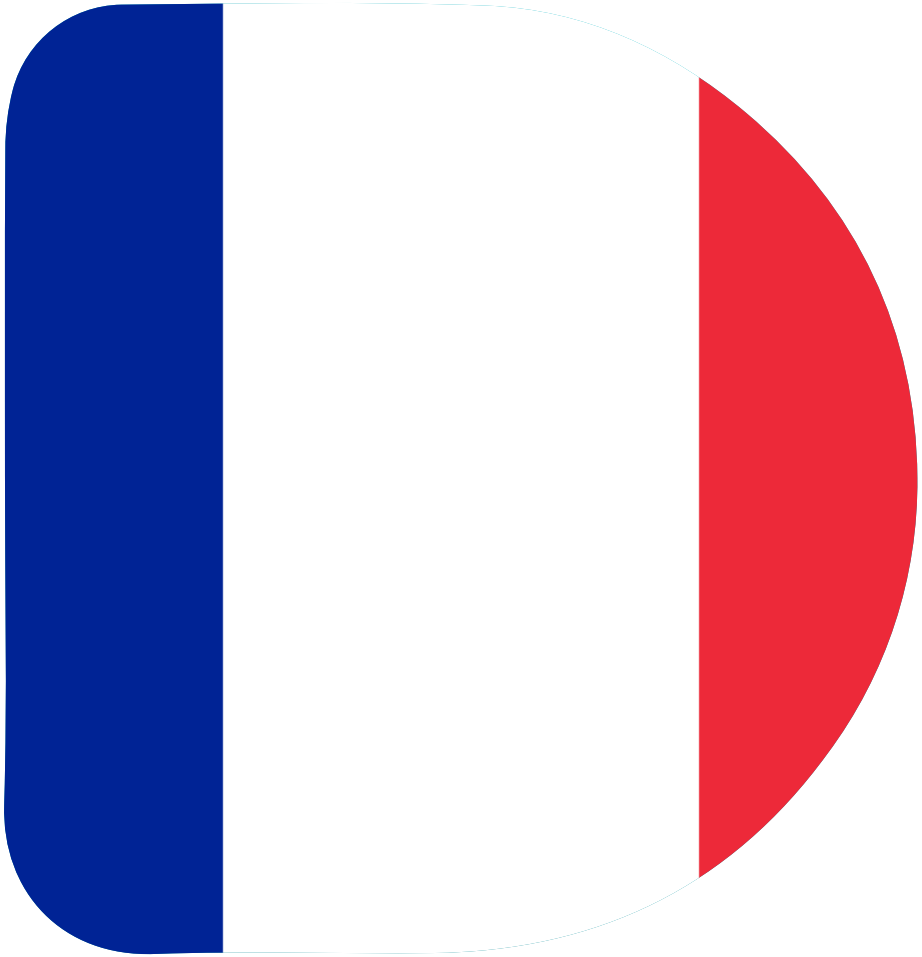
- Heating with water can replace natural gas and reduces CO_2 emissions.

Communication

- QTS first company to supply waste heat for large-scale sustainable district heating project in Groningen.
- Construction of innovative heating plant completed.
- The city of Groningen's environmental target: to be completely CO_2-neutral by 2035.
- "QTS has quickly established itself as an important member of the Groningen business community and is making an important contribution to the sustainable district heating project," said Dick Takkebos, director of WarmteStad.

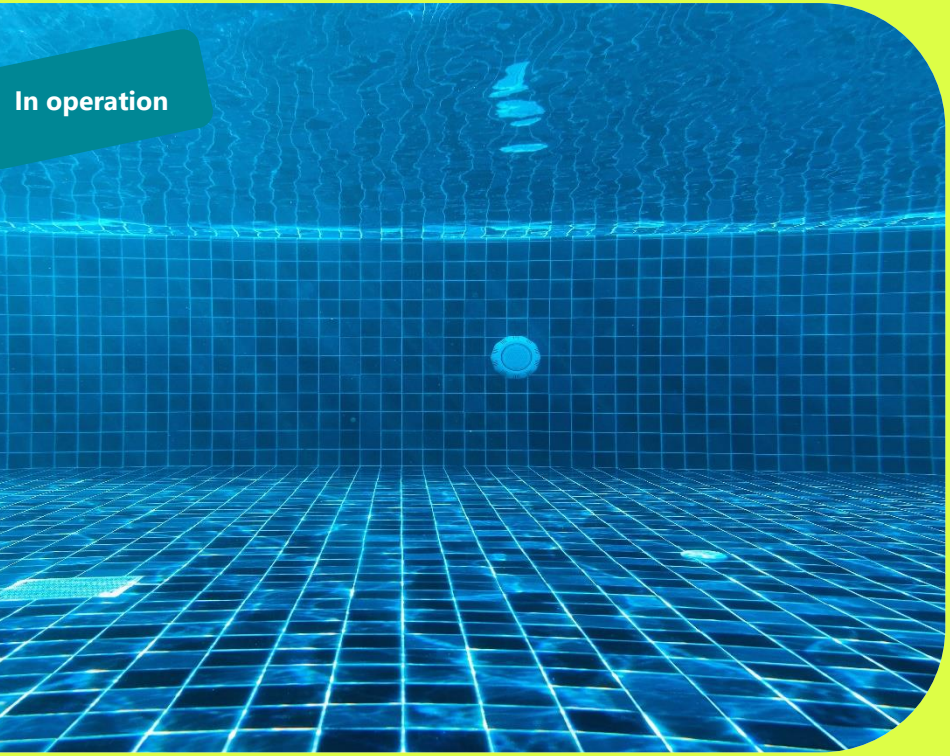
Image source: [186]; Sources: [107, 187]





FRANCE

3D-Animation Studio



France

Heat exchanger, Immersion cooling

Stimergy, TeamTo

Paris

Swimming pool heating

Technology

- Waste heat from 3D animation studio TeamTo, generated when rendering 3D images, provides 20 % of the heat needed for the public swimming pool in Paris Butte-aux-Cailles.
- Six intelligent "Stimergy Boilers" in the basement, which are effectively Edge DC.
- Up to 100 servers can be installed in these, which are immersed in an oil-based liquid.
- The liquid cooling is itself connected to a heat exchanger system connected to the central heating of the swimming pool.
- Heating up to 27 °C.
- Enough energy to heat two of the three bathrooms at the same time.
- According to Stimergy, a single server can release enough heat to heat 80 liters of water per day.
- The Stimergy system saves 45 tons of CO_2 and 250 MWh of energy per year.
- The swimming pool has been connected to the public central heating system “CPCU” since 1945.

Communication

- Green IT startup Stimergy.
- The actual impact of the project will be assessed by the Council in Spring 2018.

Image source: [188]; Sources: [189, 190]

Data Center Telecity

Technology

- Use of waste heat for heating of arboretum on site.
- Waste heat from Condorcet data center.

Communication

- Arboretum will be used to recreate climatic conditions that will prevail in France in 2050.

France

Paris

Telecity

Arboretum heating

Image source: [191]; Sources: [192, 193]

Q.Rad heater

France

In the building

Paris

Building heating

Quarnot

Technology

- Produce 150 kW of heat. Small radiators distribute heat in individual rooms.
- Q.Rads are networked with each other, switch themselves on or off as required.
- Quarnot provides special high-performance tasks.
- Payloads: Q.Blender for graphics rendering, XtremWeb for high energy physics.
- Jobs are sent to encrypted caches in buildings where Q.Rads are installed, when heat is needed appropriate Q.Rads get jobs from the cache.
- Standard Intel processors on simplified motherboards.
- Processor speed can be throttled in summer to produce less heat.
- Ensuring flexible heat through surplus of supercomputing tasks, free capacities are offered to universities.
- Free capacities in winter for student projects in the field of 3D rendering.

Other

- Installed 350 Q-Rad heaters, 300 in Paris apartment blocks (heating 100) homes, 30 in school buildings, 20 in Quarnot staff apartments.

Image source: [194]; Sources: [195, 196]

Data Center in Val d'Europe

France

Heat exchanger, natural gas boiler

4 km

Local heating network

Val d'Europe

48-55 °C

Building heating

Dalkia, ADEME

Technology

- Data center with a heat output of 7.8 MW that can be extracted should be able to cover up to 90 % of the future heat requirements of the connected buildings. This includes the current water sports center and the future commercial area.
- Local heating network with a total of 4 km of distribution lines for heating surrounding buildings.
- Construction of future commercial area (in Bailly-Romainvilliers) in the immediate vicinity of the data center.
- Two heat exchangers in the data center, connected to the heating network.
- Natural gas boiler to increase temperatures on demand and for peak loads in case of high heat demand.
- Heat exchangers can deliver district heating water temperatures between 48 and 55 °C (approx. 7.8 MW).
- Heat loss of 20,000 MWh and emissions of 4,000 tons of CO_2 equivalent can be avoided annually.

Business

- Total cost estimated at €3.46 million, of which €1.0 million is supported by ADEME (French Agency for Environment and Energy Management).
- The probability that the project will be fully realized is increased by this sustainable energy recovery. This lowers the overall heat costs, and the heat prices are further favored by a reduced VAT.
- Since the data center is in operation all year round, heat prices are low and should remain relatively stable.
- Project start: 2013.

Image source: [197]; Sources: [198–200]

Data center PA10 with roof greenhouse and swimming pool

France

One building, nearby

Heat exchanger

Saint-Denis Campus, Paris

Swimming pool and greenhouse heating

Equinix

Technology

- In phase 1, 3,775 m² of colocation space with 1,525 racks are to be built. When fully expanded, the number increases to 5,775 m² and approx. 2,250 racks.
- Use of waste heat to heat a local swimming pool. In addition, a 430 m² greenhouse is to be built on the roof, which is also to be heated with waste heat.
- In addition, the greenhouse has a hydroponic system, which is fed with collected rainwater. This reduces waste heat and wastewater emissions. The new data center PA10 will be built in accordance with international environmental standards, with the aim of obtaining LEED (Leadership in Energy and Environmental Design) certification. Equinix PA10 has set itself the goal of using 100 percent renewable energy and implementing various sustainability measures in accordance with ISO 50001.
- Temperature is maintained by heat exchangers connected to the data center's chilled water-cooling system.
- Additional sensors that monitor indoor and outdoor temperatures and humidity.
- Use of automatic sun protection, irrigation, and ventilation systems for year-round controlled climate.

Business

- Capital cost of $163 million.

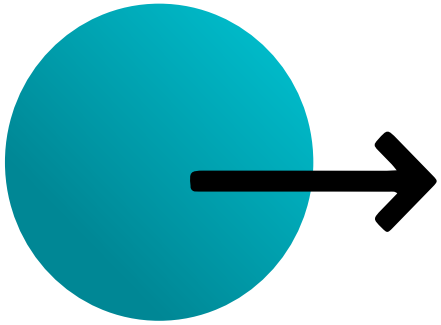
Communication

- Equinix aims to be globally carbon neutral by 2030.

Other

- Used former military bunker.

Image source: [201]; Sources: [202–204]



GREAT BRITAIN

Deep Green Data Center

Great Britain

Immersion cooling, heat exchanger

In the building

Deep Green, Exmouth Leisure Centre

Exmouth

30 °C

28 kW

Swimming pool heating

Image source: [205]; Sources: [206–211]

Technology

- 28 kW system with HPC functions "digital boiler".
- Cooling by Deep Green's own immersion cooling tubs using mineral oil that captures heat and transfers it to the pool water via heat exchangers.
- The tubs contain Dell AMD Epyc single-CPU servers, each configured with four A100 80Gb PCIe GPUs and 4TB SSDs, according to Craggs (CTO Deep Green). The servers are installed in an "open chassis to ensure the most efficient heat transfer possible."
- Additional gas boiler to increase water temperature in case of emergency.
- About 96 % of the energy used by the computer is transferred and the pool's gas consumption is reduced by 6 2%.
- Data center is the size of a washing machine.
- The pool is heated to around 30 °C.

Business

- Deep Green pays Exmouth Leisure Center for all electricity used by data center and all facility costs and Exmouth Leisure Center receives heat free of charge.
- Deep Green offers to deliver, install and service the digital boilers free of charge, including the cost of connecting the pipes. The electricity they use is paid for in advance based on the hourly rate currently being paid by the customer.
- Energy costs for swimming pools have increased by 150 % since 2019, according to advocacy group UK Active.

Communication

- Use of waste heat to heat a 25 m long pool and a children's pool.
- The company would like to put a data center under "every pool," he said. "Companies that have green ambitions and want to support their local swimming pool are welcome to contact us."
- The technology could also be used in any business that requires heat, such as a bakery, distillery, or laundromat, adds Deep Green.

Other

- Start-up plans to set up data centers at seven more pools in the UK, targeting 20 sites by 2023 due to high demand.
- Deep Green stands out because it gives off heat for free and is currently targeting an industry that could use a financial break.

Londoner Docklands

Technology

- 9 MW heat output, save 1100 tons of CO_2, heating of neighboring residential and commercial buildings.
- Telehouse West has a built-in waste heat exchange system to reuse the waste heat for distribution to third parties and to pre-cool the chilled water, reducing the power requirement for chillers and dry air coolers.

Great Britain	London
Waste heat exchange system	Building heating
2010	Telehouse West, WSP

Image source: [212]; Sources: [21, 213, 214]

London Data Freeport

Great Britain

Reef Group

2027

Havering

600 MW

Agriculture

Technology

- Development of a "zero carbon" facility on the corner of Fen Lane and Dunnings Lane on land between North Ockendon and Upminster.
- The planned campus will consist of ten 50 MW and five 20 MW units, giving a combined capacity of 600 MW.
- Total area of around 330,000 square meters of new data centers.
- Developers have announced that they will handle on-site renewable power generation and battery grid balancing.
- The campus will provide heat recovery systems for low-carbon agriculture.

Business

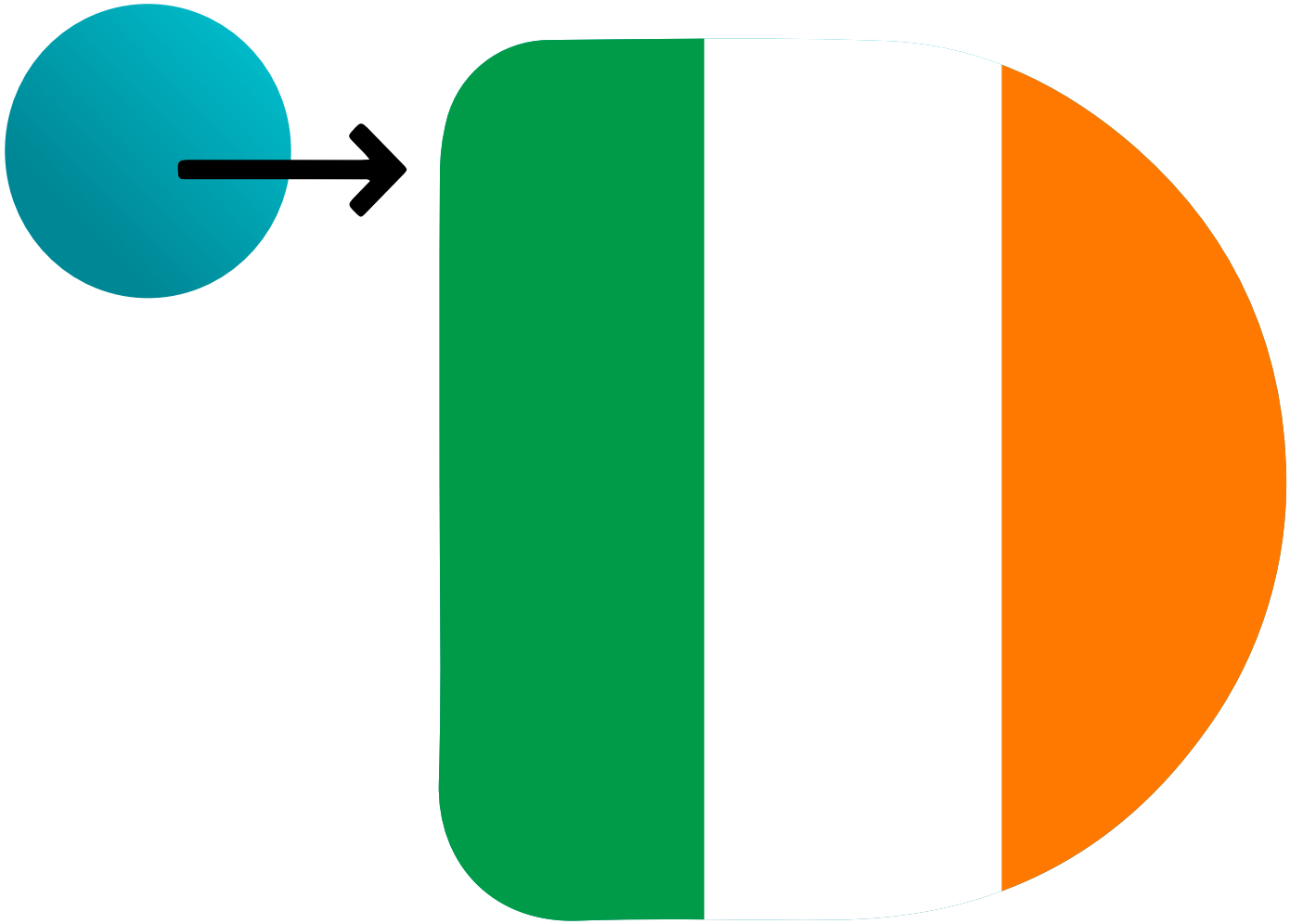
- £5.3 billion ($5.97 billion) project.

