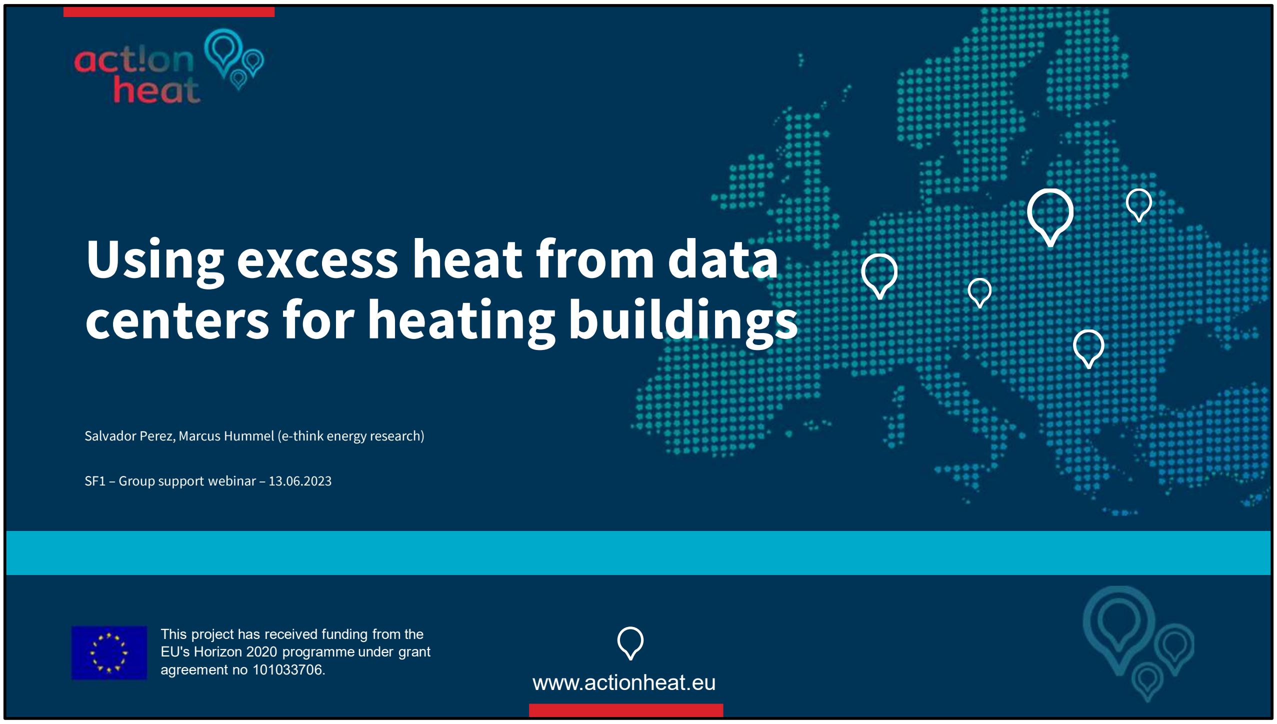

Webinar 5:
Using excess heat from data centers for heating bulidings

Act!onHeat SF1 Time: 1 h 11 min

- Serial 2:
  - Webinar 5
    - Strategical Heating & Cooling planning
    - Group support for municipalities and stakeholders
- Presented by:
  - e-think / Austria
  - TU-Wien / Austria

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- Discussion, Q&A (5‘)

Part II: How to reuse Datacenter Excess Heat

- Overview of technologies and concepts that can be used (20‘)
- Best practice examples (Technical and economic data) (15‘)
- Discussion, Q&A (10‘)

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Theoretical physical background

Part I - Datacenter Excess Heat: Introduction

This project has received funding from the EU's Horizon 2020 programme under grant agreement no 101033706.

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Datacenter background

Datacentre Excess Heat (EH) is the heat generated by the IT and HVAC equipment operating continuously without stopping nearly every day, consuming huge energy and producing very high thermal loads

- **Data centers** (DTC) will use almost **5% of global produced electricity** by 2025 (Andrae A, 2015) M0
- **DTC operates 24-7** and needs to be cooled because heat is generated by many different components
- The **annual growth** of DTC is projected to be in the range of **12-14%** per year (Cushman & Wakefield, 2023)
- It Is estimated that **68% of the excess heat in DTC can be recovered** (Huang et.al,2019) M1

Source: Andrae A., and Edler t. (2015) *On Global Electricity Usage of Communication Technology*
Cushman & Wakefield (2023) *Global Data Center Market Comparison Report*
Huang et. al., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems*

Why reuse the Excess Heat from Data Centers?

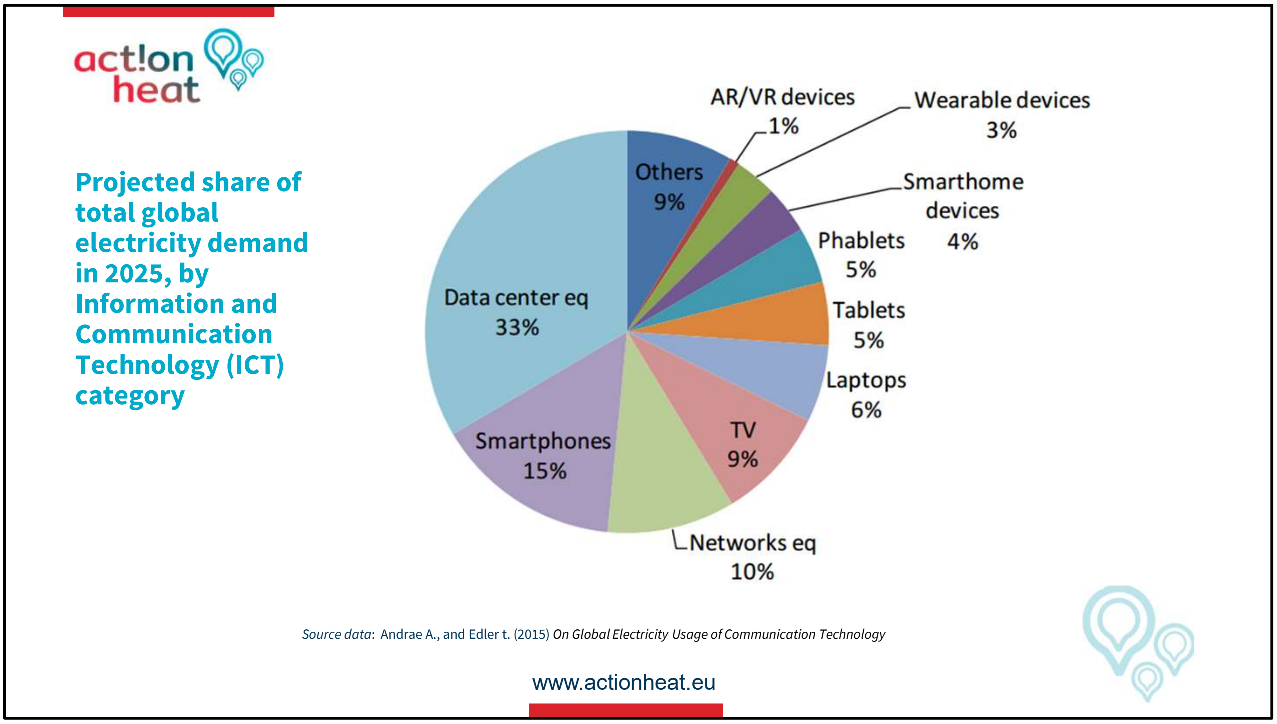
- Data centers will continue growing exponentially.
- The Data centers produce Excess Heat day and Night
- The Heat can be increased and reused for District Heating

