Beyond PUE – Global Opportunities for ITE Heat ReUse

Beyond PUE – Global Opportunities for ITE Heat ReUse

EDITORS:

Jaime Comella (Cloud & Heat); Cosimo Pecchioli (Alfa Laval); Don Mitchell (Victaulic);

CONTRIBUTORS: Otto VanGeet (NREL), David Sickinger (NREL), David Gyulnazaryan (Impleon), Rolf Brink, Aaron Wemhoff

Executive Summary

Efficient energy usage of data centers is a key global concern and tenant of OpenComputeProject (OCP). But ITE and data center design efficiency is just one factor in minimizing the carbon footprint associated with energy usage of a data center - use of renewable resources and reuse of energy present significant opportunities as well. Data Centers convert electrical energy to heat energy. Heat energy can be wasted or be reused.

Optimization of heat reuse opportunities requires an integration of thermal host opportunities with data center cooling solution design. Heat Reuse opportunities with air cooled ITE have generally been limited to colder climates. Use of liquid cooled ITE expands the range of applications for heat reuse, as well as the range of geographies. In 2020, OpenCompute launched the Advanced Cooling Facilities (ACF) Subproject to develop guidance on addition of liquid cooled ITE into data centers, and heat reuse was identified as a future workstream related to ACF.

The OCP Heat ReUse subproject mission is to advance concepts, global successes, and best practices to expand the usage of ITE heat, for both air cooled ITE and liquid cooled ITE.

Table of contents

Purpose of this white paper

The purpose of this white paper is to elaborate a guideline of future designs and establishment of intersectorial integration of data center's waste heat

This paper is about the re-use of the heat, for different cooling technologies, for different outcome temperatures and different integration scenarios.

The readers of this paper can hopefully understand how to face a new data center project if they want to or the local regulation forces to establish a heat reuse concept for the otherwise wasted heat from the data center.

First, we will present the current situation of data center heat reuse in the world and we will go through the different qualities and quantities (the characteristics of the data center waste heat).

Second, we will go through the various heat hosts that can be present in the surroundings of a data center, following different classifications for them, depending on the location type and on the heat they need. Heat reuse concepts are often complemented by the usage of machinery, which needs to be placed between the data center and the heat hosts.

After this, discussions about redundancy and carbon footprint at the data centers and their heat hosts will be lead, because sometimes one plus one does not equal two. The metrics are equally a very important pillar for qualifying and quantifying the effects of implementing heat reuse on data centers.

The early identification and definition of stakeholders is paramount for the correct accomplishment of data centers' reuse projects, such as the regulations and subsidies locally present. A project can be rather executed in a country or region with favorable regulations.

The monetization of the waste heat, as a good is one of the biggest advantages of the heat reuse concepts at data centers and will be discussed in this paper.

Finally, use case calculations, applying the listed aforementioned knowledge, will be done for different integrations' scenarios adn to illustrate what are the technical and economical considerations for a project of this characteristics.

Used terms

Heat reuse:

Waste heat:

Edge data center:

Hyperscaler:

Crypto data center:

Heat host:

Current situation in the world

Data centers are installations with high needs of electrical power for running the servers that are allocated in it and for the HVAC systems that are implemented for providing the servers with reliable cooling energy and power distribution. Each unit of power supplied to a data center is converted into heat and this needs to be removed from the ITE and data center environment to ensure proper function.

The most common way of removing the heat is by mechanical cooling in the data center. However, the emitted heat can be used for other purposes such as residential heating.

Data center heat reuse has been limited in the data center industry over the past decades, with the majority of cases in northern European countries.