Communication

- Five-year construction phase from 2023 to 2027.
- Partnering with Space Park Leicester, University of Leicester, Project Earth and Space Sustainability Initiative to encourage innovation in zero carbon energy, digital infrastructure and monitoring of agricultural and other land use activities.
- 120 hectares of the area will be available to the public as well as an eco-park.

Image source: [215]; Sources: [216]

IRELAND



AWS Data Center

Ireland

Direct evaporative cooling systems, heat pumps

Building heating

Dublin

Amazon, South Dublin County Council (SDCC), Fortum, City of Dublin Energy Management Agency

Image source: [217]; Sources: [218]

Technology

- New district heating network in Tallaght, South Dublin provides heat from AWS data center to public sector, residential and commercial customers.
- Initially heating 47,000 m^2 of public buildings, 3,000 m^2 of commercial space and 135 affordable rental homes.
- Use of heat pump technology.
- Saving of 1,500 tons of CO_2 per year → 60 % reduction of CO_2 emissions.
- • Direct evaporative cooling systems use mostly outside air to cool the servers (more than 95 % of the year no water is needed for cooling).
- New facilities equipped with roofs that capture rainwater, offsetting water use from local supplies.
- Goal: Cooling of the data center without taking water from the local supply.

Business

- Free provision of heat.
- District heating companies sell heat to end users at low cost.
- The first customers will be South Dublin County Council and the nearby Tallaght campus of Dublin University of Technology (TU Dublin). City Council buildings to be heated in the short term by this project include South Dublin County Hall, Tallaght County Library, RUA RED arts center and the Civic Theatre.

Communication

- Ireland has sustainability targets up to 2030.

Ecologic Newtownmountkennedy Campus

Technology

- Area of 1,100,000 m^2.
- 150 MW of power to heat planned local biodomes and power neighboring villages and businesses.
- Powered by clean energy such as wind and wave power sources.
- Arklow Bank and offshore wind farms are in close proximity.
- Reuse of the waste heat as heating energy for the supply of households and companies.
- Climate-negative plant planned.

Ireland

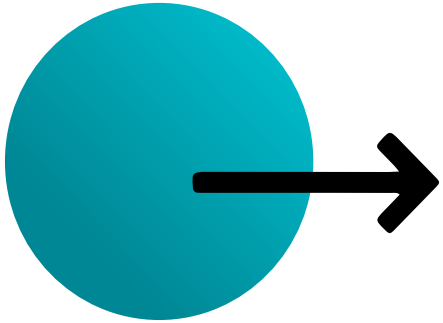
Newtownmountkennedy

Ecologic datacentre

Building heating

Image source: [219]; Sources: [220]

DENMARK



Data Center Digiplex

Technology

- Waste heat is fed into the district heating network.
- Rainwater basin for storing water for cooling

Denmark

District heating network

Kopenhagen

DigiPlex

Image source: [221]; Sources: [222]

Data Center Viborg

Denmark

Local heating network

Viborg

Building heating

Apple, Varte

Technology

- Complete operation with renewable energy from regional projects.
- Wind project in Esbjerg and solar panels in Thisted in North Jutland.
- District heating supplies 64% of all households in Denmark.
- Waste heat is fed into the local heating network and used to heat apartments. This is intended to supply around 100,000 residents with heat.

Other

- With the 2020 Environmental Progress Report, Apple released the plan to reduce emissions by 75% by 2030.

Image source: [223]; Sources: [224–226]

Odense

Denmark

Heat pumps

District heating network

Odense

Building heating

Facebook

Technology

- Heat extraction of 100,000 MWh/a to heat 6,900 households.
- Heat extraction occurs through the circulation of hot air in copper coils inside the cooling unit, which are filled with water.
- The relatively low-temperature water is routed to the Fjernvarme Fyn district heating station, where it is further upgraded using heat pumps.
- There is a wind farm right next to the DC.

Image source: [227]; Sources: [228–230]

Supercomputer Center DTU

Technology

- The Danish Technical University (DTU) Supercomputing Center in Risø has an area of 3,800 m^2.
- Electrically operated heat pump uses the waste heat to raise water to the temperature level of the district heating network.
- District heating network supplies university buildings on campus with heat and hot water.
- Up to 600 kW waste heat from IT equipment is fed into the district heating network.
- Four months of the year heating is self-sufficient.
- Supercomputers provide 19 % of the total heat required.
- The heat pump feeds six times as much energy into the district heating network as the heat pump needs in terms of electricity to operate.
- Overall balance positive for the climate.

Denmark
Risø
Heat pump
Building heating
District heating network
Danish Technical University (DTU)

Image source: [231]; Sources: [232]

Data Center Danfoss

Denmark

heat pump, surface heating

In the company

Water circuit

2024

Nordborg

1 MW

Building heating, process heating, production, canteen

Danfoss

Technology

- Internal use of waste heat in the company.
- Approximately 1 MW of waste heat from the data center is to be used almost entirely in the company (administrative headquarters, production, canteen, etc.). By 2024, around 25 % of the annual heating requirements of the approximately 250,000 m^2 factory and office area should be covered.
- There is a year-round need for process heat.
- There is a refrigeration system that should not be in operation, if possible, but serves as a backup. The heat is decoupled from the water circuit of the cooling circuit. Additional heat pumps are to be installed.
- The administration building was recently renovated and is equipped with surface heating. Some of the other buildings have different radiators.
- A photovoltaic system is installed at the Danfoss site, which takes over part of the power supply for the entire site. This means that the data center can be operated almost CO_2-neutrally.
- From 2022, work at the site is to be completely CO_2-neutral.

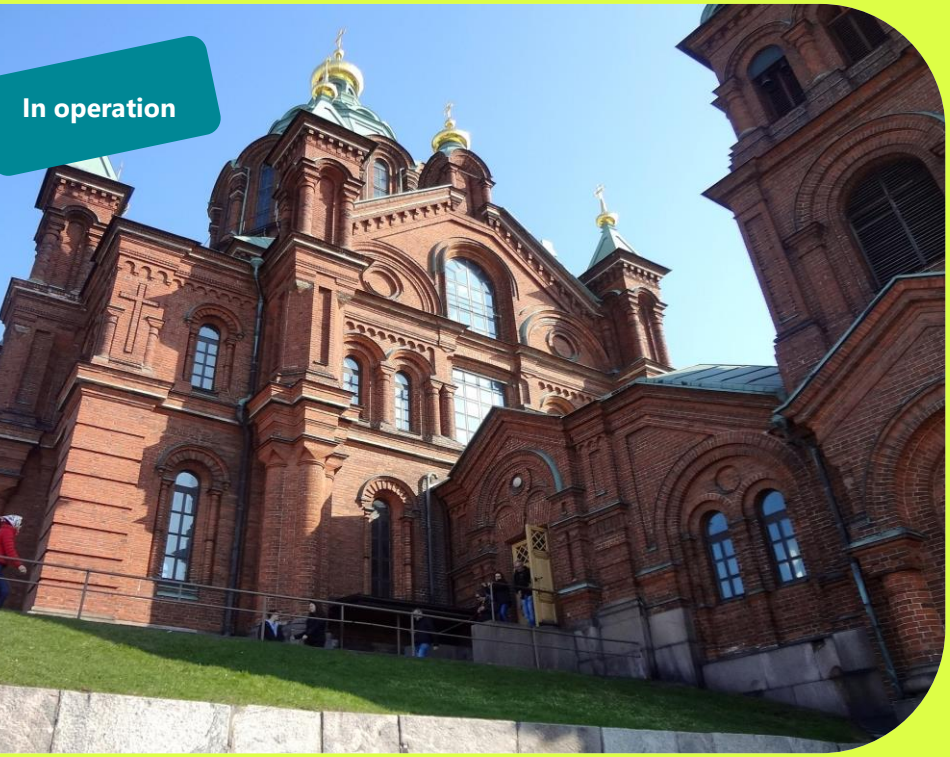
Other

- Full commissioning is expected in 2024. Not all buildings have yet been connected.

Image source: [233]; Sources: [234–236]

FINLAND

Data center Academica



Finland

Pipe system, tunnel network

District heating network

2010

Helsinki

2 MW

Building heating

Academica, Helsingin Energia

Technology

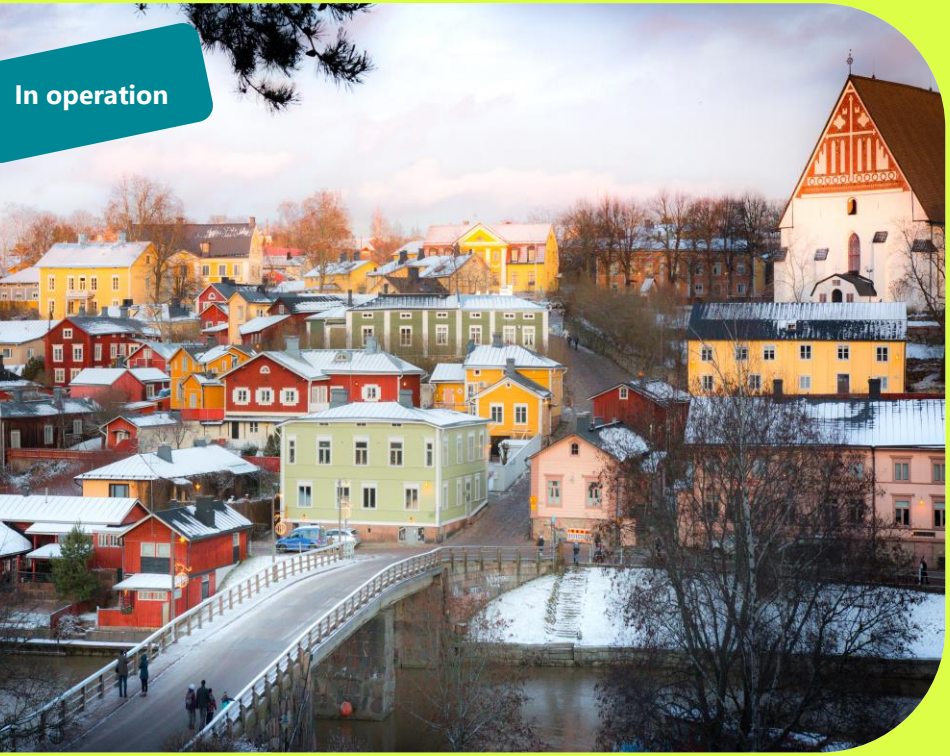
- 2 MW data center under Uspensky Cathedral.
- Waste heat heats water pipes to heat nearby homes.
- Enough heat to heat 500 large private houses.
- After removing the heat, water is fed back again.
- Heat is transferred via a separate piping system containing desalinated water and through the city's extensive network of underground tunnels to the district heating network for which the tunnels were originally built.
- Baltic Sea water is used for cooling.

Communication

- "For us in Finland, fuel and energy have always been quite expensive. This has forced us to look for solutions to reduce our energy consumption. Using the underground bunker has another advantage," says Juha Sipilä, engineer at Helsingin Energia and project leader: "The servers will be very secure."

Image source: [237]; Sources: [193, 238]

Data center in Mäntsälä



Finland	Mäntsälä
37 °C	85 °C
Heat pump, heat exchanger, heat recovery systems	15 MW
200 m	Building heating
Distrcit heating network	Mäntsälä, Yandex, Nivos

Technology

- Use of waste heat from a 15 MW data center.
- One third of the energy consumed by the data center can be used as heat thanks to heat recovery systems and heat pump systems.
- IT load of 6 MW.
- Extract air has a temperature of 37 °C (20 K difference to the colder air supplied)
- Heat pumps increase to 85 °C before feeding.
- Consider moving heat exchangers closer to servers so they can absorb heat from 45 °C warm air.
- Customers 200 meters away from DC.

Business

- Mäntsälä reduced its district heating prices by 11 % with this solution.
- The ability to use waste heat and compensate the data center for it improves the business case and can be a key factor in data center location decisions, which can lead to increased on-site investment and employment.
- Waste heat is sold to Nivos (active in electricity, heat and water management)

Communication

- In 2018, 20 GWh or 54 % of Mäntsälä's heating needs were covered by waste heat from the data center.
- The greatest advantage of the Finnish location is the district heating system that is available in every city

Other

- The designation of industrial areas close to the district heating network made it possible to use the waste heat.

Image source: [239]; Sources: [200, 240–242]

Elisa HQ

Finland

Heating network

1409 km

Helsinki

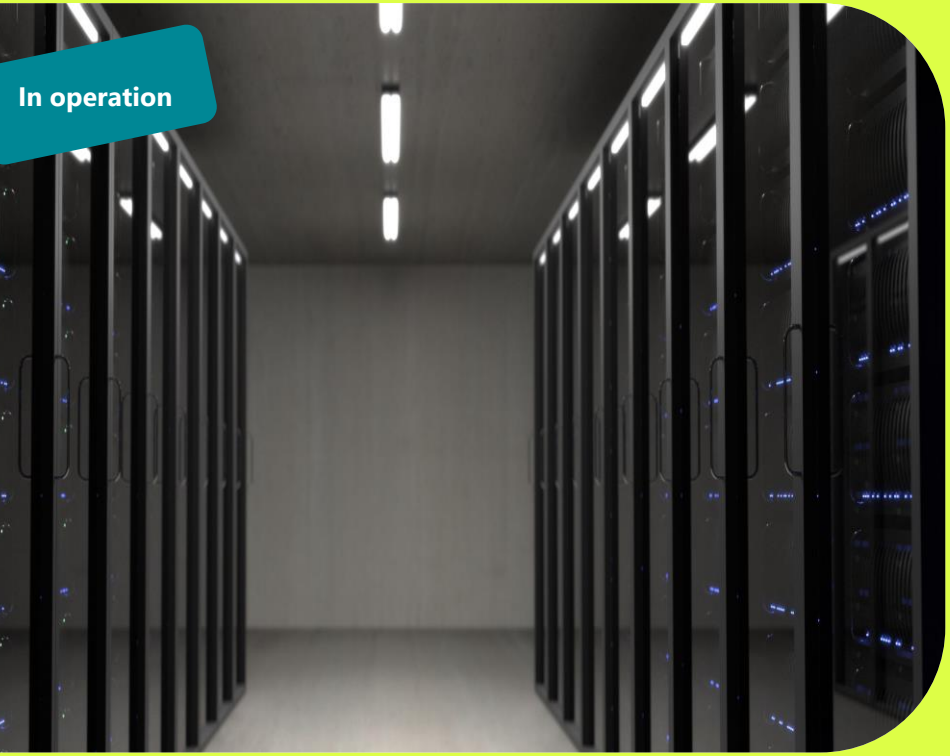
Telco Elisa, Helen Ltd.