Folie 4

M0 Source needed
Autor; 2023-06-09T12:40:32.908

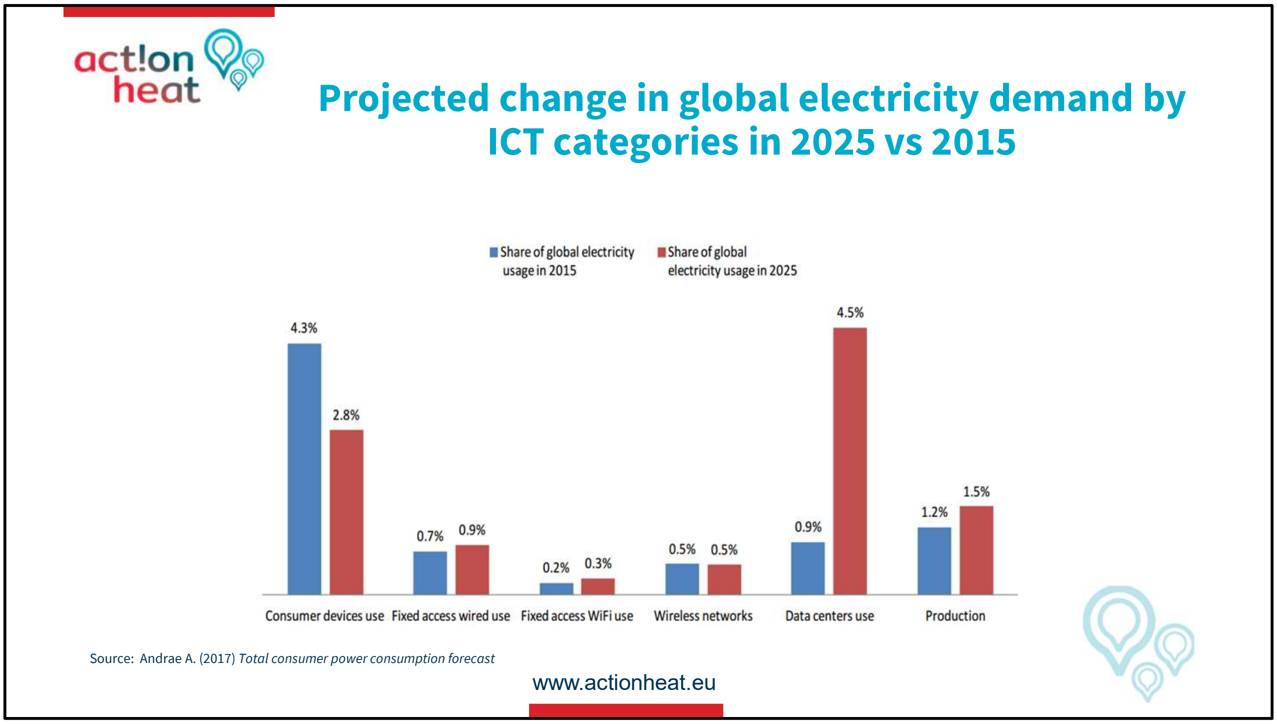
M1 What do other sources state?
Autor; 2023-06-09T12:51:22.471

M1 0 And: what are the restrictions that are taken into account in this estimation?
Autor; 2023-06-09T12:51:43.839



Datacenter DTC energetical demand by 2025

- Data centers are projected to consume 1/3 of all Information and Communication (ICT) global electricity demand by 2025
- ICT Information and Communications technology
- AR (Augmented reality) real-world and VR (Virtual reality) is entirely virtual.



Comparative projection of energetical demand in ICT

Information and Communications technology ICT comparative electricity demand by sectors

Global electricity demand by data centers is projected to increase +400% by 2025 (vs 2015)

- The blue lines represented the consumption by sector in 2015
- The red lines represent what the consumption will be by each sector in 2025

Data Center heat production: Standard vs High-performance Servers

Component	Temperature	Proportion of total heat
Microprocessors	85 °C	30%
DC/DC conversion	50 °C	10%
I/O processor	40 °C	3%
AC/DC conversion	55 °C	25%
Memory chips	70 °C	11%
Fans	30 °C	9%

Component	Temperature	Proportion of total heat
Disk drives	45 °C	6%
Motherboard	40 °C	3%
Microprocessors	85 °C	53%
DC/DC conversion	115 °C	13%
I/O processor	100 °C	10%
Memory chips	40 °C	14%

Source: ASHRAE whitepaper (2011). *Gaseous and particulate contamination guidelines for data centers*

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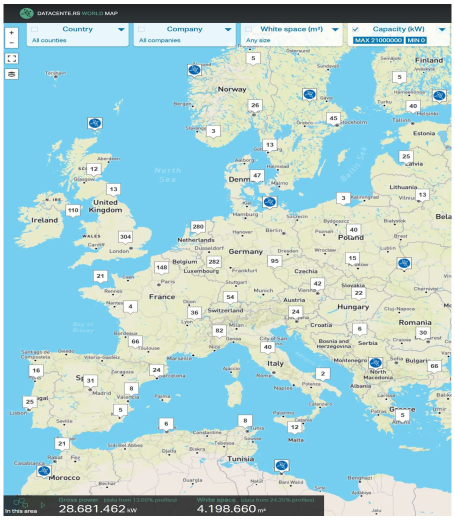
Heat demand temperature for different DTC components

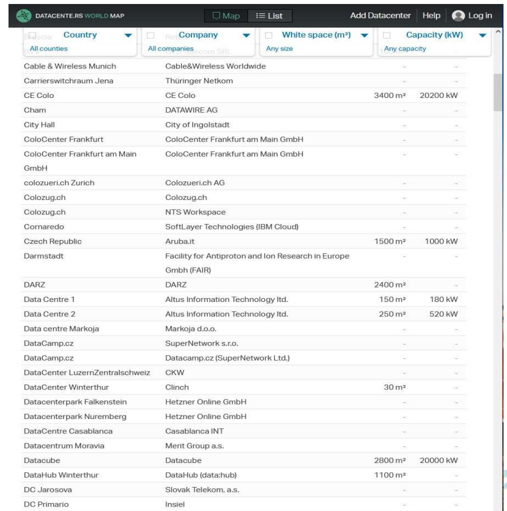
- The IT server racks have dif. temperature. Between Elect. Comp. (Dsk, MB, Mic)
- Consequently, the heat dissipation rates btw those Elec. Divs are different.
- The table summarizes the heat and temp. distribution of different components in standard and high-performance servers.
- Different types of servers dissipate dif. proportions of temp. and H densities
- Conventional DCs have Heat Dissipation Rates (HDR) in the range of 400 and 900 W/m^2, cubic meter
- With the development of compact and high-power modules in new DC the HDR has increased 10 times in ranges from 6,000 to 11,000 W/m^2
- The heat dissipated inside the DC should be removed by Cool. Sist.
- Therefore for dif. dissipation rates. Different Cool Sist and Tec. had been developed to reuse the EH from DTC

Folie 7

M0 Total of heat shares sums up to more than 100% --> why is this the case?
What exactly does the proportion of heat mean
Autor; 2023-06-09T12:35:00.452

