OPEN Compute Project

DATA CENTERS HEAT REUSE 101

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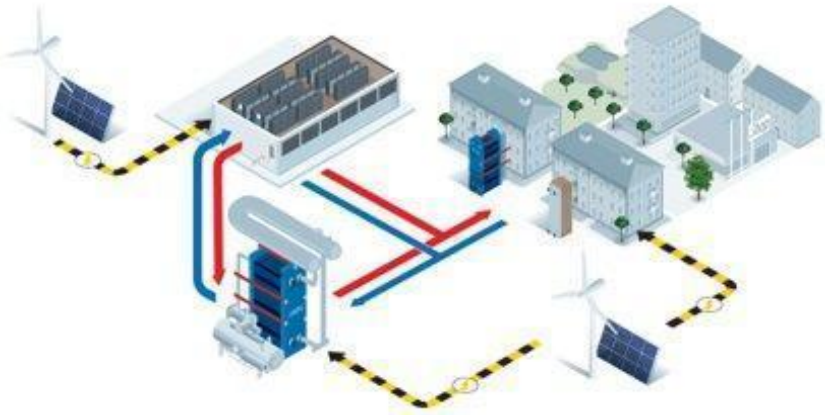

Executive Summary

Heat reuse will be a key component of sustainability for data center companies. After a couple of use cases in some concrete geographical regions and applications, we are seeing that this topic is getting momentum in the industry due to recent legislative initiatives and corporate policies seeking ambitious sustainability goals, propitiated partially by the latest geopolitical circumstances. The never-ending digitalization path will require more infrastructures and more power consumption which will need to be as carbon neutral as possible, as society demands. Heat reuse arises as a chance to increase the energy efficiency in the data center business while improving the conditions of the heat host, triggering intersectoral symbioses. A project of this kind means no small challenges to be addressed since its conception as well as the involvement of a wide list of potential stakeholders, and its results will not only be financially positive but result in societal positive impacts. Further resources will be helpful to support this movement, such as checklists, maps, techno-economic calculations, where the OCP Heat Reuse subproject is and will remain active.

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Introduction

This is the first of a series of resources that the Open Compute Project Foundation Heat Reuse group will publish. In this article we will describe why now is the time for heat reuse and what is needed for wide-scale adoption to turn heat from a liability into an asset that potentially can be a source of income and assist in meeting sustainability goals.

The Open Compute Project Foundation is an open forum, so please join our bi-weekly conversations about heat reuse and share your thoughts, insights and experiences with the community, start with the following link:

https://www.opencompute.org/projects/heat-reuse

Why heat reuse and why now

Almost 100% of the energy used by servers in a data center is turned into heat. Heat reuse is defined as the beneficial use of any recovered heat from the data center. In theory, 100% of the energy employed in a data center can be captured and reused (see Figure 1). The excess heat is not only originated at the IT equipment but also from the losses of the power facility and the thermodynamic processes of cooling machines.