Technology

- The waste heat from the computer center (in the basement) has already been used to heat the HQ building. This saves 40 % of energy consumption since 2019, equivalent to 250 tons of CO_2.
- After the conversion, the data center will be connected to the Helen Ltd. heat network. connected.
- The heating network has a total line length of 1490 km, with an "open" concept, i.e. customers can either take heat from the network or feed it into the network.

Image source: [243]; Sources: [107, 244]

Ericsson data center



Technology

- Heat pumps are used for heat transfer; Refrigerant: HFO-1234ze (1,3,3,3-Tetrafluoropropene).
- Annual waste heat flow between 10,000 and 15,000 MWh.

Law

- Contract between the energy company Fortum and Ericsson, the heat pumps belong to the energy supplier.

Finland

Heat pump

Kirkkonummi

Fortum, Ericsson

Image source: [245]; Sources: [246]

LUMI in Renforsin Ranta business park

Finland

Liquid cooling, heat pump

District heating network

2021

Kajaani

Building heating

Loiste Lämpö, CSC - IT Center for Science Ltd., EuroHPC, UPM Kiinteistöt, Vattenfall

Technology

- Waste heat from the LUMI data center (HPE Cray EX racks; 550 PFLOPS) will provide approximately 20 % of district heating in Kajaani, reducing the entire city's carbon footprint.
- The heat generated by the supercomputer (up to 60 GWh annually) is efficiently recovered through liquid cooling. The water temperature is then further increased by heat pumps to meet the needs of the district heating network.
- Between the high-performance data center and the heating network there is a heat pump that is operated with renewable energy. The heat network has a load of around 10 MW and supplies heat to the Renforsin Ranta Business Park and the city of Kajaani.
- The resulting data center has a negative carbon footprint as it is powered by renewable energy (100 % hydropower from Vattenfall) and its waste heat is used to heat local buildings. This reuse of waste heat will reduce the area's annual carbon footprint by 13,500 tons.

Law

- According to an agreement, the data center, which will be operational in early 2021, will collect the by-product heat, which Loiste Lämpö will then feed into its grid to heat homes and businesses in Kajaani.

Business

- Loiste Lämpö is currently developing a fully CO_2-neutral district heating product using waste heat.
- This reduces total energy costs by up to 40 % and CO_2 emissions.
- Half of the financing for the project, which cost a total of 202 million euros, came from the EU and a quarter from Finland.

Communication

- "The location of an eco-efficient data center in Kajaani is the result of long-term negotiations between several partners. This is an important climate action that we are taking together with our customers and it will have a positive impact on the carbon footprint of the entire city. In addition, the project will create jobs in the Kajaani region," says Heikki Juntunen, CEO of Loiste Lampö.
- Winner of the 2021 Data Center Design Innovation Award.

Image source: [247]; Sources: [248–257]

Nokia data center vLab

In operation

Finland
Heat pump
District heating network
2022
Tampere
95 °C
Building heating
Uampereen Sähölaitos, Nokia

Technology

- From the beginning of 2022, the data center will feed waste heat into the city's district heating system.
- The Valtatie 30 commercial building in Tampere will be connected to the district heating system operated by the local utility Tampereen Sähkölaitos. The connection is made possible by improvements to the data center's cooling systems, which recently transitioned to HPE's Greenlake on-premises data center-as-a-service offering.
- The connection uses heat pumps from the Finnish company Oilon to increase the waste heat up to 95 °C.
- Heat pumps will provide around 50 GWh of heat each year.
- Excess heat from the data center can be used to heat 50 residential buildings per year.
- Building was already connected to the district heating network in 2016, but only since 2022 the heat can be sold because of the Greenlake upgrade, as it allows heat recovery from the liquid cooling system (installation with the help of engineering company Sweco).

Law

- Agreement with landlord Castellum.

Communication

- vLab is part of Nokia Software and works on research for areas like 5G. It has switched to a Greenlake Cloud-as-a-Service running on HPE hardware in the Valtatie 30 building. According to HPE and Nokia, this reduces energy requirements and makes the data center carbon negative by using renewable energy sources and liquid cooling with water from a nearby lake.

;

Other

- Finland has an ambitious goal of being carbon neutral by 2035 and Valtatie's owner, Castellum, is aiming for 2030. Nokia itself plans to become carbon neutral by 2040.

Image source: [258]; Sources: [259]

Pitäjänmäki Data Centre

In operation

Finland

Heat pump

District heating network

2022

Helsinki

24 MW

Building heating

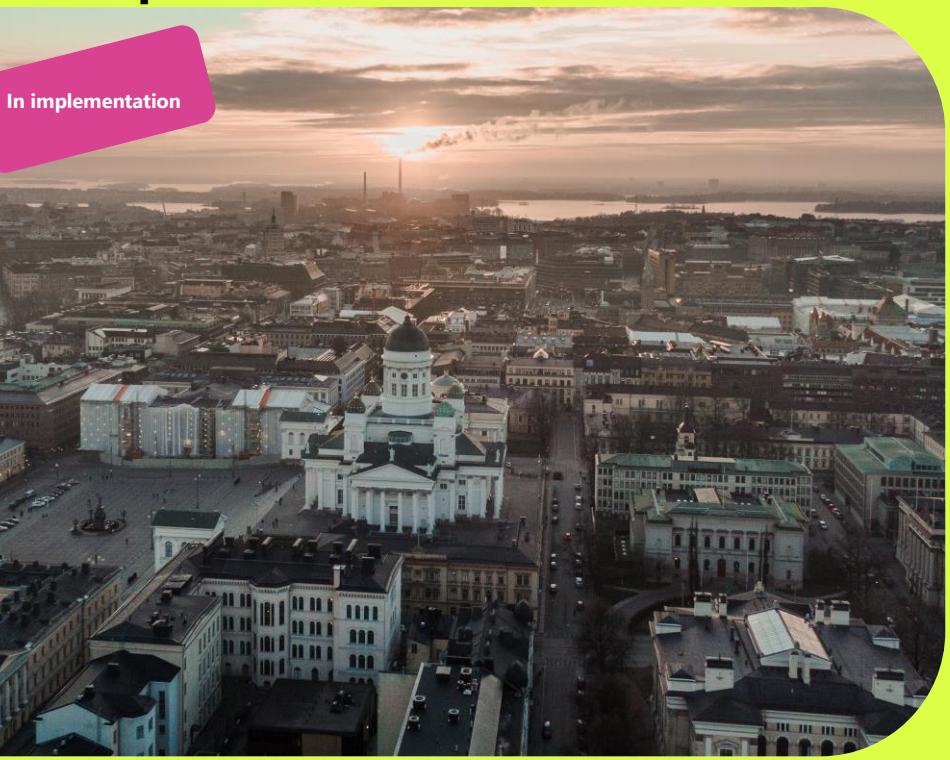
Telia, Helen Ltd.

Technology

- 24 MW IT performance.
- The built-in heat pump generates at least 1.3x more heat from the data center than it consumes electricity. This heat is intended to supply around 20,000 residents in Helsinki (by feeding it into the district heating network).
- Commissioning expected around June 2022.

Image source: [260]; Sources: [261]

Equinix HE3 & HE5



Technology

- Equinix data centers in Suvihlati (HE3) and Viikinmäki (HE5) are connected to the Helen Ltd. heat network. connected to supply districts in Helsinki.
- To heat thousands of additional homes and businesses in Helsinki.
- Helen's 1,409 km long district heating network also enables flexible implementation of various waste heat concepts.

Finland	Helsinki
1409 km	Building heating
District heating network	Equinix, Helen Ltd.

Image source: [262]; Sources: [263–265]

Data center near Helsinki

Finland

Espoo, Kauniainen, Kirkkonummi

Microsoft, Fortum

Building heating, hot water processing

Image source: [266]; Sources: [107, 267–269]

Technology

- Data center, which is operated with 100 % emission-free energy.
- The data center is expected to provide enough waste heat to cover around 40 % of the needs of around 250,000 district heating customers in the three municipalities (Espoo, Kauniainen and Kirkkonummi) and save 400,000 tons of carbon dioxide emissions annually.
- In a unique collaboration with Fortum Corporation, the waste heat generated in the data centers will be converted into district heating that supplies Finland's second largest city Espoo and neighboring Kauniainen and the municipality of Kirkkonummi. The waste heat processed for district heating, along with other measures, will help the city of Espoo and the surrounding communities meet their ambitious targets for reducing CO_2 emissions, which among other things will lead to the decommissioning of Fortum's last coal-fired heating block in Espoo.

Business

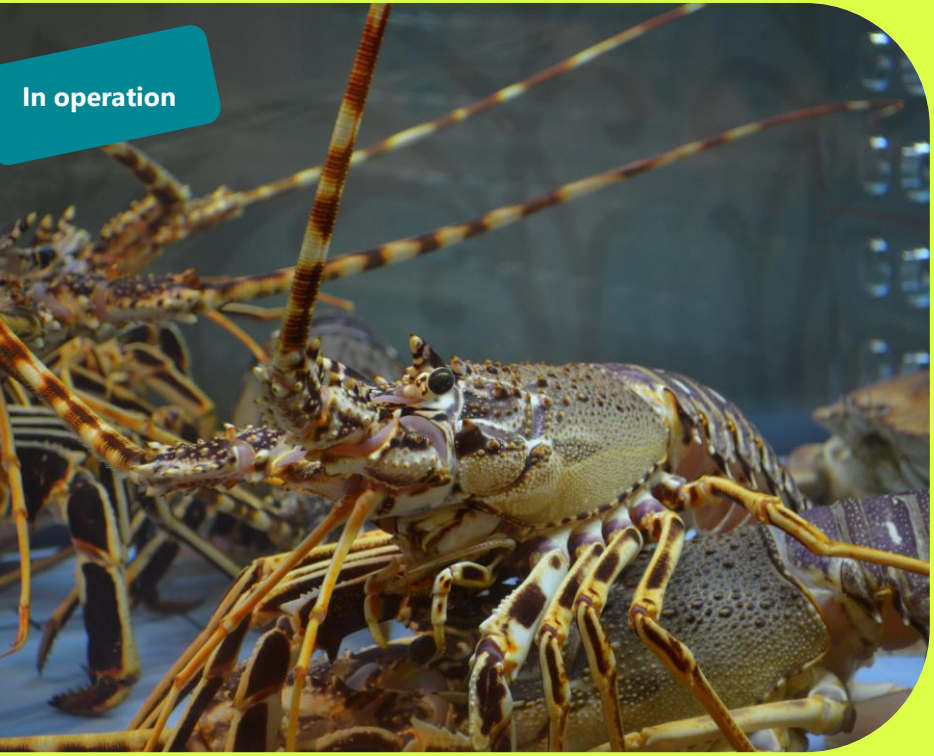
- The investment is a response to Finland's growing demand for powerful and sustainable computers and fast and reliable access to Microsoft services.
- Cooperation with the company Fortum for the use of waste heat.
- "Developing solutions to global challenges together with partners is a strategic priority for Fortum and we are proud to embark on this extraordinary journey together with Microsoft. By using waste heat from data centers, we can provide clean heat for homes, businesses and public buildings in the Finnish capital and save up to 400,000 tons of CO_2 emissions annually. This is an important and practical step towards a cleaner world," said Markus Rauramo, President and CEO of Fortum.

Communication

- "The decision to invest in a data center region that also supplies our cities [...] with surplus heat is a win-win situation. It will accelerate Finland's digital growth while making our energy system greener. [...]," said Sanna Marin, Prime Minister of Finland.
- "[...] In this unique collaboration, Microsoft and Fortum combine their world-leading expertise in cloud computing and sustainable energy solutions, transforming the design concept for the data centers of the future," said Cindy Rose, President of Microsoft Western Europe.

NORWAY

DC1-Stavanger



Norway	Rennesøy
20 °C	20 °C
Seawater cooling	Fish farm
adjacent	Green Mountain, Norwegian Lobster Farm

Technology

- The colocation data center DC1 is located in a former NATO ammunition depot and has a total area of 22,600 m². The cooling capacity can be up to 2 x 26 MW (PUE < 1.18).
- Norwegian Lobster Farm is the first company in the world to produce plate-sized lobsters on a land-based fish farm. To grow optimally, the lobster needs a temperature of 20 °C in the sea water. This is the exact temperature of the seawater used to cool the IT equipment in Green Mountain's data center.
- In the DC1-Stavanger an innovative fjord cooling solution is used for this purpose. The seawater enters the data center at a temperature of 8°C. The data center then releases the water back into the fjord at a temperature of 20°C. The plan is to build a new production facility next to the data center. Here, the heated seawater can be used directly for lobster farming. This allows the energy to be reused and no complicated RAS technology („Recirculating aquaculture system“) is required.

Law

- Norwegian colocation company Green Mountain and Norwegian Lobster Farm have signed an agreement to reuse data center waste heat in the world's first land-based lobster farm.

Business

- The agreement provides the farm with a constant supply of water at the lobster-preferred temperature of 20 °C, reducing the farm's costs and environmental footprint.
- There is potential to produce 900 tons of lobsters annually. The optimal temperature of the sea water reduces the time to market for plate-sized lobsters from 60 to 18/24 months. In addition, 360 tons of fish sludge are produced as "waste", which could be further processed in biogas plants.
- “In practice, this means that we can ramp up production. We can reduce technical risk and save both CAPEX and OPEX. In addition to the environmental benefits, of course," says Asbjørn Drengstig, CEO of Norwegian Lobster Farm.
- "Here in Rennesøy, which is sparsely populated, district heating is not a viable alternative. This project, on the other hand, fits like a glove. So we hope that we can extend this and similar concepts to our future facilities," says Green Mountain CEO Tor Kristian Gyland.

Image source: [270] ; Sources: [271–279]

DC2-Telemark

Norway

Heat exchanger, closed-loop aquaculture (RAS)

800 m

Pipe system

2023

Rjukan

Process heat - trout farming

Green Mountain, Hima Seafood

20 MW

Technology

- Extension of RJU1-Rjukan, construction of 2-storey 20 MW building.
- Hima will set up an onshore trout farm in Rjukan. Only 800 meters from the trout farm is the DC2 Telemark. By connecting the two plants with a pipe system, Green Mountain can supply heated water to Hima.
- The heat exchanger technology then ensures that the Hima system can use the water's energy to maintain the correct water temperature for its RAS solution.
- DC-2 is near a hydroelectric power station.

Law

- Green Mountain entered into an agreement with Hima Seafood to recycle waste heat from the data center for the world's largest land-based trout farm.
- Hima Seafood and Green Mountain are both committed to minimizing the environmental impact of their operations and recognize that this project is a pioneering example of circular economy in practice.

Business

- Construction started in 2021 and when the plant is fully operational in 2023, the waste heat will be used to produce 9,000 tons of trout per year.
- €100 million ($99.9 million) will be invested in the project and all waste heat from the new plant will be used by a nearby onshore fish farm.

Communication

- Sten Falkum, Executive Director of Hima Seafood: "Green Mountain's waste heat represents a significant cost savings in our production and we are excited that our heat requirements can help reduce Green Mountain's environmental footprint and in turn the data center to cool. This is really a win-win solution for both parties.
- Green Mountain CEO, Tor Kristian Gyland, adds: "Data centers are undoubtedly very energy intensive. Although our data centers are powered by 100% renewable hydroelectric power, we don't want to waste the energy. This project is a pioneering example of circular economy, at that benefits one company's production for another company and on top of that it's good for the environment. Our vision is to "set the green standard" and this project really supports that."