Datacenters World Map





Country All counties	Company All companies	White space (m²) Any size	Capacity (kW) Any capacity
Cable & Wireless Munich	Cable&Wireless Worldwide	-	-
Carrierswitchraum Jena	Thüringer Netkom	-	-
CE Colo	CE Colo	3400 m²	20200 kW
Cham	DATAWIRE AG	-	-
City Hall	City of Ingolstadt	-	-
ColoCenter Frankfurt	ColoCenter Frankfurt am Main GmbH	-	-
ColoCenter Frankfurt am Main GmbH	ColoCenter Frankfurt am Main GmbH	-	-
colozueri.ch Zurich	Colozueri.ch AG	-	-
Colozug.ch	Colozug.ch	-	-
Colozug.ch	NTS Workspace	-	-
Cornaredo	SoftLayer Technologies (IBM Cloud)	-	-
Czech Republic	Aruba.it	1500 m²	1000 kW
Darmstadt	Facility for Antiproton and Ion Research in Europe Gmbh (FAIR)	-	-
DARZ	DARZ	2400 m²	-
Data Centre 1	Altus Information Technology ltd.	150 m²	180 kW
Data Centre 2	Altus Information Technology ltd.	250 m²	520 kW
Data centre Markoja	Markoja d.o.o.	-	-
DataCamp.cz	SuperNetwork s.r.o.	-	-
DataCamp.cz	Datacamp.cz (SuperNetwork Ltd.)	-	-
DataCenter LuzernZentralschweiz	CKW	-	-
DataCenter Winterthur	Clinch	30 m²	-
Datacenterpark Falkenstein	Hetzner Online GmbH	-	-
Datacenterpark Nuremberg	Hetzner Online GmbH	-	-
DataCentre Casablanca	Casablanca INT	-	-
Datacentrum Moravia	Merit Group a.s.	-	-
Datacube	Datacube	2800 m²	20000 kW
DataHub Winterthur	DataHub (data:hub)	1100 m²	-
DC Jarosova	Slovak Telekom, a.s.	-	-
DC Primario	Insiel	-	-

Source: www.datacente.rs

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Some DTC localization and information

The World Map of Datacenters internet site shows some Information about the company like:

- Name of the Datacenter
- Size of different data centers
- Capacity of different DTC around the EU

For the participants of the Webinar, it will be possible to find one in their regions.

Political Landscape

Part I - Datacenter Excess Heat: Introduction

This project has received funding from the EU's Horizon 2020 programme under grant agreement no 101033706.

Political Landscape:

- **According to** the revisions of the **EED and RED**:
  - **DTC with more than 1 MW** total rated **energy input** will need a cost-benefit analysis of **using the Excess Heat.** (EED) M0
  - The use of Excess Heat for district heating will **need to increase from 1% to 2.1% per year** (RED)
- Advantages of using excess heat from DTC:
  - **Most DTC** infrastructures are **located near urban areas** (Oró et.al, 2019).
  - The excess heat of data centers can be **used to heat buildings**.

Source: EED *Energy Efficiency Directive* recast proposal by the COM 2023 – Article 24, paragraph 4
RED *Renewable Energy Directive.* Package "Fit for 55", directive 2018/2001/EU Article 24, 9b
Oró, Taddeo, und Salom, (2019) *Waste Heat Recovery from Urban Air Cooled Data Centres to Increase Energy Efficiency of District Heating Networks*

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According to the revision of the Energy Efficiency Directive EED and the Renewable Energy Directive a RED for the 'Fit for 55' package, two legislative policies will affect data centers and their excess heat recovery and may indirectly promote heat recovery for DC.

One of the revisions requires that DTC with more than 1 MW total rated energy input need to do a cost-benefit analysis of using the Excess Heat,

Unless they can prove that it is not technically or economically possible, this proposal will be mandatory for the future construction of data centers.

Additionally, the proportion of excess heat in district heating and cooling should increase from 1% to 2.1% per year, pushing district heating companies to look for additional excess heat sources.

In September 2022, the European Parliament adopted the two revisions, and the European Council is still considering both. It is expected that adoption by the EC will happen by the end of this year. Once the EU has adopted them, a deadline will be set by which each member state must have incorporated the directives into national law.

Folie 10

M0 Would be interesting to see the exact formulation of the paragraph in the EED recast --> also cite article

Autor; 2023-06-09T13:09:09.422

EU working on!

Countries with active or proposed initiatives to **promote heat recovery from data centers.**

	Denmark	Norway	Netherlands	Germany
Regulatory initiatives and proposals	Removal of tax on excess heat New price regulation on excess heat	Requirement for planned data centres above 2 MW to assess the potential to utilize excess heat	Data centres must explore the use of excess heat for heating nearby homes	Draft of the Energy Efficiency Act: Mandatory reuse of 30% and (later) 40%
Political focus on excess heat	✓	✓	✓	✓
Proposed DC heat recovery regulation	✗	✓	(✓)	✓
Example of excess heat recovery	Meta's data centre in Odense is suppling excess heat to 7,000 households	Excess heat recovery in Hima Seafood's trout farm (world's largest trout farm)	NorthC data centre south of Amsterdam	Pilot project on excess heat recovery in Frankfurt to supply 1,300 apartments

Source: https://www.ramboll.com/sv-se/extract-heat-from-data-centres/will-data-centers-be-required

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European political initiatives by country

Denmark removed taxes on EH from electrical processes to promote the recovery of EH from DTC and other electrical-based industries. Furthermore, a new price regulation on EH removes taxes to supply it to DH networks. Nevertheless, there are not yet any requirements in Danish law to recover the EH from DTC.

Norway is processing a low-to-require DTC with more than 2 MW capacity to reuse its EH for DH unless they prove it is not technically or economically possible. Additionally, the government has created a map of distribution stations to assist DTC in finding a spot to connect its EH to the DH network.

Netherlands developed new policy measures that required DT to explore using EH for heating nearby homes. At the beginning of 2022, the government announced it is working on new rules to control the construction by area of new hyper-scale DC.

German government drafted a legal framework in 2023 for DC, which, in addition to strict demands on energy consumption, includes mandatory reuse of EH. It is specified that 30% of the EH from DC that starts operations in January 2025 and 40% that starts operations in January 2027 must be reused.

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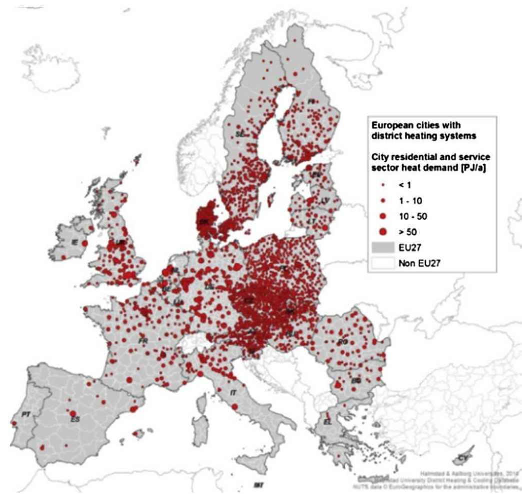
District heating networks

Country	Supply Temperature [°C]	Return Temperature [°C]
Denmark	70	40
Finland	70	40
Germany	80	60
Spain	90	70

Examples from the International Energy Agency of standard operational temperatures in European district heating networks (Skagestad & Mildenstein, 2018)

M0



Source: Oró, Taddeo, und Salom, (2019) *Waste Heat Recovery from Urban Air Cooled Data Centres to Increase Energy Efficiency of District Heating Networks*

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Existing H&C networks to connect data centers

Actually, it is a trend to develop low-temperature DH networks. Nevertheless, the most common DH networks are "high-temperature".