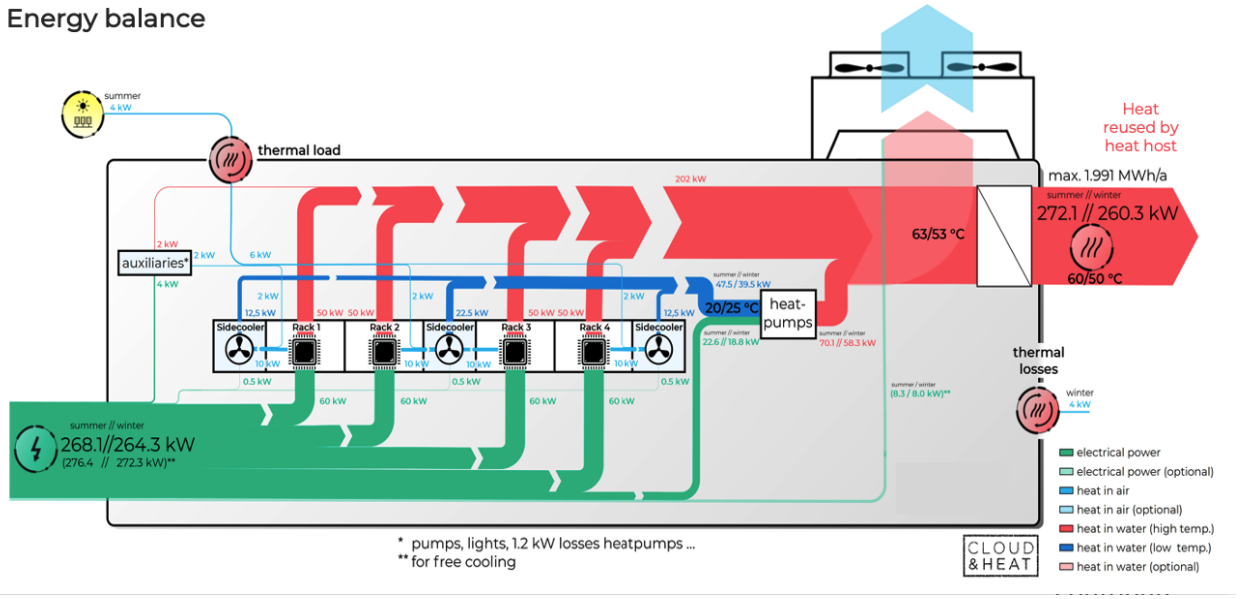

Figure 1- Exemplary energy balance in a data center

Data center heat reuse has been around for over 10 years and there are already many cases worldwide. We have started researching these use cases around the world and ended up putting a map together with the locations of the data centers where there is any heat reuse concept in place. See snapshot of this map (from November 2022) in Figure 2.

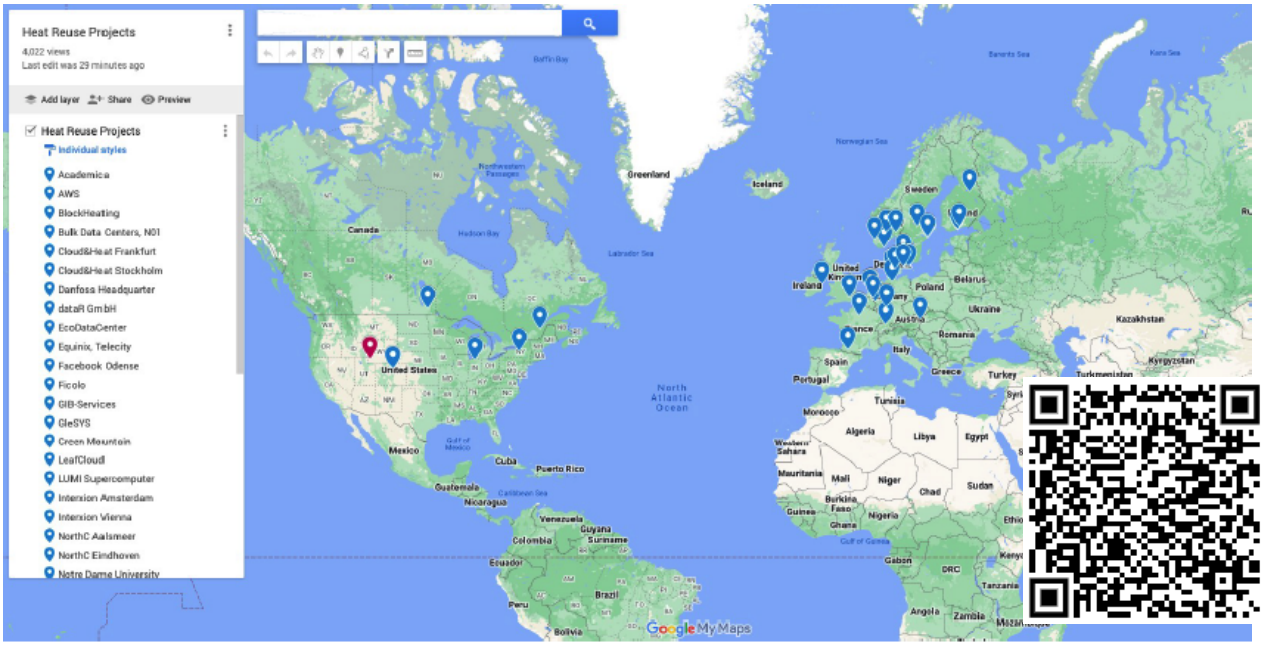

Figure 2 - November 2022 snapshot of the Heat reuse projects map

https://www.google.com/maps/d/viewer?mid=1bTp4Ugy7FGwfPadNlmfZpYwGY5Z5B7o&ll=34.49331722074101%2C-59.2473 8150576559&z=-1

Even though there are extremely important early examples of a large-scale application of heat reuse, they have not been followed by a significant number of projects, even in a very energy sensitive and environmentally conscious area like the European Nordic Countries. Some reasons why heat reuse has seen limited adoption to date:

1. The local conditions are hard to replicate: infrastructure connecting data centers to heat hosts are not always located in close proximity. New infrastructure cost can be significant.
2. Some climate conditions favor an extended period of time when heat is needed for human comfort
3. Local and central legislation is not always facilitating these projects

4. There are no generalized subsidies from the authorities to financially support this kind of projects[1]
5. Collaboration between data center and heat host is hard to establish

6. Is it easy to understand that even if the energy balance is positive the amount of energy that the system requires is significant, as is the investment, underground pipes, pumping stations, heat pumps, controls and such.

All the previous mentioned points are partially the reason why those projects have not been followed by many others, even though the availability of heat from data centers exploded in the last 10 years, essentially in all the corners of the developed world.

What has recently changed to encourage heat reuse now?

1. Governments have committed to sustainability goals including decarbonization and are putting in place new legislations and subsidies.[2]
2. Large companies have committed to ambitious sustainability goals, particularly IT companies, which tend to be more involved in Data Centers, either as operators or users.[3]
3. The price of fossil fuel has increased dramatically which improves the economics of data center heat reuse.[4]
4. Greater adoption of direct liquid cooling in data centers to support increasing processor power, which enables potentially higher return temperatures (45-65 °C vs 27-28 °C, as shown in Figure 3) meaning higher heat quality to work with.

Let's have a look at the temperatures we find in the most common liquid cooling solutions:

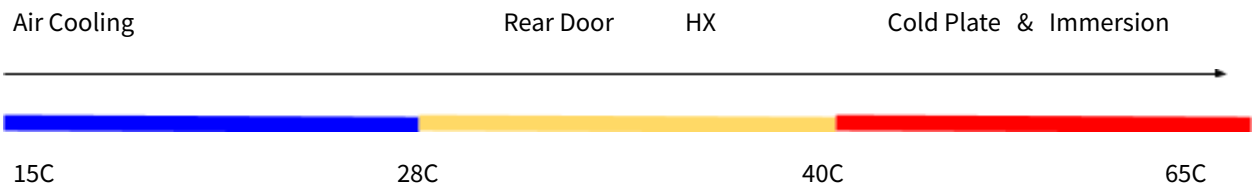

Figure 3 – Typical Equipment operating temperature range and cooling technology

[1] One USA example: Industrial symbiosis grant program Washington State: https://app.leg.wa.gov/rcw/default.aspx?cite=43.31.635

[2] https://digital-strategy.ec.europa.eu/en/policies/green-cloud https://www.mckinsey.com/capabilities/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost

[3] https://www.theguardian.com/environment/2020/sep/15/facebook-and-google-announce-plans-become-carbon-neutral

[4] https://ourworldindata.org/grapher/fossil-fuel-price-index?time=1997..latest

What makes data center heat reuse possible and sustainable?

To make a data center heat reuse project possible we need a combination of:

1. A heat host (or heat consumer) nearby the data center area, possibly adjacent to it. If this is not the case, the collaboration of a utility will be needed as medium (or as heat host itself).
2. A temperature level that is interesting for the heat host: optimally the heat will be directly used without transformations.
3. Ideally the heat host and the data center have the same ownership structure (see Figure 4, the example of a campus); if not, then different entities must be willing to collaborate
4. Finally, a legislative structure that encourages collaboration.

Edge computing facilities are envisioned to be widely distributed enabling placement near a heat host. With Increasing rack power densities, containerized/modular data centers can surpass 0.5 MW which is a significant amount of heat for many applications and simplifies the piping required. It matches with a distributed heat generation, which is by far the most common way households are heated[5].

Is it beneficial for a heat host to receive the heat from a data center?

Data centers are one of the most reliable heat sources currently available in the market. For a data center to be completely down, a major event must happen. Data center uptime is over 99,8% yearly, meaning that, in the worst case, there would be maximum 20 h of downtime per year. The heat host will receive the heat, considered a subproduct, which implies zero carbon footprint. The costs associated with the extraction of heat from the data center should be split by data center and heat host but the costs associated with the transformation of the heat (storage, increase of temperature, heat-to-cooling, etc.) should be invested by the heat host. In the best case a heat host can receive the excess heat for free, if not, it must be cheaper than the alternative considered for heating (gas, electricity, heat pump using the ambient air, etc.).

Is it beneficial for a data center to provide the heat to a heat host?