Image source: [280]; Sources: [274, 277, 278, 281]

Ulven

In operation

Norway

20 °C

Heat exchanger

District heating

Building heating

Oslo

20 °C

Stack Infrastructure, Hafslund Oslo Celsio

Technology

- A custom heat exchanger system was installed on campus while the data center was upgraded with new insulated piping and cooling coils.
- The OSL01 data center exports around 3.5 MW of heat to the Oslo district heating system, which corresponds to an energy volume of around 25 GWh per year.
- Green electricity from Celsio is released for other purposes such as the electrification of the transport sector.

Law

- Cooperation with energy supplier Hafslund Oslo Celsio with a contract for the supply of heat to 5000 apartments in the city.
- In return, Hafslund Oslo Celsio returns cold water to the campus.
- Meanwhile, in May 2022, Fortum sold its 50% stake in Fortum Oslo Varme, which is now 60 % owned by Hafslund Eco (Infranode and HitecVision each own 20 %).
- Celsio operates a 60-mile heat distribution network in Oslo.

Business

- There are other systems, but no partners who can take the excess heat.

Communication

- Cooperation with the heat supplier Hafslund Oslo Celsio.
- In 2018, Nordic data center operator DigiPlex announced it would work with energy supplier Fortum to recover heat from its campus in Ulven, Oslo, and use it to heat residential buildings. As part of the agreement, Fortum would return cold water to the campus.
- Knut Inderhaug, Managing Director of Hafslund Oslo Celsio. "Data centers in urban areas are stable and good sources of surplus heat for district heating, and together we can contribute to the reuse of zero-emission heat. Projects like this are positive for us as an energy provider, for our city and its residents, and for the climate."
- Halvor Bjerke, CEO, Stack EMEA Nordics, commented: "Heat reuse is now standard in our new data centers and we expect to continue working with city authorities, heat and electricity suppliers to ensure that this circular economy for energy is widely adopted so that the digital economy is sustainable."

Image source: [282]; Sources: [283]

SWEDEN

Container data center

Sweden

60 °C

Heat pumps, direct water cooling

District heating system

550 kW

Jordbro

60 °C

Building heating

Cloud&Heat Technologies, Vattenfall

Image source: [284]; Sources: [285–287]

Technology

- Two 20-foot containers (container construction), in which around 1,600 Nvidia graphics cards are installed. The included high-end servers are equipped for artificial intelligence (AI) and high-performance computing (HPC) applications. Overall, the output is 550 kW.
- Resource-saving IT operations are made possible by using the heat generated according to the "Combined Heat and Compute" principle. Direct water cooling (60/50 °C) allows excess heat to be used in the adjacent district heating system for maximum sustainability. The heat from the main IT consumers is transferred to the heating network without the involvement of heat pumps.
- There is a small heat pump for residual loads.
- The data center is located on the site of Vattenfall's biomass-fired district heating plant in Jordbro, south of Stockholm. Vattenfall's know-how and Cloud&Heat's technology enabled the construction of a water-cooled data center that does not emit any CO_2 during its operation and, moreover, is directly integrated into Vattenfall's heating network to reuse the heat," says Dr. Jens Struckmeier, CTO at Cloud&Heat Technologies.
- Up to 86 % heat recovery with a PUE of 1.04.

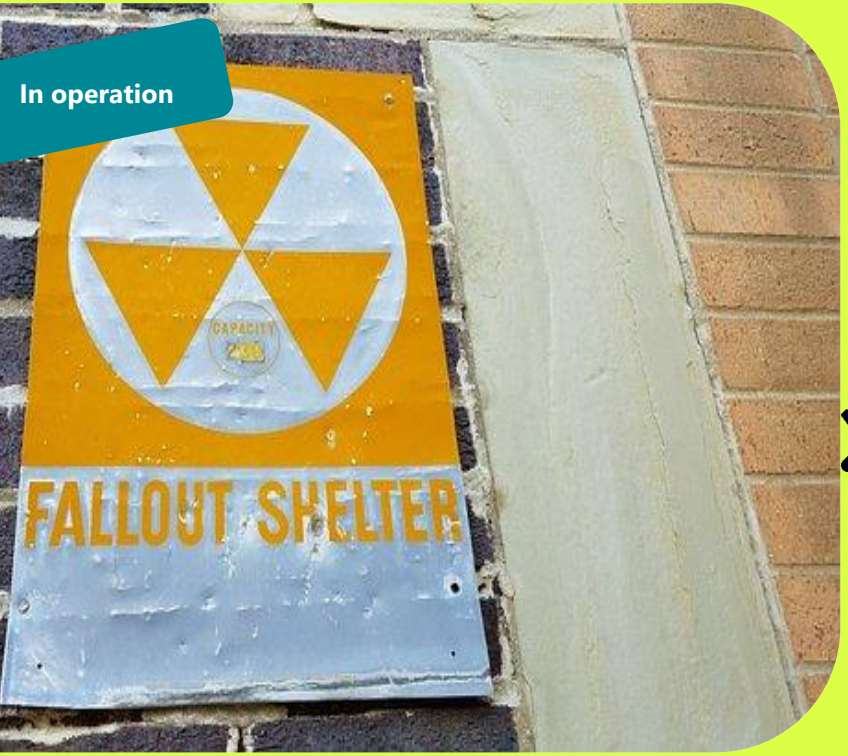
Law

- To protect the necessary infrastructure against unauthorized access, the cloud offering is equipped with additional security mechanisms from Secustack GmbH, a Cloud&Heat subsidiary.
- Vattenfall provides the infrastructure and the secure location, Cloud&Heat Technologies is responsible for operation.

Other

- The aim of the pilot project is to win the first beta customers for the cloud offering, who will test the infrastructure and thus contribute to the further development of the service.

Data center Bahnhof Pionen



In operation

Sweden	Stockholm
Heat pumps	68 °C
67 m	Building heating
District heating network	Bahnhof, Stockholm Exergi, Fortum Värme
2014	

Technology

- Subsequent installation of two heat pumps connected in series and a heat pipe (67 m long, DN 125) from the data center to the Stockholm Exergi district heating network.
- he cooling capacity of the heat pumps is 694 kW and the heating capacity is 975 kW (COP = 3.47).
- There is a temperature control on the "cold" and "hot" side.
- In an emergency, the old chiller is activated.
- The heat pumps correspond to pressure class PN16 on the condenser side, so that they can be connected directly to the district heating distribution network. In normal operation, the heat output is around 600 kW at a temperature of 68 °C.
- 2x 61XWH0802 AquaForce units (<70 °C hot water).
- Heating control (Carrier Plant System Manager based solution with control solution developed by AdvanTE3 C).
- Providing 100 % system redundancy for server cooling in the data center thanks to the existing Carrier AquaSnap water-cooled system (two 30RWs) installed in 2013 which will act as a backup for the new system;
- Achievement of a "theoretical" PUE value of less than 1.0 if the hot water produced from waste heat were included in the PUE calculation.
- Plant oversizing to allow for increases in supply capacity and higher energy densities.
- Control of the system by regulating the temperature on the cold and warm side of the heat pump.
- In the event of a failure, the backup system consisting of old train station refrigeration machines kicks in.

Business

- In 2015, £35K was reported to have been raised over a three month period.
- Bahnhof has invested SEK 3.4 million in the new cooling system in Pionen, while Stockholm Exergi has invested SEK 1.3 million. This includes costs for heat pumps, pipes, hot water connections, wiring, control systems, insulation, installation and a new supply line to the existing district heating network.
- Sale of excess heat through Stockholm Exergi's Open District Heating. Amount of remuneration at the station depends on outside temperatures.

Other

- Located in a disused nuclear bunker under bedrock at Vitabergs Park in Stockholm.

Image source: [288]; Sources: [289–294]

Data center Bahnhof Thule

Sweden

Heat pumps

District heating network

Stockholm

68 °C

Building heating

Fortum, Bahnhof, Stockholm Exergi

Technology

- Three data center halls with a total of three heat pumps (carriers) connected in series.
- The heat sink is the district heating network.
- The total cooling capacity is around 1,200 kW if district cooling is supplied at 5.5 °C (cooling water temperature) and district heating at 68 °C.
- The heating output corresponds to around 1,600 kW. At outside temperatures of down to 0 °C, temperatures of 65 °C are required in the flow line, at lower outside temperatures higher flow temperatures are required, up to 100 °C at -18 °C outside temperature.
- Cooling also works without heat extraction and adapts to the heat requirement.
- In normal operation, heat pumps use the return line of the district heating network and cool down to the desired temperature for use in the data center.
- System can operate without District Cooling if there are interruptions in District Cooling supply.
- When the outside temperature is at least 20 °C, the refrigeration system produces refrigeration at full capacity, excess refrigeration energy is made available to other district cooling customers in the network system.
- If the outside temperature is below 20 °C and there is a cooling requirement, the chillers run at a lower capacity so that the Thule train station can cover its cooling requirements.
- There is a permanent need for heat in the city.

Business

- Price depends on environmental conditions and demand.
- The excess heat from the heat pumps in the district heating network is mainly used when the outside temperature is below 7 °C, which is around half the year.
- Bahnhof has invested a total of SEK 5.3 million in the cooling system, which includes three heat pumps (which are pressure class PN16 on the condenser side, so they can be connected directly to the district heating distribution network), piping, wiring, control systems, data collection and installation . Stockholm Exergi has invested SEK 2.6 million in new district heating and cooling supply lines.

Image source: [295]; Sources: [200, 290, 296–298]

Data center DigiPlex

Sweden

DigiPlex, Stockholm Exergi

District heating network

Stockholm

Building heating

Technology

- World premiere in which an already operational data center is equipped with indirect air-to-air cooling.
- Will be retrofitted to recover excess heat for the local district heating network.
- DigiPlex provides approximately 5 MW of heat.
- Contract for heating 10,000 modern homes.

Business

- A goal of Stockholm Exergi is that 10% of Stockholm's heat demand should be covered with waste heat from data centers.
- Sustainability is part of Digiplex's DNA.

Communication

- Demonstrator for the compatibility of heat extraction with air cooling.

Image source: [299]; Sources: [300, 301]

Data center H&M

Technology

- 1 MW IT load.
- Data center is cooled via return line in the district cooling system, Fortum Värme takes excess heat. System can also be used as backup when original cooling system is not available.
- Cooling water temperature 6 °C.
- Heating of 2500 modern homes with heat pumps in an N+1 configuration.
- 90 % of households in Stockholm are connected to the district heating network.

Business

- Energy supplier Fortum Värme distributes the heat in the city through the district heating network.

Sweden

Heat pumps

District heating network

H&M, Fortum Värme

Stockholm

1 MW

Building heating

Image source: [302]; Sources: [200, 303–305]

Data center Rosersberg

Technology

- Distribution of waste heat to homes and offices in the greater Stockholm area.
- Cooling capacity of over 10 MW at a cooling water temperature of 11 °C.
- Approx. 8000 h per year is cooled cia waste heat utilization, whereby 14,000 modern apartments can be heated.

Business

- Fortum Värme invests in a new, separate state-of-the-art refrigeration plant with heat pumps next to Ericsson DC and close to the district heating network.
- Ericsson also uses Fortum Värme's cooling service for DC in Kista, where Fortum Värme supplies 3 MW of cooling capacity.

Sweden	Rosersberg
Heat pumps	Building heating
District heating network	Fortum Värme, Ericsson
2017	

Image source: [306]; Sources: [307]

Datentechnik Moll

In operation

Sweden

Immersion cooling

DTM Group, Boden Business Agency

4,4 MW

Boden

Greenhouse temperature control, wood drying, rearing of temperature-sensitive feed animals

Technology

- Two existing pods with an output of 2.2 megawatts (MW) were supplemented by two more with an output of 2.2 MW. With CPUs that are now around 20 % more powerful, the computing capacity can now be realized with significantly fewer servers.
- With the expansion, the DTM Group is intensifying its research activities around the topics of immersion cooling and waste heat utilization in the data center. The company wants to test a total of four concepts for "Novec"-based immersion cooling in the new part of the data center and bring them to series maturity. Hybrid concepts, in which only performance-intensive components such as CPUs are immersion cooled and the power supplies continue to use air cooling, are also being researched.
- In cooperation with the Boden Business Agency, the Swedish partner of the DTM Group, practical usage scenarios are to be set up on the newly acquired area. This includes, for example, the cultivation of plants in a greenhouse that is tempered by the waste heat, the drying of wood or the rearing of temperature-sensitive feed animals. In order to ensure a constant air temperature, the exhaust air must be treated with an air box, which allows the admixture of outside air

Other

- According to DTM, the data center works completely autonomously and is monitored with an AI-supported DCIM solution. The electricity for the operation of the data center is regenerative and comes from a nearby hydroelectric power plant.

Image source: [308]; Sources: [309–311]

EcoDataCenter

Sweden

Falun

Local heating network

2 MW

EcoDataCenter (Falu Energi & Vatten und EcoDC AB)

Building heating, wood drying

Technology

- 2 MW data center with PUE = 1.15 and 100 % renewable energy.
- Customized cooling system and heat dissipation into the local district heating network.
- Heat supply to residential and commercial properties (approx. 95 % of the city) and a local wood pellet factory (for wood drying).
- Link to the city's CHP plant (combustion of wood waste in a thermal power plant).

Communication

- Joint project between a local energy company and the operator of the data center.

Other

- According to the company, it should be the first climate-positive data center.
- It is a pilot project. A second data center is planned on the same basis with 6 - 7 MW.

Image source: [312]; Sources: [313, 314]

Edge data center

Sweden

Luleå

50 °C

35 °C

Liquid cooling, solid oxide fuel cells

Air preheating fuel cell

Heat recovery circuit

RISE (Research Institute of Sweden)

Technology

- Small data center powered by fuel cells. At the Luleå site, the data center and the fuel cells were housed in two containers stacked on top of each other. The fuel cells, which are operated with locally generated biogas (polar gas), are located in the upper container. The lower container contains a liquid-cooled unit and the data center, which is supported by an uninterruptible power supply.
- The system works with solid oxide fuel cells (SOFC, Fab. SOLIDpower), which generate electricity from biogas. They work at high temperatures of around 600 °C and are therefore a particularly efficient variant of combined heat and power systems, as the waste heat can be used well for heating and cooling.
- There is a smaller heat recovery circuit inside the two containers. The heat generated by the submerged liquid cooling tank inside the data center container is used to preheat the air entering the fuel cells.
- The return water temperature from the cooling manifold unit in the Submer is approximately 50 °C. The fuel cells consume air at an optimal temperature of 35 °C, so the outside air (-25 to 25 °C) can be heated by the heat from the Submer system.
- The CHP should decouple heat with a temperature of 90 °C and in winter at -20 °C outside temperature the flow temperature is increased to 110 °C.

Other

- RISE is a partner in the EU-funded WEDISTRICT project, which aims to demonstrate that district heating and cooling networks can be built using a combination of renewable energy sources and heat recovery solutions.

Image source: [315]; Sources: [316, 317]

Green Hub

Technology

- Use of seawater for free cooling and series of heat pumps, to feed the heat into the district heating network.
- Space for 1,600 high-density racks with power consumption in excess of 25 kW/rack.

Sweden

District heating network

2017

Stockholm

Bahnhof, Fortum Värme

Image source: [318]; Sources: [319]

STO6

Technology

- Heat pumps provide hot water to heat homes in Stockholm.
- Hot water with a temperature of at least 65 - 80 °C is fed directly into the district heating network.
- Excess heat from Interxion's data centers in Stockholm can heat 10,000 modern homes in Stockholm.

Business

- Fortum provides free cold water for data center cooling.

Other

- Part of the Stockholm Data Park.