- On the left side, the table shows the standard temperature operation of some DH networks in Europe. Explain
- On the right side, the map shows that DH systems are widely spread around Europe.

Folie 12

M0 Link does not work

Autor; 2023-06-09T13:12:11.403

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DTC in Act!on

Examples of **locations using excess heat** from data centers to **heat buildings** and homes, through district heating networks

Company	Year	Location	Excess heat reuse?
Tieto	2011	Espoo, Finland	1 500 detached houses
Telecity Group	2013	Helsinki, Finland	4 500 apartments
Yandex	2015	Mämtsälä, Finland	1 000 private houses
Ericsson	2016	Kirkkonummi, Finland	1 000 single homes
Facebook	2019	Odense, Denmark	7 000 homes
Veolia	2019	Braunschweig, Germany	600 households
Telia Company	2022	Helsinki, Finland	20 000 single homes
Bahnhof	2030	Stockholm, Sweden	30 000 households

Sources: Huang u. a., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems*
Wahlroos u. a., (2018) *Future Views on Waste Heat Utilization – Case of Data Centers in Northern Europe*

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Datacenters supplying buildings

The table shows successful examples of data centers supplying buildings and households with their Excess Heat around Europe.

Over the last ten years, data centers have increased in capacity and size. Therefore, the potential to distribute excess heat for district heating has increased by more than 100 per year, as can be seen in the table.

Discussion, Q&A

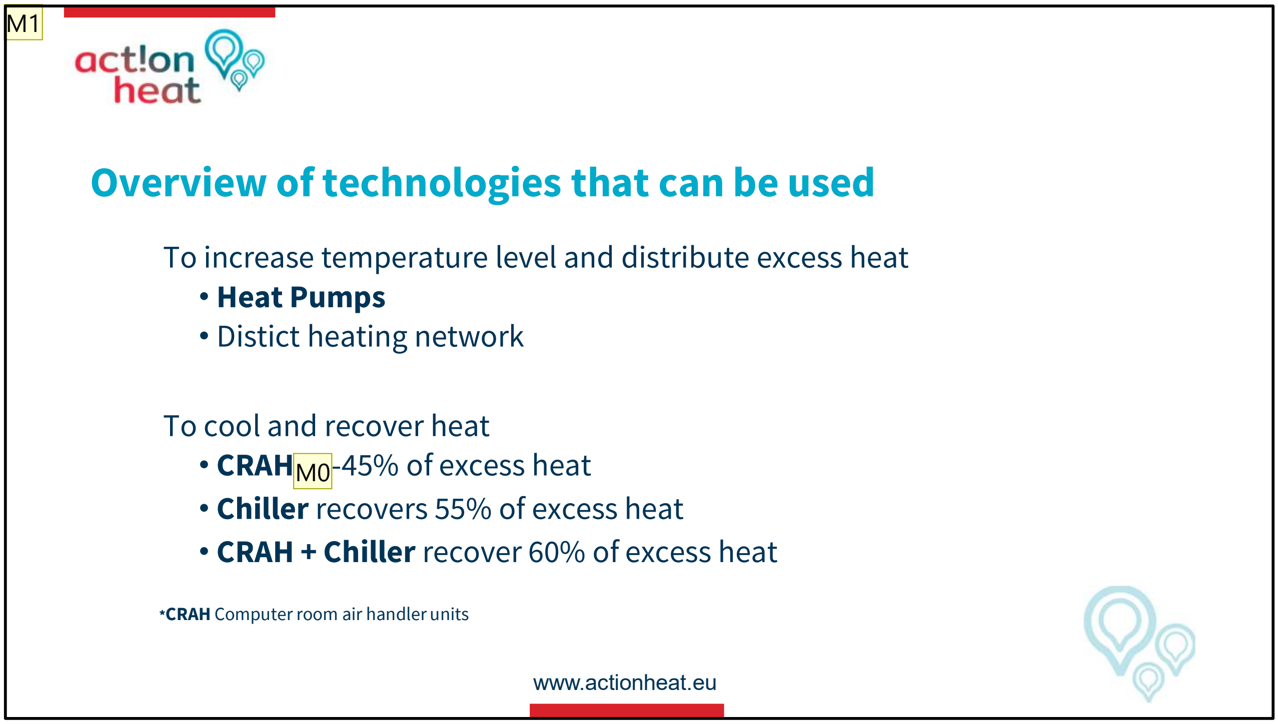
Part I - Datacenter Excess Heat: Introduction

This project has received funding from the EU's Horizon 2020 programme under grant agreement no 101033706.

Overview of technologies

Part II - How to reuse Datacenters Excess Heat

This project has received funding from the EU's Horizon 2020 programme under grant agreement no 101033706.



The EH from data centers requires a heat pump.

Heat pumps are the best solution to reuse the low temperature of EH for district heating, increasing the low water temperature to be distributed in the DH network.

Now speaking about heat recovery, the best place to recover EH in DTC is after or before the cooling system. CRAH and Chiller are the most common cooling systems.

For example (CRAH) or Computer room air handler units are primarily used in medium-big size data centers (>100 kW).

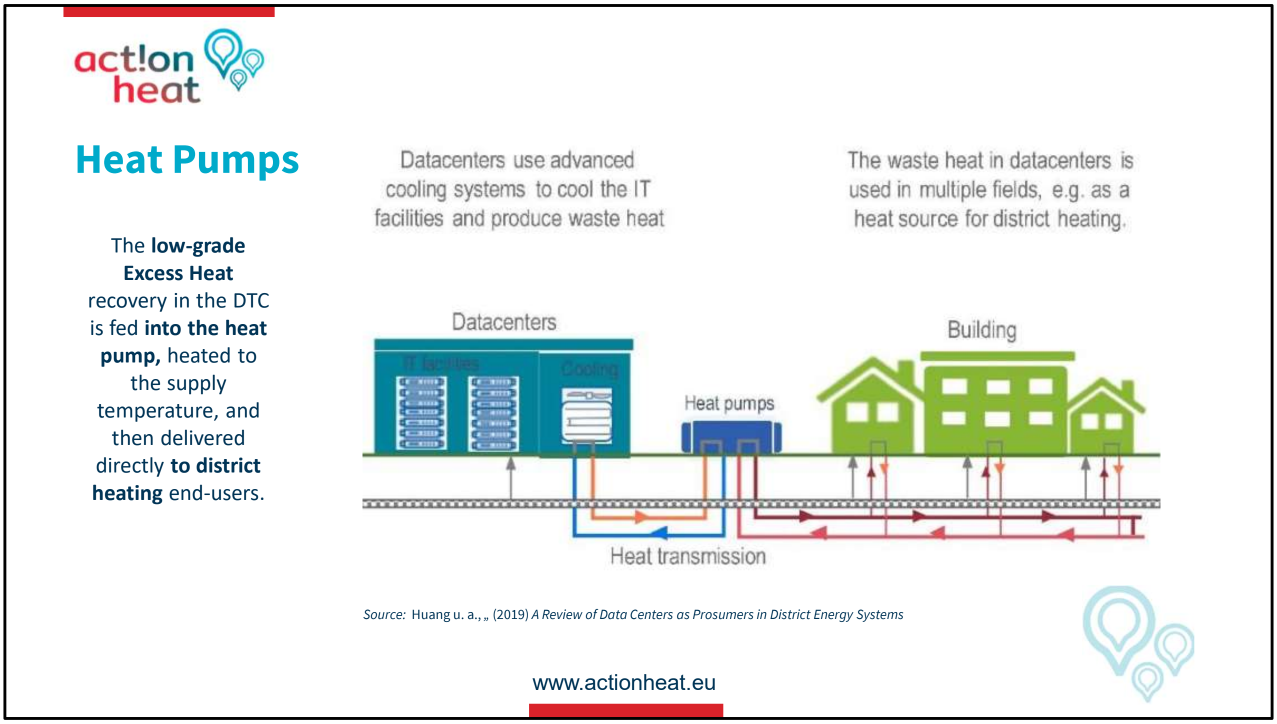
Nevertheless, the absorption chiller is the most promising passive cooling technique for recovering heat.