Data centers require a reliable heat host that will receive its excess heat. In any case, data centers will almost always have a redundant cooling system able to remove the heat if something were to happen to the heat host. From the data center point of view, a heat reuse project will rarely reduce the investment costs but the operational costs, making the usage of chillers or dry-coolers less needed. The costs associated with the

[5] IEA (2022), District Heating, IEA, Paris https://www.iea.org/reports/district-heating, License: CC BY 4.0

extraction of the heat from the data center should be split by both parties, but the costs associated with the transformation of the heat (storage, increase of temperature, heat-to-cooling, etc.) should be invested by the heat host.

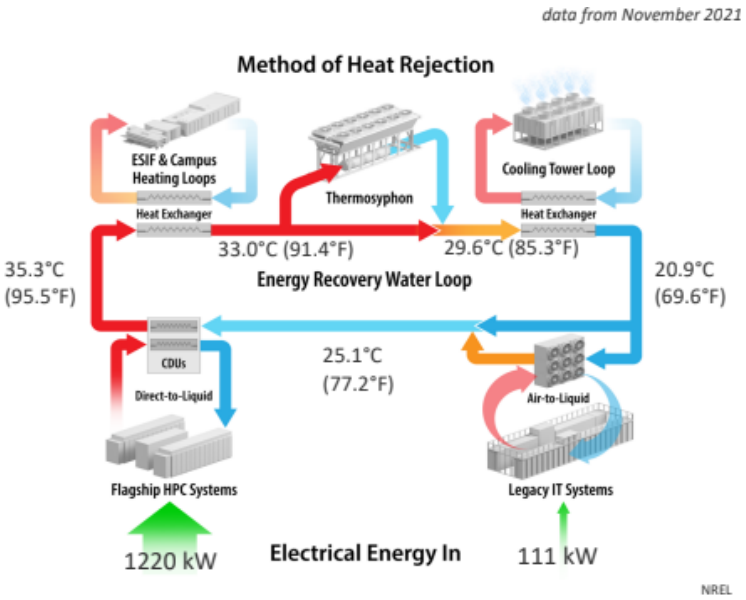

Figure 4 - Exemplary energy recovery concept for a data center integrated in a campus

Candidates for a heat host

The ideal heat host has a very high, consistent, and defined heat need 24/7 such as[6]:

a) Water pre-heat
b) Industrial laundries
c) Bio-ethanol production plants
d) Food and beverage
e) Breweries
f) Large hospital campuses
g) Distillation of water (desalination and wastewater treatment)
h) Other chemical/textile/metal industries
i) Pharmaceutical

[6] Classifications taken from "Potential Applications and Policy Opportunities for Reusing Data Center Waste Heat in the U.S.", David Gardiner, August 9, 2022

There are other interesting opportunities, but the heat they need tends to be influenced by the season with big variation between summer and winter:

a) Districts heating networks (of any size)
b) Biomass drying
c) Greenhouses
d) Fish farming

As an example, let's see in Table 1 a possible list of heat reuse opportunities (not meant to be comprehensive) Based on the World Bank classification[7]:

Table 1 - Heat reuse opportunities in different scenarios for different sectors

Heat Reuse Opportunities							
High Density Urban	District Energy	Private District Energy	Building HVAC reheat	Swimming Pools	Hospitals/ Hotels	Wastewater Treatment	
Intermediate Density Urban	District Energy	Private District Energy	Building HVAC reheat	Industrial Laundries	Swimming Pools	Hospitals/ Hotels	Wastewater Treatment
Low Density populated Areas	Swimming Pools	Hospitals/Hotels	Wastewater Treatment				
Agriculture	Biomass Drying	Green Houses	Heat Storage in aquifer	Ethanol Production			
Coastal (Sea)	Desalination	Fish Farming					
Coastal (lake and rivers)	Fish Farming						
Industrial	Industrial Laundries	Decarbonization	Pre-Heating	Wastewater Treatment			

Who gets the CO2 emissions reduction?

The heat host is the one using the excess heat from the data center as an alternative to another heat source. The CO_2 emissions avoided are the ones generated by that alternative and can only be accounted for by the heat

[7] https://blogs.worldbank.org/sustainablecities/how-do-we-define-cities-towns-and-rural-areas

host. Nevertheless, the data center could get to an agreement to be compensated for this. The data center will only directly profit from the CO_2 avoidance subject to the energy savings of their infrastructure.

What is the impact on water usage?