Sweden	Stockholm
65 - 80 °C	65 - 80 °C
Heat pumps	Building heating
District heating network	Interxion, Fortum, Stockholm Exergi

Image source: [320]; Sources: [321, 322]

Stockholm Data Park

Sweden

Stockholm

Heat exchangers, heat pumps

Building heating, district heating supply

District heating network

10 MW

City Stockholm Business Region, Fortum Värme, Stockholm Exergi, Ellevio, Stokab, Ericsson

85 °C

2021

Image source: [323]; Sources: [200, 324–328]

Technology

- 10 MW data center can heat approx. 20,000 modern apartments, with the annual district heating requirement being 12 TWh.
- The objective of the Stockholm Data Park (SDP) is to cover 10 % of the heat demand in Stockholm. For this purpose, 20 MW from data center are to be fed in from spring 2021. This is intended to heat 35,000 apartments.
- There has been a district heating network in Stockholm since the 1950s. There are 2,800 km of pipelines in the city, and every house has a heat exchanger.
- Heat pumps raise the temperature level to around 85 °C.

Business

- In Sweden, electricity costs are the lowest in the EU and specific CO_2 emissions are low.
- Efforts are made to ensure independence from subsidies and market viability from the outset.
- Some companies prioritize ROI while others accept lower revenues.
- Business model: With Open District Heating, data centers, supermarkets, etc. can sell their waste heat to the energy supplier via a kind of open marketplace. It is comparable to a stock exchange, where the price depends on many factors (demand, temperature level). Depending on the situation, the supplier can decide whether he wants to feed in.
- Ericsson operates a data center in the SDP and the reason for heat extraction was to reduce operating costs and increase sustainability. Energy consumption and operating hours of the cooling could be reduced.
- Exergi's goal is a 100 % renewable heat supply.

Communication

- Initiative by the City of Stockholm, district heating and cooling provider Stockholm Exergi, electricity network operator Ellevio and fiber optic provider Stokab, which offers greenfield sites for data center construction.
- The district heating provider Exergi actively approached the heat sources, especially the data center, and informed them about the possibility of heat extraction for heating purposes and the simultaneous reduction of cooling costs. Another argument was that from a thermodynamic point of view, heat pumps and coolers function in the same way, with the cooler only dissipating heat to the environment.

Other

- Due to the geographic location, there is an increased need for heating.

Elementica

Sweden

Water cooling compatible

Ericsson, Stokab, Fortum Värme, Ellevio, Elementica

~250 m

Stockholm

21 MW

Refinement in biomass cogeneration plant

Technology

- Redundant cooling system compatible with water cooling.
- 10 MW are to be decoupled.
- 21 MW data center.

Law

- Due to the fixed installations, long-term and transparent contracts with a term of up to 15 years can be offered.

Business

- Over a period of 15 years with an output of 10 MW, up to 23 million euros are to be generated via the open district heating contract.
- Electricity tax in Sweden is around 3.2 eurocents/kWh and from 2017 for data center at 0.06 eurocents/kWh. In comparison, this is 15 cents/kWh in Germany.
- Waste heat from the data center is sold to an adjacent biomass heating plant in Värtaverket (~250 m away) and then refined.
- Fortum Värme has created a marketplace for recovered heat and production capacity, giving the opportunity to offer long-term transparent contracts and open prices for trading surplus heat and cold.
- Heat extraction halves the energy costs.

Other

- Industrial cooperation between the energy company Fortum Värme, the energy supply company Ellevio and Elementica.

Image source: [329]; Sources: [12, 330–332]

Data center Kista

In implementation

Sweden

24 °C

Heat exchangers, heat pumps, circulation pumps

District cooling & district heating network

Kista

Building heating

Interxion, Fortum Värme

Technology

- 4,800 m^2 data center by Interxion.
- Data center is supplied with chilled water (14 °C) and delivers water at approx. 24 °C
- Fortum Värme refrigeration service is used.
- Chilled water cooling and heat recovery is supplied via Fortum Värme's plant in Kiste/Akala and via the district cooling network.
- Heat exchanger, mixer and circulation pump at the Interxion site.
- Waste heat is fed into large heat pumps at the Fortum Värme mill and then fed into the district heating network.

Image source: [333]; Sources: [334]

EcoDataCenter2

Sweden

Östersund

2026

20 MW

EcoDataCenter, WA3RM

Agricultural use

Technology

- 2.0 version of EcoDataCenter.
- Delivery of the waste heat to a food production area (fish farm and greenhouses).
- Circular operation, collaboration with circular economy company WA3RM for symbiosis with food production.
- Green energy from Jämtkraft.
- 20 MW IT output after the first construction phase, target is 150 MW in 2033.

Communication

- "Together with the EcoDataCenter, we design and build a circular concept from the beginning and do not add it after the fact, which is unique," said Jaques Ejlerskov, CEO of Wa3rm.

Other

- First construction phase decided in 2026.

Image source: [335]; Sources: [336–339]

UNITED STATES OF AMERICA

National Renewable Energy Laboratory HPC Data Center

USA

30-40 °C

Direct liquid cooling, heat exchanger, snow melt loop, active chilled beams

In the building

Domestic hot water circuit

Golden, Colorado

10 MW

U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Alliance for Sustainable Energy LLC

Building heating

Technology

- 900 m^2 data center (HPC "Kestrel" and "Eagle") with a capacity of 10 MW in full expansion (LEED platinum certificate with PUE ≤ 1.04).
- There are no mechanical chillers, eliminating expensive and inefficient chillers. Direct liquid cooling at the component level (power density of the racks: between 60 and 80 kW/rack) with a cooling water supply at 24 °C, which is heated to 30 to 40 °C via the racks. The waste heat generated is decoupled and used to heat offices and laboratories. At least 95 % of rack heat is dissipated directly to the fluid.
- The extracted heat is fed into the building's domestic hot water circuit and supplies the following systems: active chilled beams, air conditioning units, snow melting loops and the district heating circuit. If additional heat is needed for the building, the domestic hot water circuit can draw heat from the campus heating circuit.
- Key design parameters for the liquid-cooled NREL data center include IT chilled water supply and IT return, as the ESIF can only generate 24 °C (ASHRAE "W2" class) on the hottest day of the year with cooling towers and the building at coldest day of the year requires at least 35 °C to heat the system.

Business

- Lower capital and operational expenses compared to a typical data center.

Communication

- NREL was recognized with the 2018 Data Center Dynamics Data Center Eco-Sustainability Award for its pioneering approach to data center efficiency.

Image source: [340]; Sources: [341–351]

South Bend Greenhouse and Botanical Gardens

In operation

Technology

- Rack with HPC (High Performance Computing) nodes near a municipal greenhouse.
- Heating of flowers and plants in the facility (South Bend Greenhouse and Botanical Garden).

USA

Notre Dame Center for Research Computing, South Bend Greenhouse and Botanical Garden

South Bend, Indiana

Greenhouse heating

Piping

In the greenhouse

Image source: [352]; Sources: [193]

Westin Building Exchange

USA

Heat exchangers, chillers with heat recovery

Opposite side

Water pipes

Seattle, Washington

Amazon, Edo, Westin Building Exchange

Building heating

Technology

- The heat recovery system at the Westin Building Exchange delivers up to 5MW of waste heat from the data center to an Amazon campus, saving 75 % of energy. Area of 38,000 m^2 is heated.
- The heat harvesting concept is based on an EcoDistrict approach with underground pipes, heat exchangers, heat recovery chillers and water storage tanks.
- The waste heat from the data center is absorbed via the cooling water circuit and piped to the Amazon campus, where heat recovery chillers use the heat to heat the company campus. Cooled water is piped back to the Westin building.
- In front of the EcoDistrict, the Westin Building released excess heat to the atmosphere.
- The data center uses the virtual cooling tower to remove heat and reduce water consumption and the use of cooling compressors.
- Over 20 years, the Westin Building Exchange's heat recovery system will save 180 million kWh of energy and avoid 650 tons of CO_2 emissions.

Law

- Largest combined energy system in the US that crosses property lines. The data center and the Amazon campus are located in two different buildings, which are separated by a street.
- Edo operates the Seattle EcoDistrict to over optimize shared energy opportunities and building performance.
- The City of Seattle was a key partner in the EcoDistrict project, helping to clear the way for the hot and cold water lines to run under the street as a standard utility facility.

Business

- Annual energy and operational savings of $240,000.
- Efforts result in tangible energy and cost savings for all stakeholders - the Westin Building Exchange, Amazon, the EcoDistrict facility owners and the local utility.

Image source: [353]; Sources: [354]

Wyoming Hyperscale White Box

USA	Wyoming
Immersion cooling	130 MW
Opposite side	Indoor-Farming
Geothermal aquifer	Kay Thornock & Sons

Technology

- IT power capacity totals 130 MW. The 1st construction phase comprises 30 MW.
- The first construction phase covers around 235,000 m^2. A total of around 2.6 million m^2 belong to the project.
- The entire data center is designed from the start for immersion cooling with submersible systems. In this way, almost all of the waste heat can be recycled. A power density of 80 kW/rack is achieved with immersion cooling.
- Immersion cooling for extreme density, efficiency and sustainability.
- Geothermal aquifer for heat exchange with the help of aquifer.
- Hot water is routed to Indoor Farm (another Thornock Clan subsidiary) and then returned to aquifers.
- The site is located in the inhospitable mountains of Wyoming, with a total of 500 MW of renewable electric power around.
- It consists of five wind farms and a 58 MW solar farm, which will supply the facility with operational power. They were built independently of the data center park and do not bother anyone in the wasteland. The data center park also uses geothermal energy.
- Expected PUE of 1.08 and water use efficiency of 0.0 at resiliency level 3.

Business

- Customers who generate particularly high calorific waste heat receive a credit.

Communication

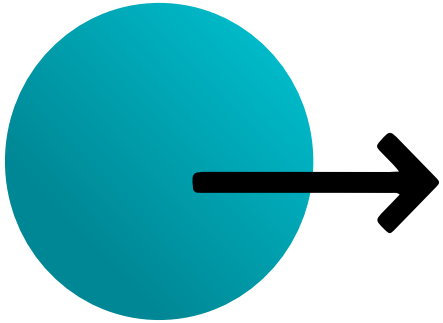
- CO_2 impact tracking.
- Further data center projects planned in Tuscon and Phoenix.
- Goal: regenerative data center.

Other

- Location chosen for fiber optic expansion opportunities, hub for data centers, good access to renewable energy from nearby wind and solar farms.
- Still under construction.

Image source: [355]; Sources: [356, 357]

CANADA



Winnipeg data center

In operation

Technology

- Waste heat is sent to the nearby offices of a local newspaper.
- The company moved a second duct from the exhaust air plenum to the intake duct of the editorial office on the upper floor. The process is controlled by pneumatic baffles that open and close depending on readings from thermometers in the channels.

Canada	Winnipeg
Pneumatic baffles, ventilation system	Building heating
Nearby	Quebecor

Image source: [358]; Sources: [193]

QScale Q01 Campus

In implementation

Canada

Agricultural use and building heating

Quebec

96 MW

QScale, Energir Development

Technology

- QScale is specifically designed to recover all IT systems waste heat.
- This sustainable colocation infrastructure is designed for high density hardware such as machine learning, artificial intelligence and supercomputing.
- Total campus IT capacity is 96 MW IT Load.
- QScale is powered by renewable energy at 99.5 %.
- Agriculture and industrial space heating projects are underway.
- The facility is located nearby existing greenhouses and over 100 hectares of agricultural land.
- Potential to produce 2 800 tons of berries and 80 000 tons of tomatoes.
- Use of waste heat in summer for drying grain and revitalization of surrounding agricultural land.

Business

- QScale will provide free waste heat from its centers. Having carried out pre-feasibility studies and confirmed technical and economic viability, Énergir will ensure project implementation from design through to operation.
- A second Campus at Ecoparc Saint-Bruno-de-Montarville in Montreal is planned, QScale is also scouting several additional location to expand.
- QScale is scouting location based on clean energy availability and heat recovery potential.

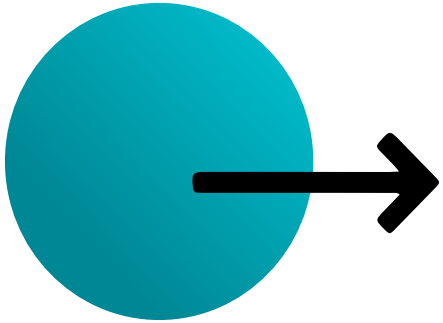
Communication

- QScale announced its partnership with Energir in March 2023 and its first Anker customer, HPE, in May 2023.

Others

- QScale Q01 Campus is designed into 8 phases. As of 2023, Phase 1 is operational and Phase2 is under construction.

Image source: [359], Sources: [122, 360–362]



JAPAN

White Data Center Project (WDC)

Japan	Bibai
33 °C	27 °C
Snow melt water, waterpool	40 kVA
Right next to the data center	Process heat – eel farming
Water pipes	White Data Center
2021	

Image source: [363]; Sources: [364–371]

Technology

- A data center in northern Hokkaido Island is cooled with snow melt water and uses its waste heat to run an eel farm. A heap of snow is piled up on the data center site in winter, which cools the data center with the help of antifreeze, which circulates in a line from the heap to the data center. The snow pile is covered with insulating materials (wood chips and earth) in summer or warmer periods, so it lasts for up to a year. This can save 20 % of the energy costs of the data center.
- Currently 20 server racks are in operation, but there are already plans to open a second data center with 200 server racks by the end of 2022. The racks of the have a power density of 2 kVA, while they should be 5 kVA in the new DC. This results in an IT power of 40 kVA or 1000 kVA.
- After the data center has been cooled, the water has a temperature of 33 °C, which the company says is ideal for agriculture and aquaculture, including eel farming. For this purpose, the WDC imported 1700 glass eels (young eels) and will breed them in tanks in the data center. During its tenure as a research project, WDC studied various agricultural options for this warmth, including abalone, sea urchins, Japanese mustard spinach, cherry tomatoes, and other produce.

Business

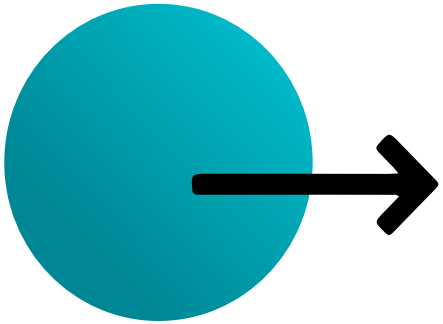
- In cooperation with the city of Bibai, 6,000 eels have been bred in warm meltwater since November 2021. Often affected by heavy snowfalls, Bibai is working with the WDC on the possibility of using the snow collected by the city's snowplows as pre-cooled water for the servers and as a freshwater source for the eels.
- The pools are kept at 27 °C all year round. WDC expects to ship about 300,000 eels, which will be farmed on-site for seven months until they reach a commercial weight of 250 g.

Communication

- From 2014 to 2019, the city implemented the "White Data Center" project, supported by the Japanese research organization NEDO, to show that snow can be stored in winter and used to cool a data center all year round.

Other

- The implementation of this method at other locations will be difficult because there are few places that meet the necessary conditions.



SOUTH KOREA

Tomorrow Water Project

South Korea

Seoul, Jungnang

On one property

Process heat - water treatment

Common water and energy flows

Tomorrow Water, Arcadis

Technology

- Co-flow idea: combine sewage treatment plants, biogas plants and data centers in one place and use AI to increase the efficiency of the entire process across the entire value chain.

Law

- After examining the patents, Arcadis plans to collaborate on possible projects in the USA.