Folie 16

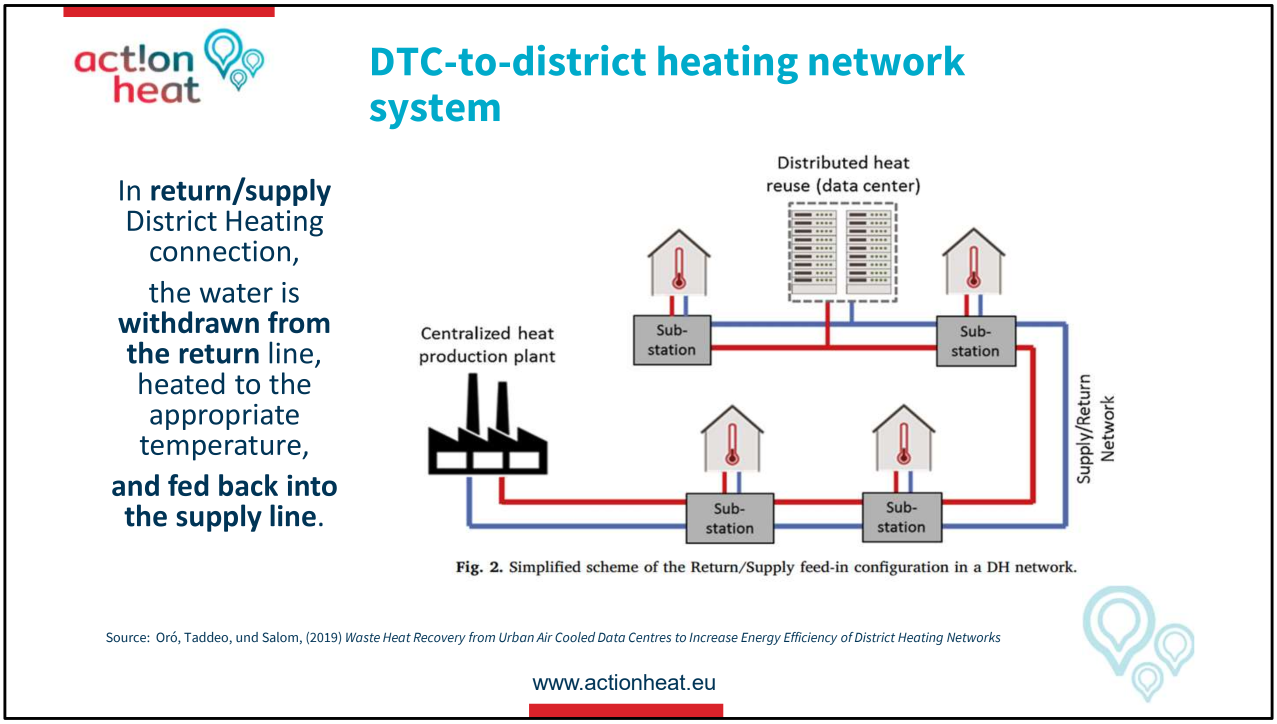
M0 Abbreviation needs to be written / introduced somewhere
Autor; 2023-06-09T13:18:19.231

M1 Re fre
Ger ator
Autor; 2023-06-10T18:51:16.329

M1 0 Cooling system
Autor; 2023-06-10T18:59:16.162



Heat pumps are the best solution to reuse the Excess Heat for district heating because heat pumps are made to work with low- temperatures rates. Therefore, we do not recommend another technic to reuse the Heat for building use.



Different connections to district heating

Exist four different ways to connect and distribute heat reuse from data centers to a DH network (i) return/supply, (ii) return/return, (iii) supply/return, and (iv) supply/supply.

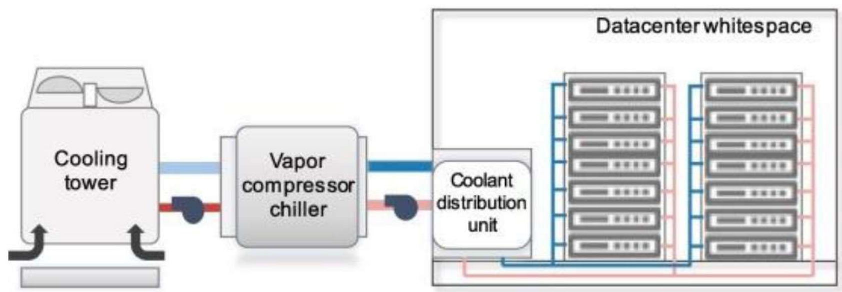
The most beneficial system for DTC is the return/supply solution.

In this configuration, the water is withdrawn from the return line, heated to the set temperature, and fed back into the supply line. This feed-in configuration does not affect the return line temperature.

In addition, supplying the DTC excess heat close to the consumers reduces the heat loss in both lines due to the lower mass flow rate circulating in the entire loop. This is reflected in reducing the heat power requirement from the heat pump and, therefore, the distribution prices in the hold network.

Excess Heat recovery from water

In **water-cooled systems**, the temperature of water is at the highest when exiting server racks (**75–80 °C** maximum). Thus, the optimal location to recover excess heat is **where the water exits the server racks**. This can be done by adding a water-to-water heat exchanger.



Source: Huang u. a., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems*

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Water cooler system for DTC

In water-cooled systems, the water temperature is at the highest on the exit for the server rack (75–80 °C maximum). So, there is the optimal location to recover excess heat. This can be done by adding a water-to-water heat exchanger.

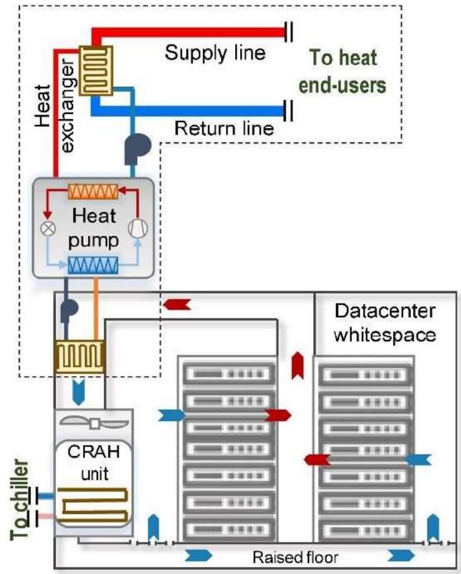
It is essential to mention that most of the existing DTCs have air cooling systems because of installation costs.