Deploying heat reuse allows to reduce the use of chillers and in some cases of cooling towers evaporating tons of water. Heat reuse itself can be done employing a close circuit and heat exchanging mechanisms transferring the heat from the producer (the data center) to the user (the heat host) with the smallest heat losses. The avoided water usage linked to the recovery of excess heat taken by a heat generator must be as well considered as a positive impact on the water footprint associated to the heat generation.

How to collaborate for such a project?

For the plan to exist and be implemented we need a legislative environment that is open and supportive of this effort. We are talking about bringing together, around a table, data center owners and heat users, with possibly a utility company as a liaison between the other two parties.

The stakeholders are those that are directly involved in a heat reuse cycle, the environment which benefits from it, and society since a new and less expensive form of energy is now available.

Techno-Economic Analysis

Heat reuse projects are specific. The heat reuse project will depend on:

1. Quantify the amount of heat and the temperatures we have available (do we have 1 MW at 40°C or 100 MW at 60°C?),
2. Availability of existing thermal piping network, or distance between data center and heat host to determine extra installation costs,
3. Geographical location and type of environment (dense urban environment or a vastly open desert)
4. Benefits of CO_2 reduction and water savings

Techno-economics on a life-cycle basis will determine if the project is viable or not.

What are the next steps?

The Open Compute Project Foundation (OCP) is an open organization and a natural partner to establish a matchmaking platform, where data center operators discover potential heat users and start a conversation. A

great number of the large IT companies are already OCP members, the nonprofit nature of the organization and its credibility seem to be the ideal starting point to make this happen. What is needed next is a program to promote such a platform within the heat hosts such as the district heating organizations, hospitals, industries requiring low grade heating, real estate companies, etc. Once we have proved that the concept makes sense, these organizations need to lobby to improve the legislative structure. That is particularly true in some regions, like the US.

Based on best practices, and following the openness of the OCP Foundation, define guidelines on how the "OCP way" of doing heat reuse in data centers can be, allowing to stay agnostic regarding different heat hosts, sharing basic general concept designs and Total Cost of Ownership analysis. Resources such as a checklist to assess the feasibility and desirability of a heat reuse project seems very helpful to initiate new projects.

Conclusion

The data center journey to sustainability started around 2006 when IT companies started to use energy from renewable sources. Heat reuse is just another step toward that goal.

In this article we have seen why heat reuse is becoming more relevant these days and how this is related to a mix between current geopolitical conditions and ambitious public and corporate policies. We have seen why and how it can be beneficial for a data center to plan a heat recovery project and what the challenges and opportunities are. We have stated one of the biggest challenges as the lack of a structured system to facilitate intersectoral fluent communication and collaboration.

The OCP heat reuse subproject is able and willing to pave the way with its work on a detailed guideline, a comprehensive list of use cases, a map format and a checklist for the pre-evaluation of heat reuse projects. The matchmaking platform between heat producers and heat consumers would be a logical next step.

References

1. Web resources:
    a. Industrial symbiosis grant program Washington State: https://app.leg.wa.gov/rcw/default.aspx?cite=43.31.635
    b. https://digital-strategy.ec.europa.eu/en/policies/green-cloud
    https://www.mckinsey.com/capabilities/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost

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e. IEA (2022), District Heating, IEA, Paris https://www.iea.org/reports/district-heating, License: CC BY 4.0
f. "Potential Applications and Policy Opportunities for Reusing Data Center Waste Heat in the U.S.", David Gardiner, August 9, 2022. https://drive.google.com/drive/folders/1Q9-sQDY--aVF3EIScOgDoioIddqIC1ja
g. https://blogs.worldbank.org/sustainablecities/how-do-we-define-cities-towns-and-rural-areas

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About Open Compute Foundation

At the core of the Open Compute Project (OCP) is its Community of hyperscale data center operators, joined by telecom and colocation providers and enterprise IT users, working with vendors to develop open innovations that, when embedded in product are deployed from the cloud to the edge. The OCP Foundation is responsible for fostering and serving the OCP Community to meet the market and shape the future, taking hyperscale led innovations to everyone. Meeting the market is accomplished through open designs and best practices, and with data center facility and IT equipment embedding OCP Community-developed innovations for efficiency, at-scale operations, and sustainability. Shaping the future includes investing in strategic initiatives that prepare the IT ecosystem for major changes, such as AI & ML, optics, advanced cooling techniques, and composable silicon. Learn more at www.opencompute.org.

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