Business

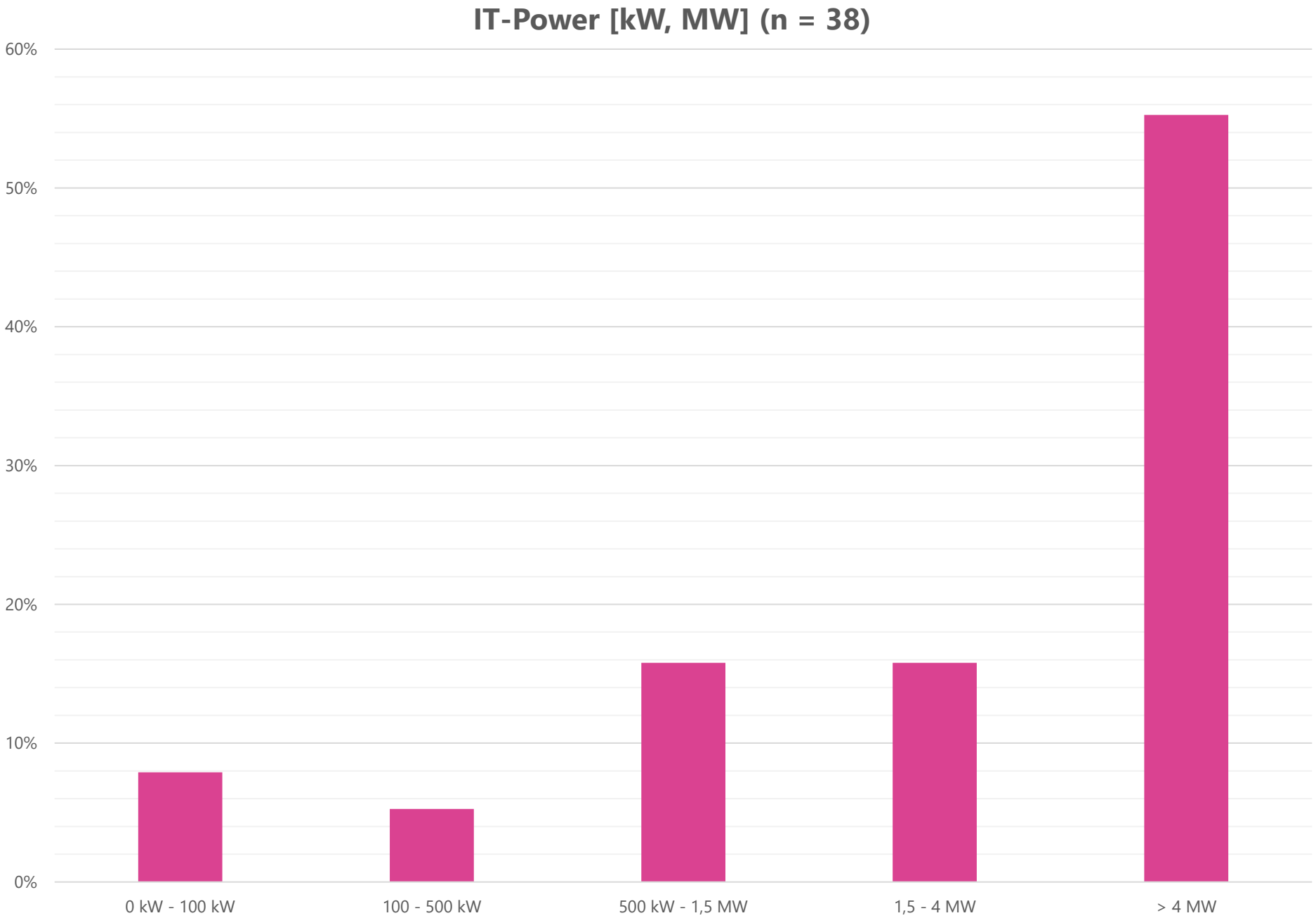
- Build data centers on the same property as wastewater treatment plants so that both can share water and energy streams.
- Data center uses treated water.
- Wastewater treatment plant uses waste heat from the data center.
- BKT, has built a Waste Water Treatment Plant (WWRF) in Jungnang, Seoul, South Korea that uses Tomorrow's Proteus biofiltration system in place of settling tanks.

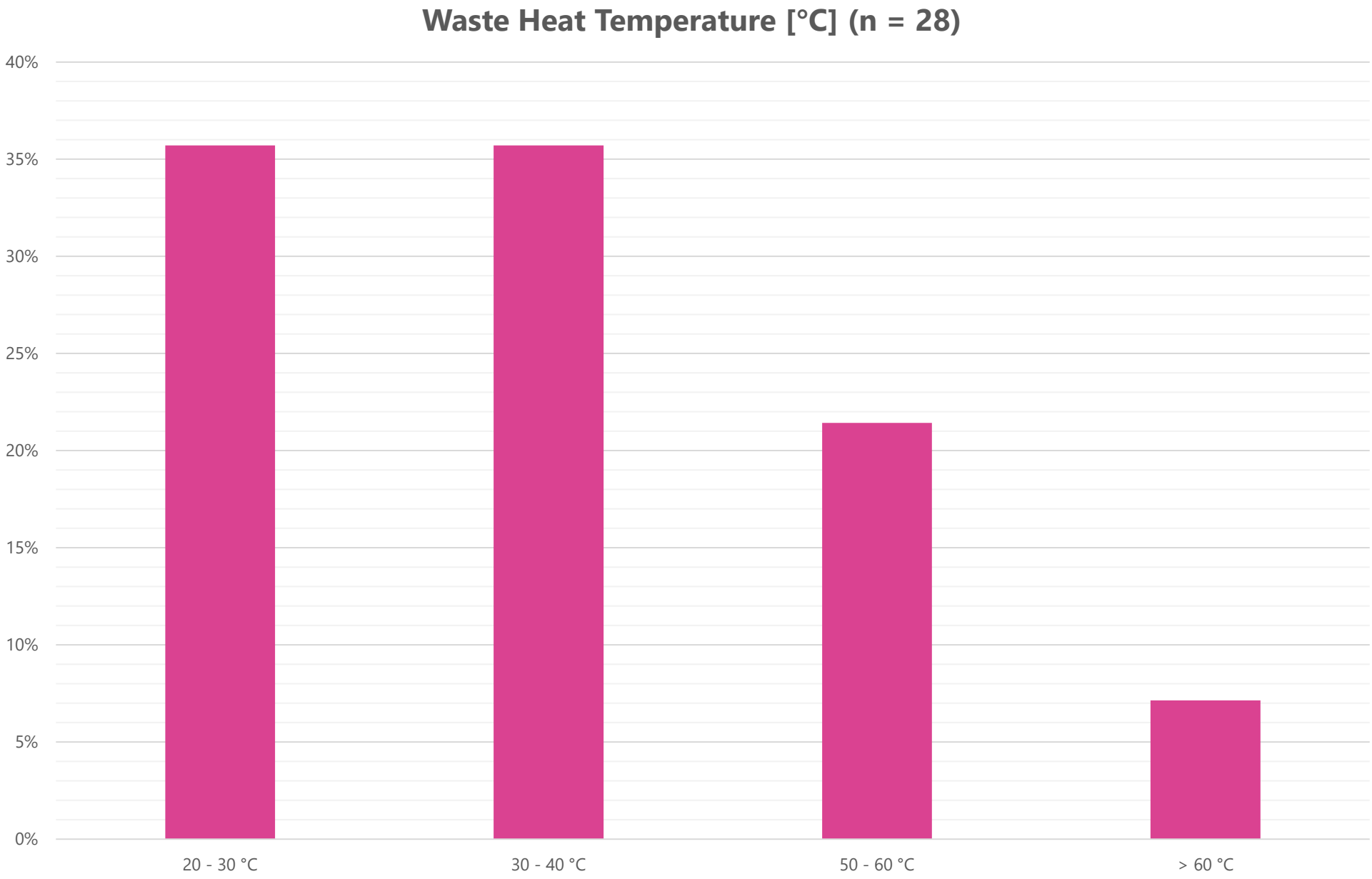
Communication

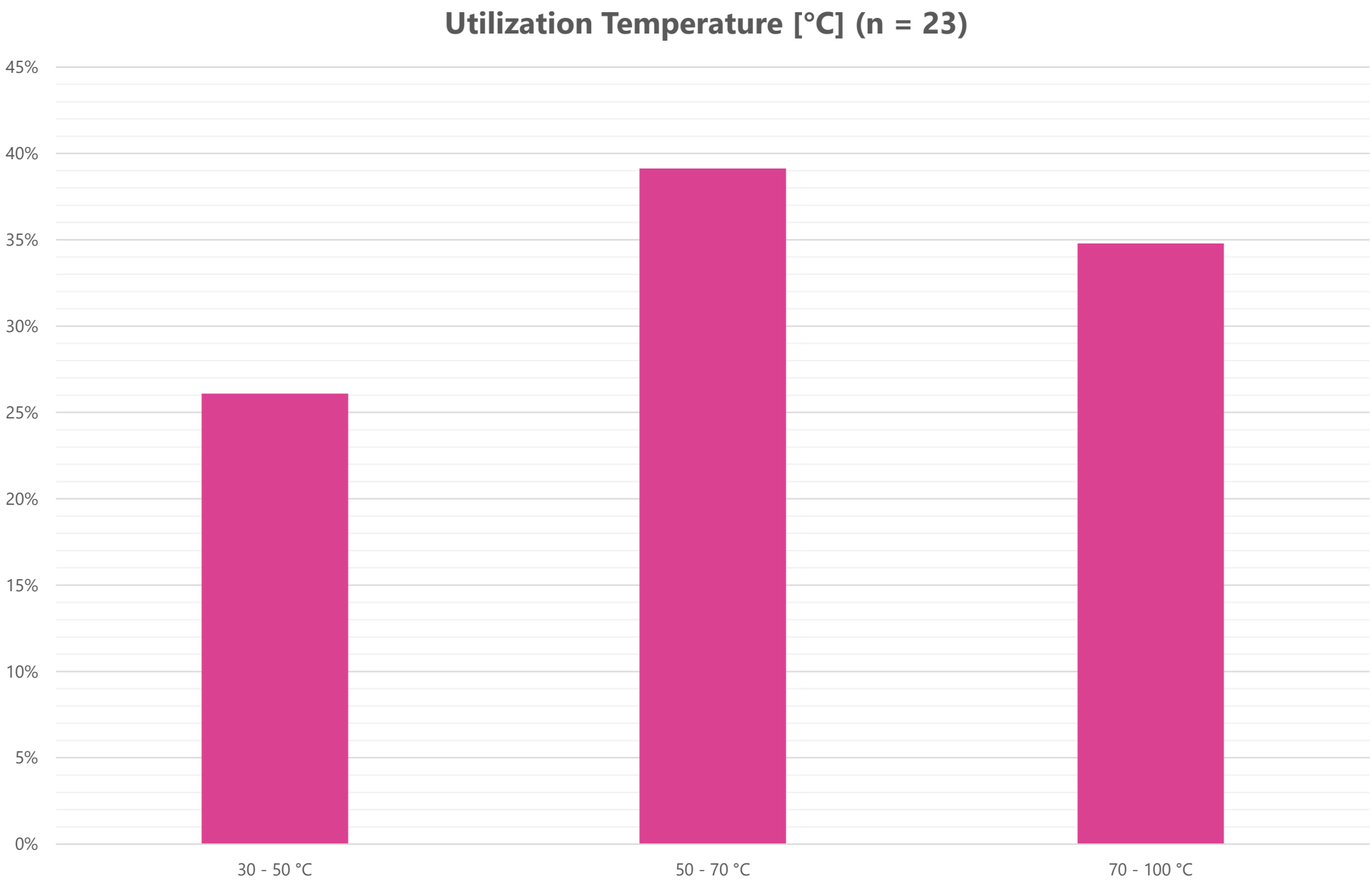
- According to Tomorrow Water, wastewater treatment plants could be built much smaller if large clarifiers were replaced with the Proteus biofiltration system. These facilities are typically located in urban areas that are attractive to edge data centers, which Tomorrow says could be co-located, where they can contribute waste heat to reduce the energy demands of the water treatment systems by heating the biological systems and drying them contribute to the mud.
- "Combining data centers and wastewater treatment plants will help reduce wastewater discharges, balance drinking water needs and provide triple benefits for water-stressed regions. We're excited to partner with Tomorrow Water to explore how the co-flow process can work together projects that improve the quality of life," said Ufuk Erdal, senior vice president and director of water reuse at Arcadis.

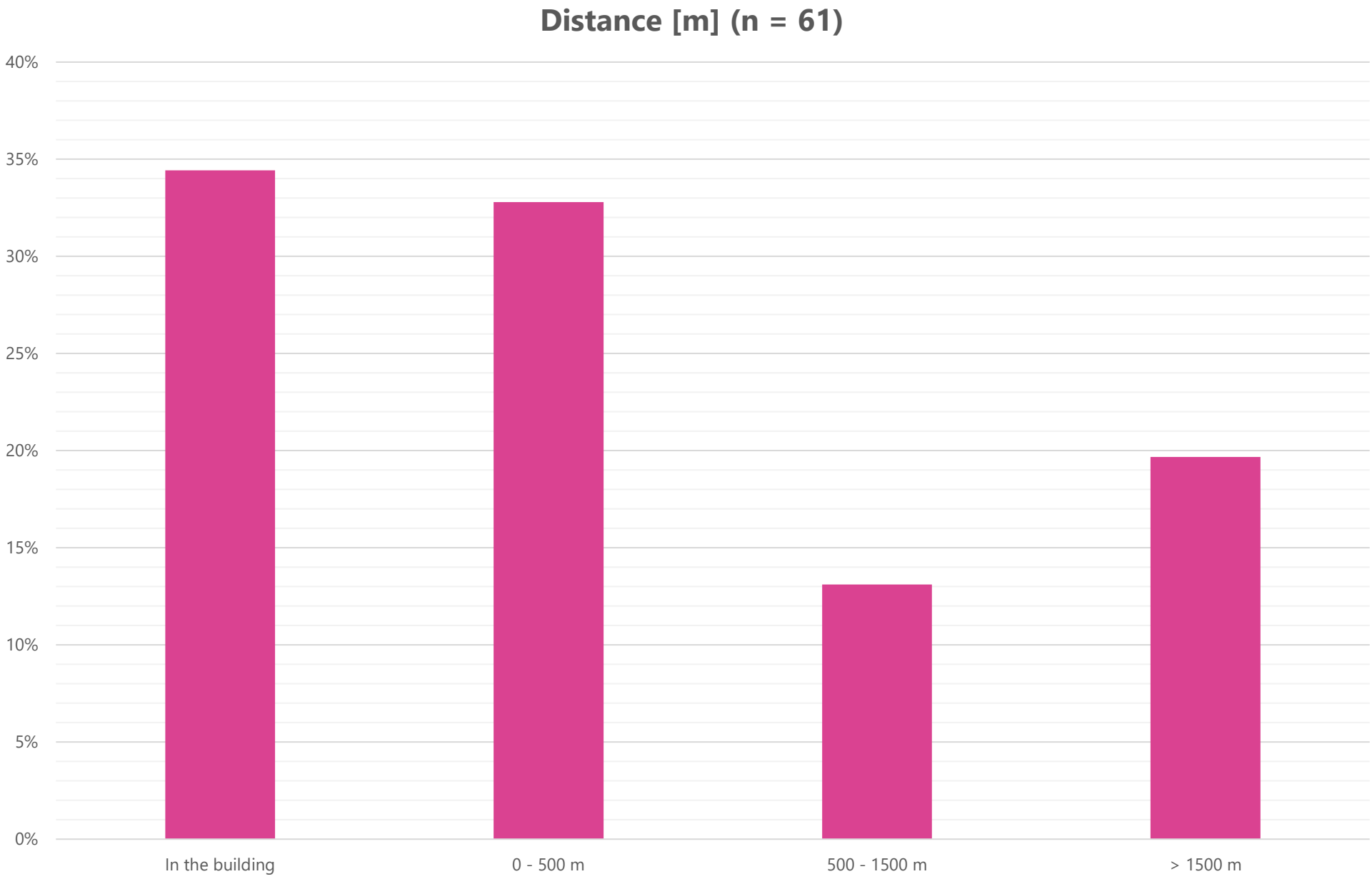
Image source: [372]; Sources: [373–375]