The water cooling systems are costly because the water needs to flow close to the electronic components.

This system is best for small DCs.

Excess Heat recovers from CRAH

In **air-cooled** systems, the **optimal location** to capture excess heat is at the **rack room exit (35–45 °C),** before mixing with room temperature air



Source: Huang u. a., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems*

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Air cooler system

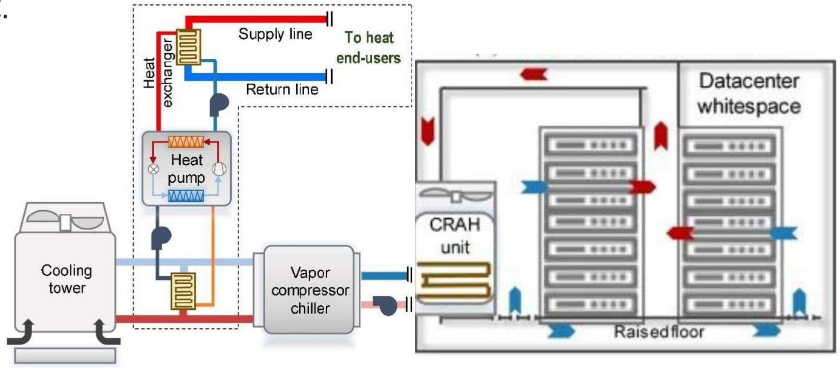
The optimal location to capture EH in air-cooled systems is at the exit point of the rack room (35–45 °C). In the diagram, this is at the top-left point. Here is where to connect the HP before mixing with room air temperature to prevent energy loss.

At this point, a water-to-air heat exchanger must be installed.

In the heat exchanger, the low-grade water is fed into a heat pump, where the water temperature is upgraded to the required level for use by the DH network.

Excess Heat recovery from Chiller

In air-cooled systems, it is also possible for heat recovery following the **chiller condenser** systems, using a water-to-refrigerant heat exchange installed in parallel with the condenser (or dry cooler) of the chiller. The temperature can reach up to 50 °C.



Source: Huang u. a., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems*

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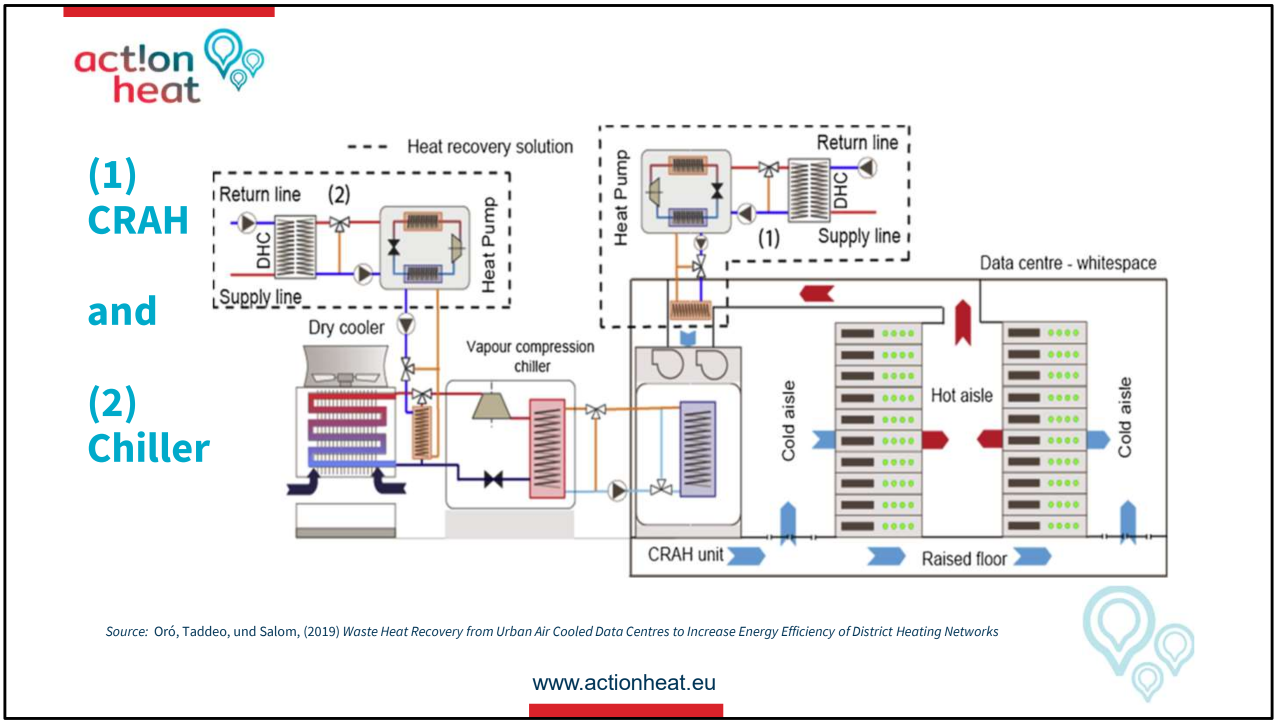
Air cooler to water

Another option to recover excess heat is the chiller condenser, which applies to air and water-cooled systems.

For heat recovery from the chiller, a water-to-refrigerant heat exchange is installed in parallel with the chiller’s condenser (or dry cooler).

Part of the heat produced by the chiller passes into the surrounding environment, and the remaining heat is captured by a secondary water circuit. The temperature can reach up to 50 °C.

Here, the low-grade water from the chiller is fed into a heat pump, where the water temperature is upgraded to the required level for use by the DH network.