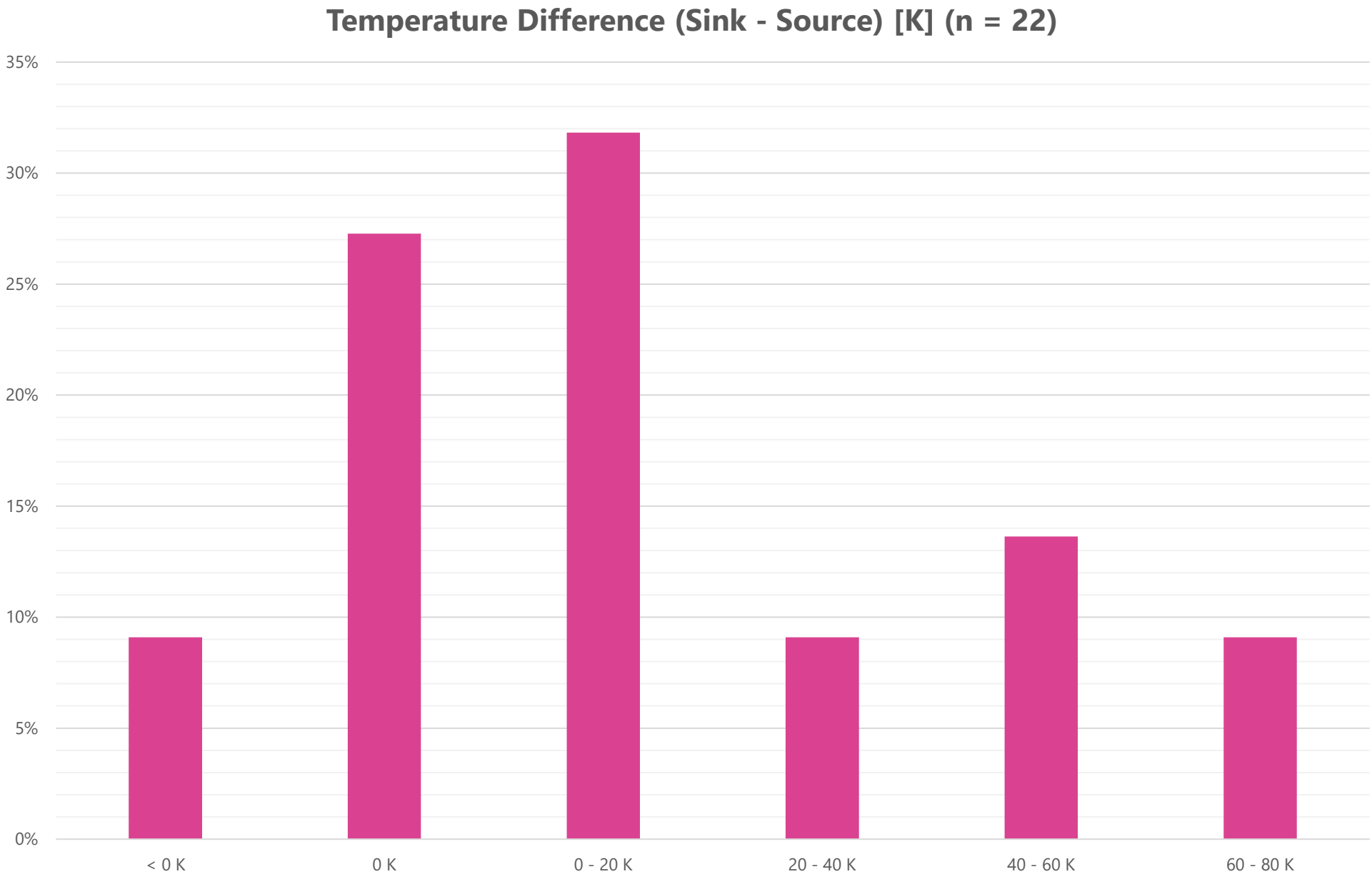
Statistical data on waste heat recovery projects worldwide

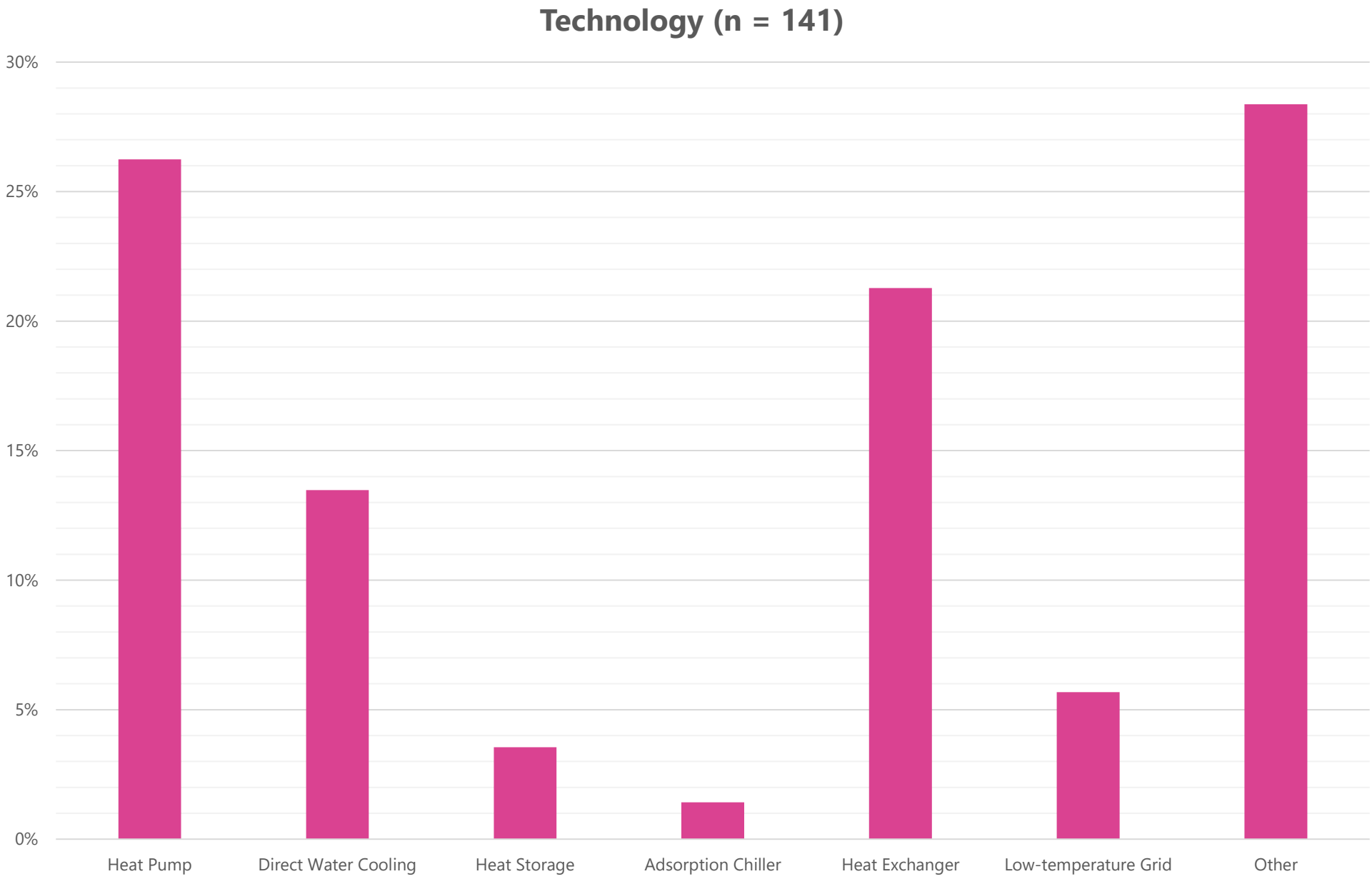

IT-Power [kW, MW] (n = 38)
60%
50%
40%
30%
20%
10%
0%
0 kW - 100 kW
100 - 500 kW
500 kW - 1,5 MW
1,5 - 4 MW
> 4 MW

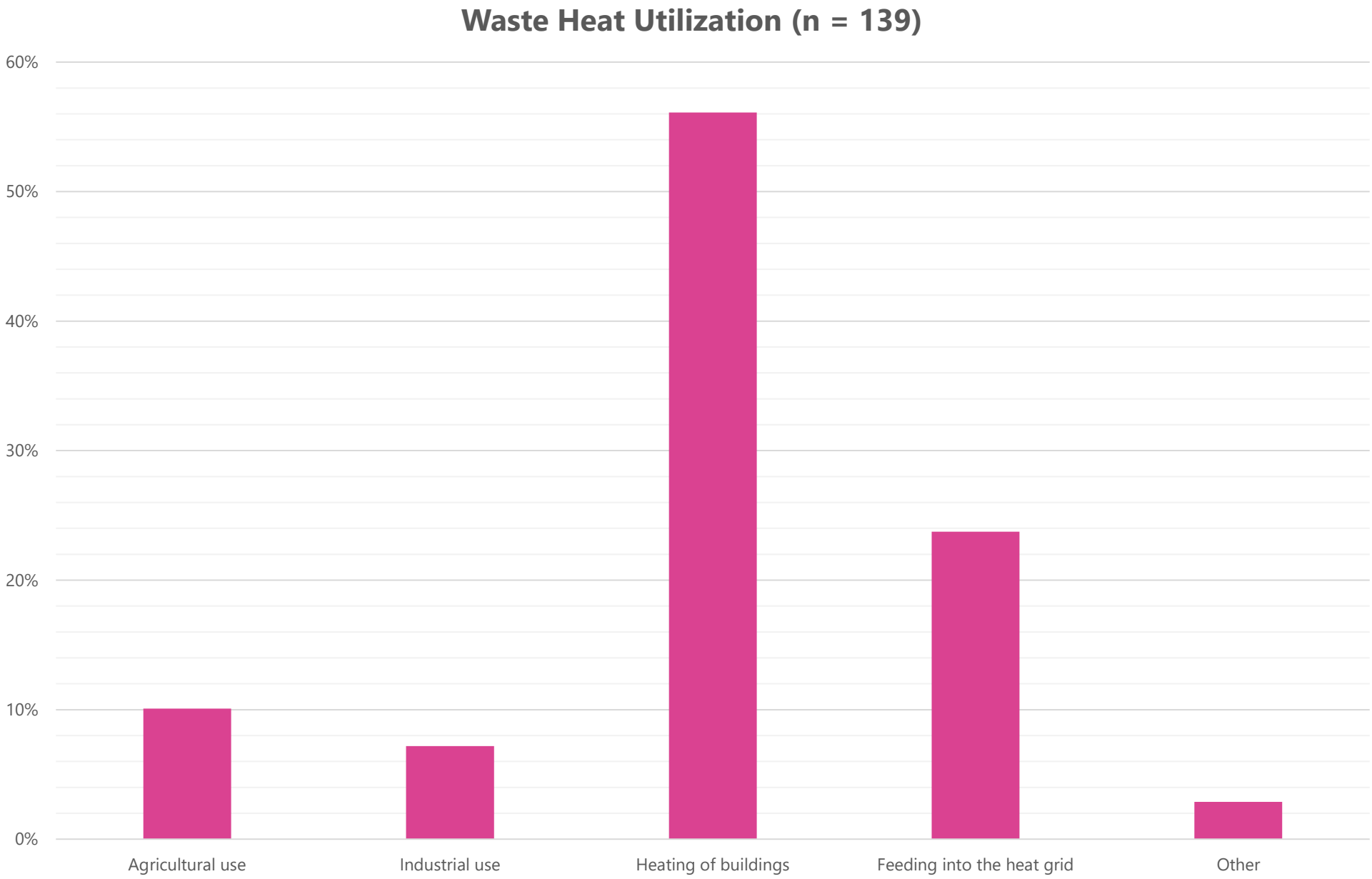

Waste Heat Temperature [°C] (n = 28)
40%
35%
30%
25%
20%
15%
10%
5%
0%
20 - 30 °C
30 - 40 °C
50 - 60 °C
> 60 °C

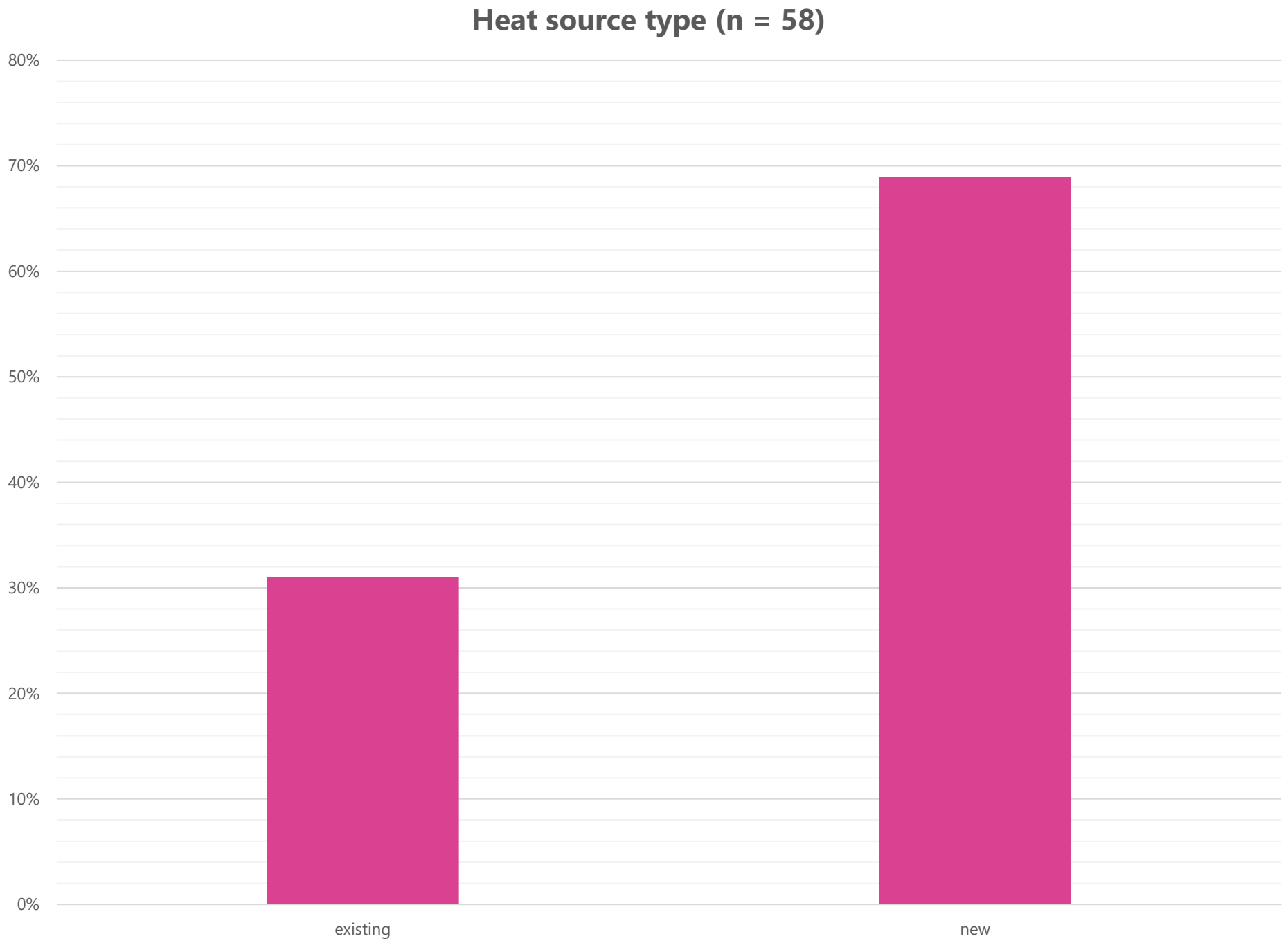

Utilization Temperature [°C] (n = 23)
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
30 - 50 °C
50 - 70 °C
70 - 100 °C