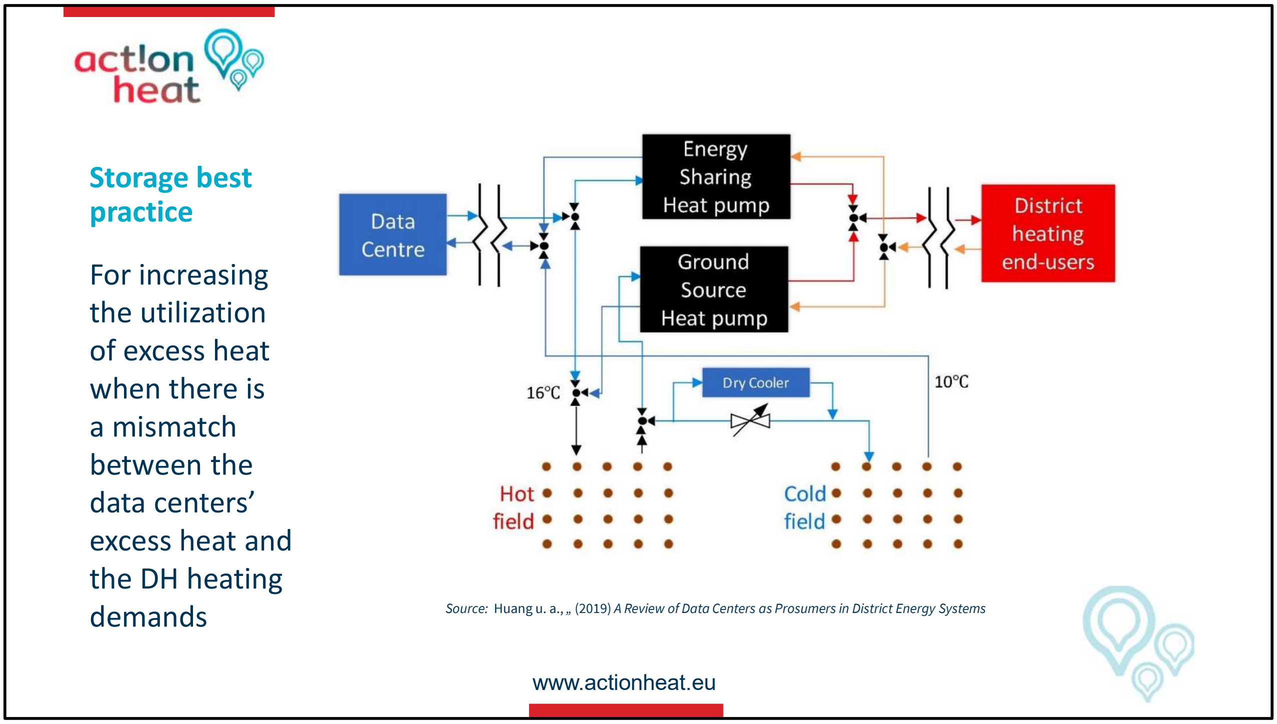


Combination of cooling systems

Air-cooled systems are the most common cooling systems in existing data centers.

They typically arrange server racks into cold areas and hot areas. The cooled areas carry cool air to each server, while the hot air exits the servers in the hot aisled area.

In general, the best option to optimize the use of excess heat in this system is to use two Heat pumps, one at the rack room exit point and the other after the condenser of the vapor-compression chiller.

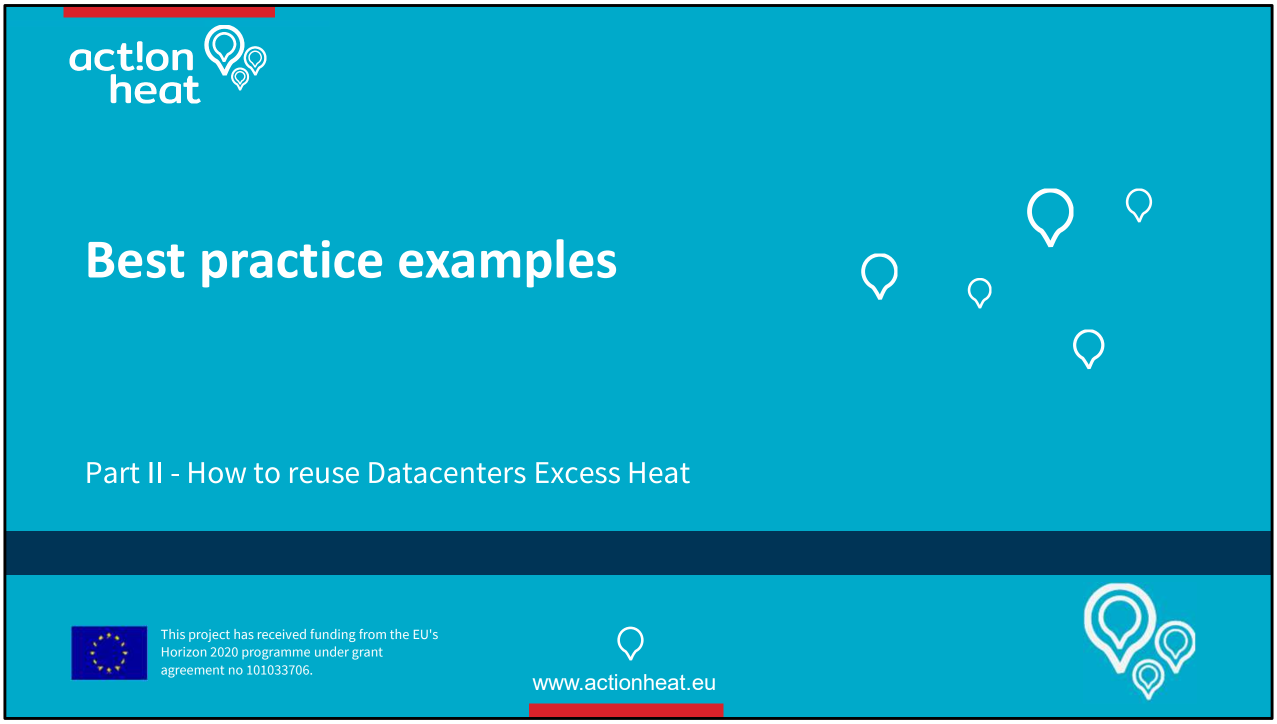


Possible extra adaptations to the cooling system

To increase excess heat utilization when there is a mismatch between the DC excess and the DH demands, a ground source heat pump and a bore field can be integrated into the system.

In this case, the ground source heat pump will operate in cooling/heating mode to control the temperature. The bore field acts as a large thermal energy storage to alleviate the mismatch. Typically, more than one heat pump is required to manage temperatures between all system parts. Therefore, it is recommended to install two heat pumps.

Finally, to improve the ground source heat pump heating efficiency and provide free cooling for the DTC, an additional bore field can be added. In that case, one bore field acts as a 'hot' thermal storage, and the other as a cold thermal storage.



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Best practice examples
Part II - How to reuse Datacenters Excess Heat
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Excess heat recovery in DTC in Act!on

Company	Location	IT load capacity	Cooling technology	Excess heat reuse	Estimated excess heat reused / recovered	Nr. Of buildings supplied by the excess heat
Telecity Group (5 locations)	Helsinki, Finland	7 MW (2 MW with excess heat reuse)	District cooling	District heating	unknown	4 500 apartments 500 detached houses
Telia Company	Helsinki, Finland	24 MW	Unknown	District heating	200 GWh/a	Unknown
Bahnhof (3 locations in operation, 1 under construction)	Stockholm, Sweden	3 MW (21 MW under construction)	Heat pumps	District heating	600 kW (Pionen) 500 kW (St Erick) 1 500 kW (Thule)	Unknown
Tieto	Espoo, Finland	2 MW	Heat pumps	District heating	30 GWh/a	1500 detached houses
Yandex	Mäntsälä Finland	10 MW	Free cooling	District heating	20 GWh/a	1 000 detached houses
Meta	Odense Denmark	Unknown	Heat pumps free cooling	District heating	25 MW, 100 GWh/a	6 900 homes

Sources: Huang u. a., „ (2019) *A Review of Data Centers as Prosumers in District Energy Systems.*
Wahlroos u. a., (2018) *Future Views on Waste Heat Utilization – Case of Data Centers in Northern Europe.*

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When analyzing the table, it is important to consider several factors:

IT capacity refers not only to the computing power of the systems and the support staff but also to the capacity designed in the plan, which may not always be fully utilized.

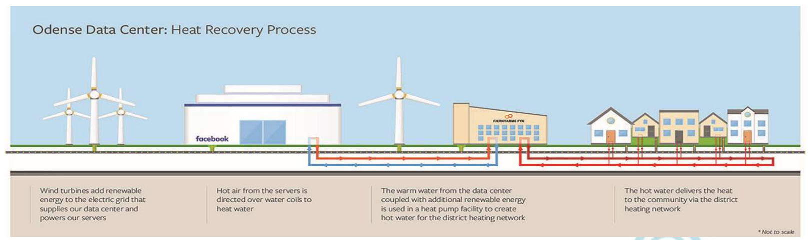
If excess heat from a Data Center (DTC) is used for district heating, the temperature needs to be increased using a heat pump. The efficiency of this process is determined by the Coefficient of Performance (COP) of the heat pump.

In the table, the 20 MW supplied to the network does not indicate that the entire amount is solely from excess heat. Due to the heat pump, the actual amount of usable heat will be lower, as the heat pump efficiency reduces the output.

Additionally, when evaluating examples of heat pumps used in district heating systems, it’s important to recognize that the COP can vary, especially if the heat pump is also used for cooling the network.

Facebook – Odense, Denmark

- Organisations involved:
  - Data center operator: Meta (Facebook) – supply of excess heat for free
  - DH operator: Fjernvaerme Fyn – took all investment
- Heat recovery:
  - 176 cooling units on the roof of the data center
  - Water is heated from hot air in the coils
- Reused heat:
  - Up to 25 MW
  - 100 GWh/a
- Start of operation: 2023



Source: https://tech.facebook.com/engineering/2020/7/odense-data-center-2/
https://www.datacenterdynamics.com/en/news/metafacebook-to-expand-odense-data-center-campus-in-denmark/

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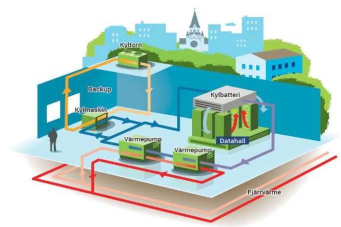
A recent example of heating reuse

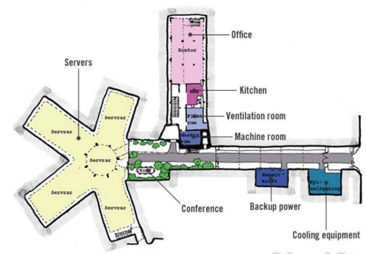
The business model there is that the operator takes all the investment, and Facebook does not receive anything from the income of the use of Excess Heat for district heating.

The reuse of the energy in the system works with heat exchangers on the top of the roof in the building through recovery metal pipes and sent to the Heat Pumps to be increased and sent to the district heating network.

Banhof Thule – Stockholm, Sweden

- Organisations involved:
  - Data center operator: Banhof Thule
  - DH operator: Fortum Värme AB
- Installed capacity:
  - Cooling: 1.2 MW
  - Heating: 1.6 MW
- Temperatures:
  - District cooling delivered at approx. 5.5°C
  - District heating delivered at approx. 68°C
- Investment costs:
  - 0.53 MEUR for the cooling system (3 heat pumps, pipe installation, electrical work and control equipment, data collection and construction)
  - 0.26 MEUR for expansion of DH grid
- Start of operation: 2014





Source: https://www.euroheat.org/resource/open-district-heating-in-stockholm-sweden.html
www.oppenfjarrvarme.se
Wahlroos u. a., (2018) *Future Views on Waste Heat Utilization – Case of Data Centers in Northern Europe.*

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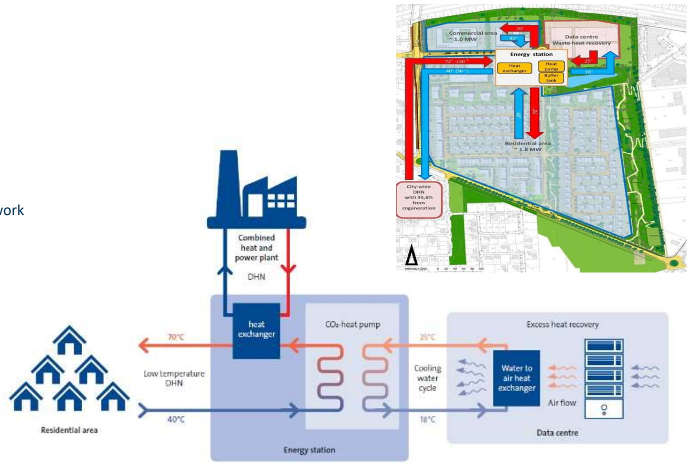
Data center added to existing DH network

The Bahnhof Tule data center is one of several DTC the Stockol heating and cooling network has. becaues they have an open network, and it is possible to be integrated into the grid by advice and discussion with the operator.

With 3 heat pumps deliver district heating with almost 70 degrees. The installation cost is also divided between heating and cooling, where the first investment cost is more becaues the pumps and then a second expansion phase to the network was added to the grid and started to work in 2014.

Veolia – Braunschweig, Germnay

- Organisations involved:
  - Data center operator: ??
  - DH operator: Veolia Deutschland / BS | Energy
- Local district heating network:
  - New network for newly constructed buildings
  - Excess heat from data centers to supply base load
  - Peak load supplied by existing high temperature network
  - Heat storage of 6 m³
  - Peak load 1.8 MW
- Temperatures:
  - DH system: 70/40°C flow/return
  - Data center excess heat: 25/18°C before/after HP
- Excess heat recovery:
  - 1.75 GWh/yr
  - Supply for 600 housing units
  - COP Heat pump 3.6
- Start of operation: 2019



Source: https://www.euroheat.org/resource/excess-heat-recovery-from-data-centre-in-braunschweig-germany.html
ReUseHeat – Excess heat recovery from data centre in Braunschweig, Germany – Project Factsheet

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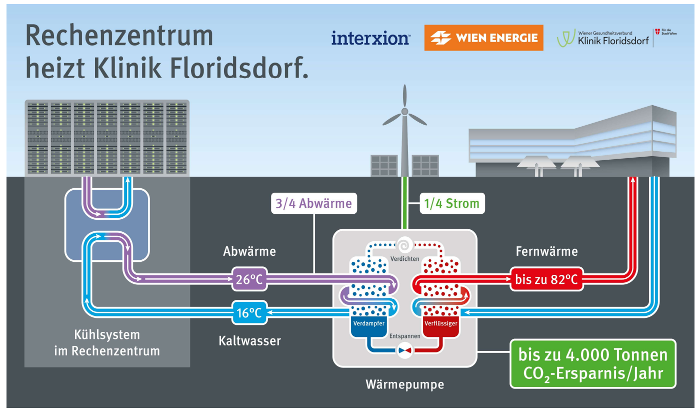
The data center was built, and nearby construction of houses was built.

The district heating operation operates the complete district heating in Braunschweig, with a high-temperature district heating.

Therefore they built a separate district heating network with low-temperatures to supply the house with storage capacity.

Interxion – Wien, Austria

- Organization involved:
  - Data center operator: Interxion
  - DH operator: Wien Energie
- Installed capacity:
  - Cooling: 2.1 MW; around 120 k Servers
  - Heating: 3 MW; 50-70% of heat demand of the hospital should be supplied by the excess heat from the data center
- Temperatures:
  - DH systems: up to 82°C flow temperature
  - Date center excess heat: 25/18°C before/after HP
- Investment costs:
  - 3.5 MEUR
- Start of operation: 2023



Source: https://klinik-floridsdorf.gesundheitsverbund.at/rechenzentrum-heizt-ab-2023-die-klinik-floridsdorf/
https://wien.orf.at/stories/3153437/

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Example of Vienna

- The data center is only connected with a Hospital.
- It is a small project that supplies 70 percent of the hospital.
- The system heat and cool the hospital; therefore, the COP is high.
- Is in the final face of construction and will operate soon.

Discussion, Q&A

Part II - How to reuse Datacenters Excess Heat

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