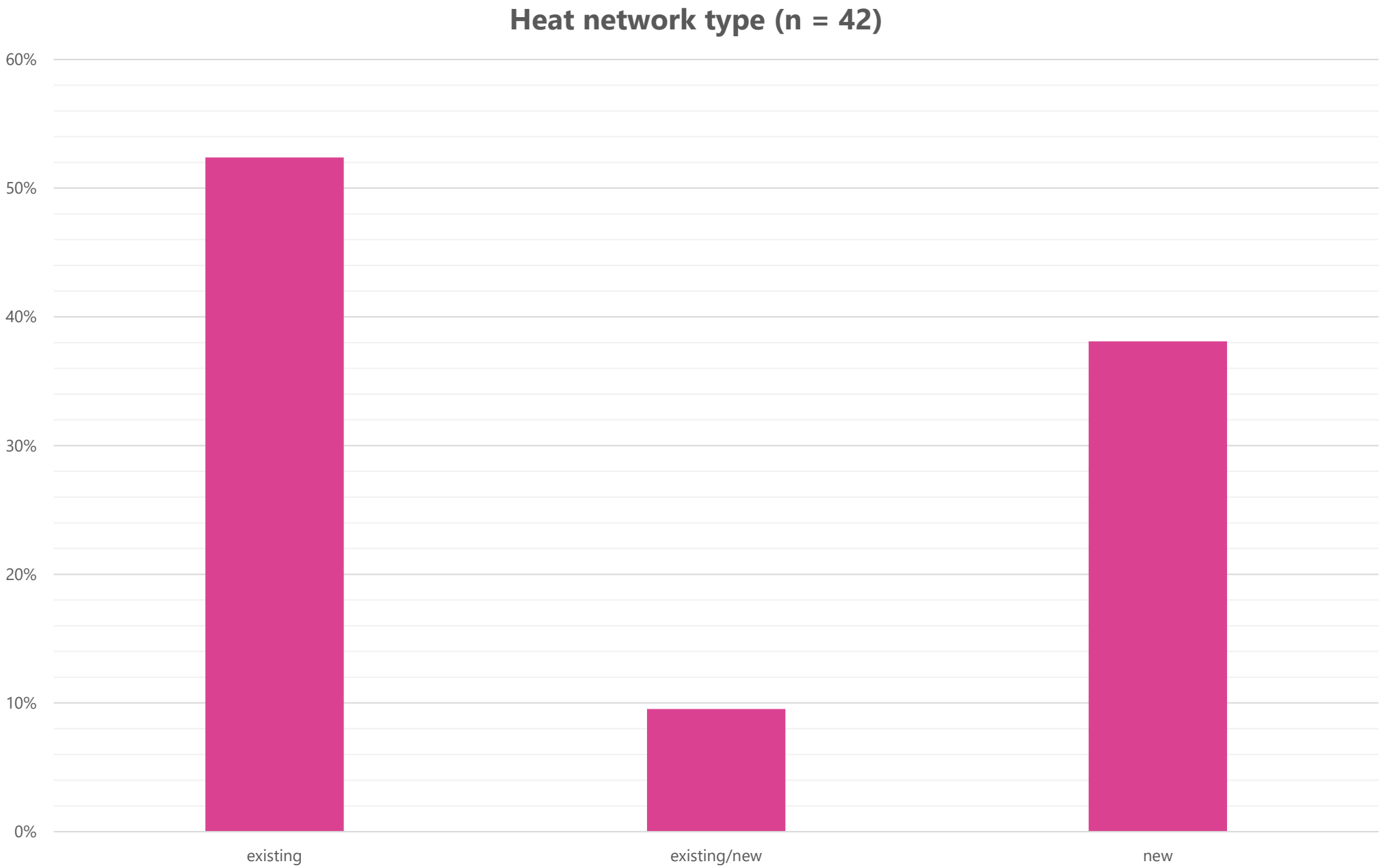

Distance [m] (n = 61)
40%
35%
30%
25%
20%
15%
10%
5%
0%
In the building
0 - 500 m
500 - 1500 m
> 1500 m

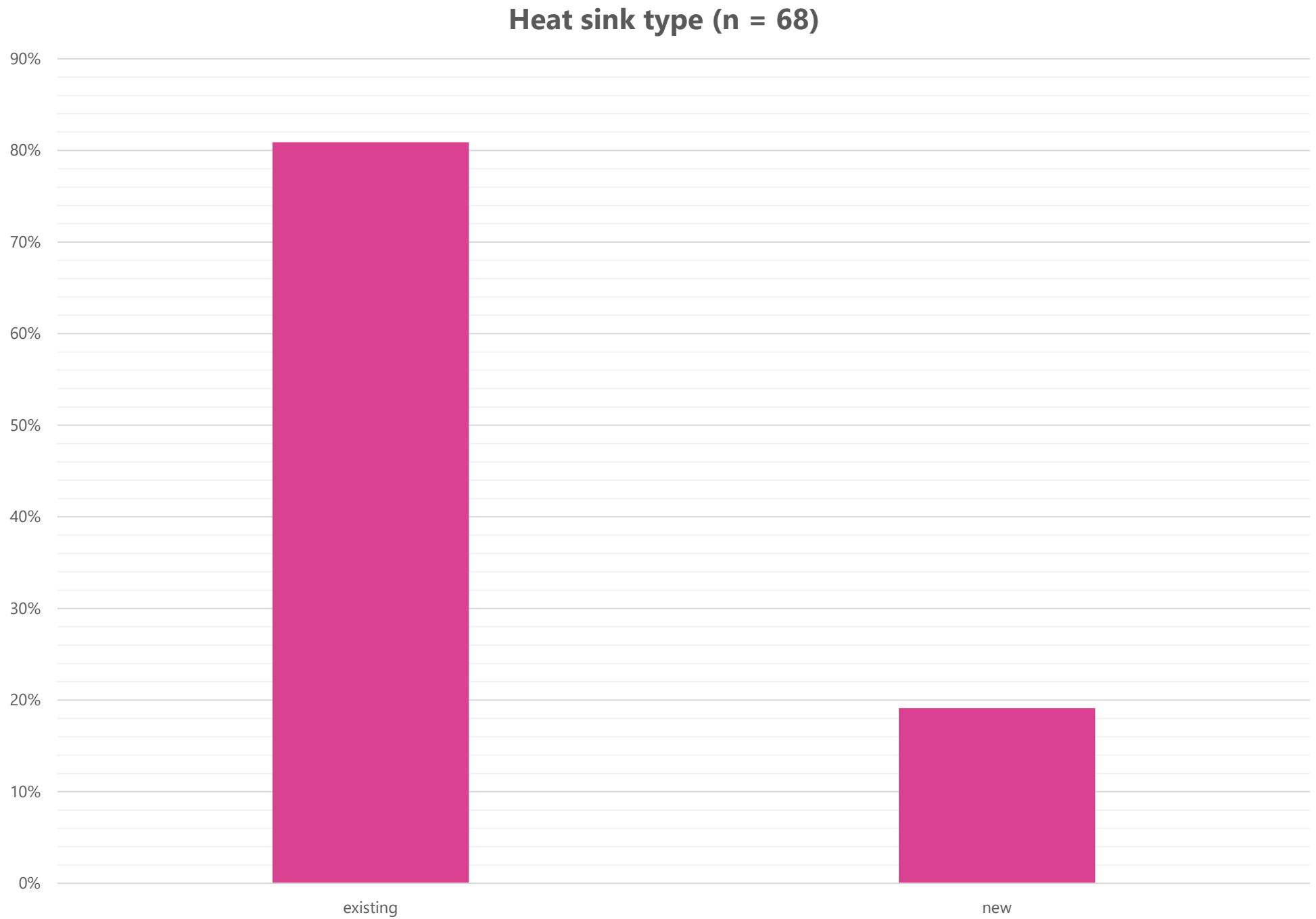

Temperature Difference (Sink - Source) [K] (n = 22)
35%
30%
25%
20%
15%
10%
5%
0%
< 0 K
0 K
0 - 20 K
20 - 40 K
40 - 60 K
60 - 80 K

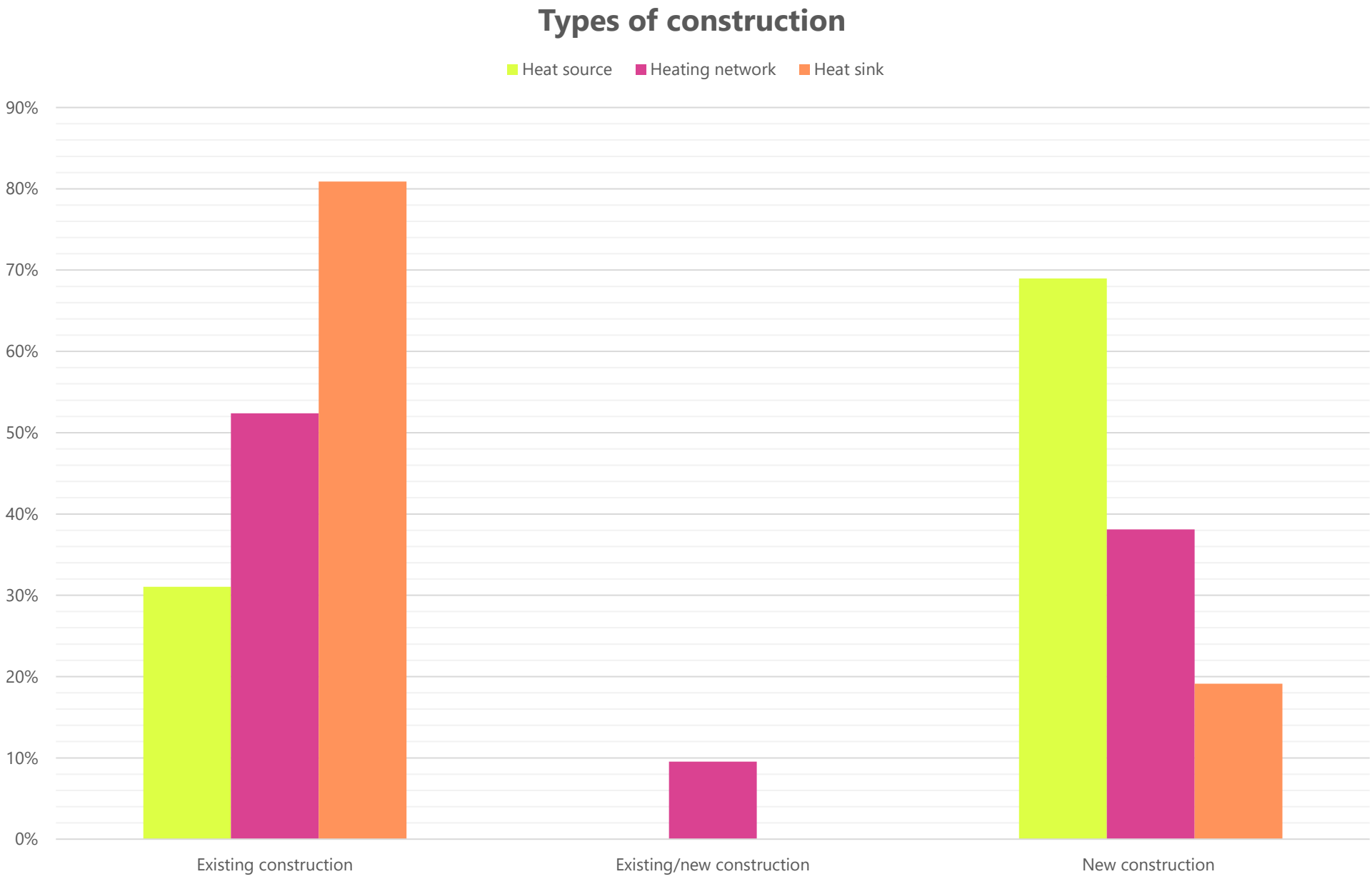

Technology (n = 141)
30%
25%
20%
15%
10%
5%
0%
Heat Pump
Direct Water Cooling
Heat Storage
Adsorption Chiller
Heat Exchanger
Low-temperature Grid
Other

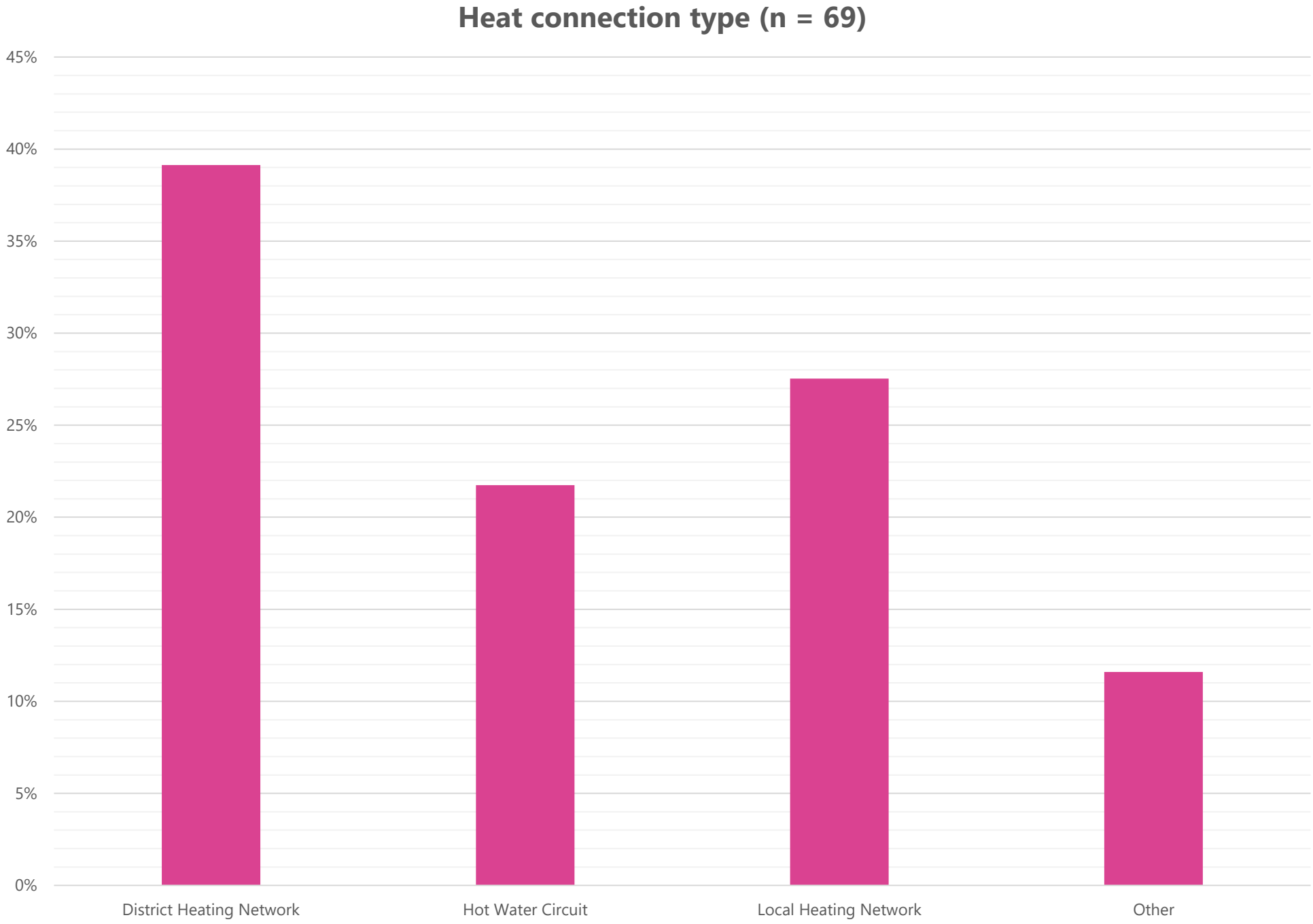

Waste Heat Utilization (n = 139)
60%
50%
40%
30%
20%
10%
0%
Agricultural use
Industrial use
Heating of buildings
Feeding into the heat grid
Other


Heat source type (n = 58)
80%
70%
60%
50%
40%
30%
20%
10%
0%
existing
new


Heat network type (n = 42)
60%
50%
40%
30%
20%
10%
0%
existing
existing/new
new


Heat sink type (n = 68)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
existing
new


Types of construction
Heat source
Heating network
Heat sink
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Existing construction
Existing/new construction
New construction


Heat connection type (n = 69)
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
District Heating Network
Hot Water Circuit
Local Heating Network
Other

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