https://www.google.com/maps/d/edit?mid=1bTp4Ugy7FGwfPadNlmfZpYwGY5Z5B7o

Data center waste heat

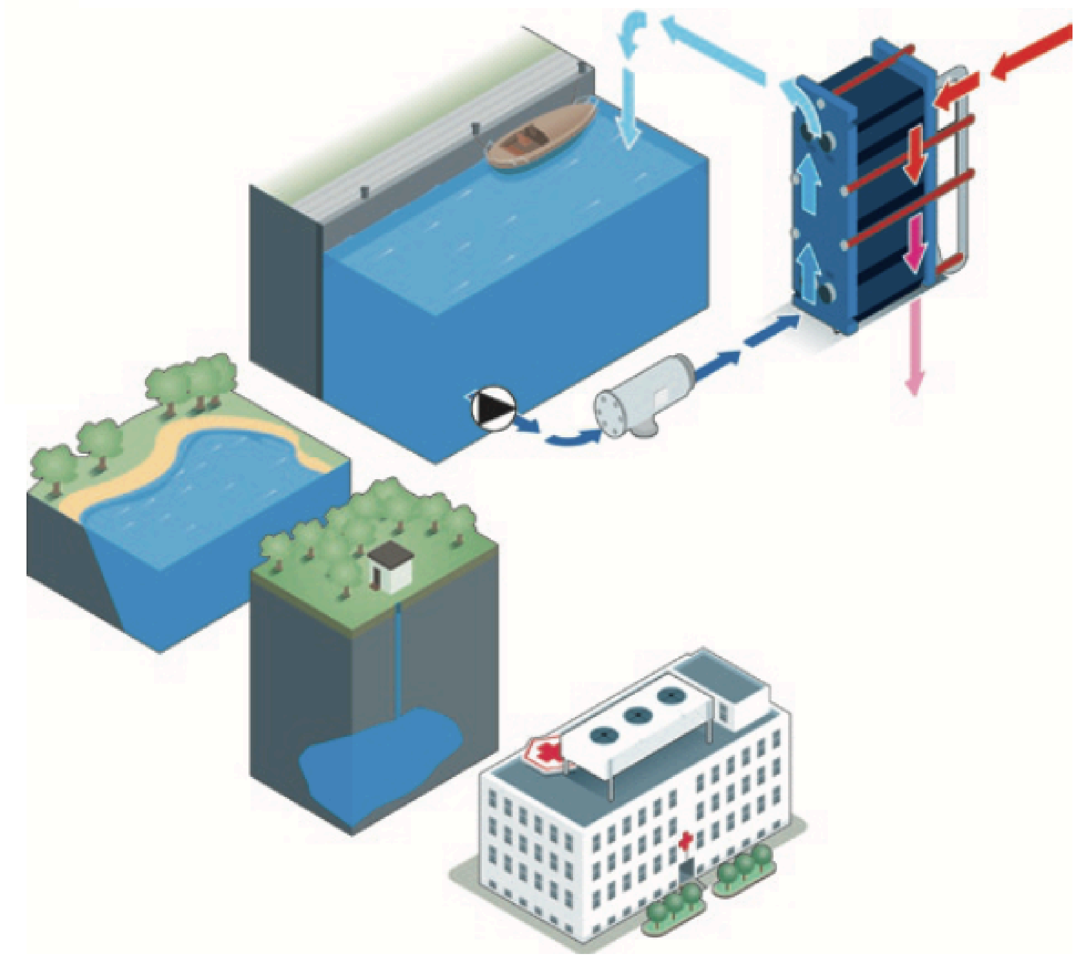
Is waste heat the right term?

Is waste heat the right term? We call it waste heat if this heat, as a sub product of another activity is not further used but only wasted, rejected, blown in the environment, with or without consequences for it or the living beings in it. Once the subproduct of heat is used, this cannot be called waste, since this has already a value and a usage. From the data center point of view, the heat must be rejected away from the ITE and it is a waste that needs to be removed. From the perspective of the user of this heat, it is an asset and has a value. One’s waste is another’s value.

Current sources of cooling for data centers

The majority of data centers use air as cooling media for the servers and usually it is cooled by chillers and during cold season by dry coolers. During summertime, chillers are cooled by air (DX system), dry coolers, cooling towers or adiabatic coolers. Some data centers use the sea, lakes and rivers round year as the source of cooling.

(Picture from Alfa Laval Comfort Handbook)



~~Many OCP based hyperscalers use fresh air free cooling without any water based cooling systems(air coolers, pumps, chillers, dry coolers, cooling towers) and for them can be used the warm air heat reuse system.~~

Insert reference of the ACF white paper/guideline about cooling methods...

“Quality” of heat (different temperatures) from data centers

In cold aisle inlet air temperature between 18°C to 28°C (for short term it can go up to 35°C) and that is the reason for the low temperature (between 15°C to 22°C) of inlet cooling liquid for internal air coolers. From air coolers we can get up to 32°C which is possible to use in some applications.

The chillers which are the source of inlet cooling liquid on their condenser side can provide the hot water with temperatures from 35 to 63°C and, in two stage series connected, up to 100°C.

Servers with direct-to-chip technology can provide up to 70°C outlet liquid without heat pumps and can capture up to 95% of IT-load.

Immersion cooling technology takes out all the IT-load heat rejection and can heat up the dielectric liquid up to 60°C ~~in dependence from immersion technology~~.

Quantity of heat (different sizes) from data centers (different data center applications/types -Edge, HPC, Crypto, Hyperscalers)

The limitations by minimal IT-capacity to create heat reuse:

- By air is approx. 500kW (25-100 racks) to achieve the optimal heat pumps efficiency
- RDHX
- With direct-to-chip is starting from one rack (30-100kW) as the efficiency is high
- With immersion beginning from one tank (15-200kW) or from one CDU (in case of vertical rack)

The capacity of heat rejection from data centres:

- MicroDC /data rooms <100 kW
- Edge 100kW-1MW
- HPC 1MW-10MW
- Hyperscalers 10-500MW
- Crypto 250kW-30MW

Other considerations (terms of contracts, durations, commitment, old vs new installations)

Heat hosts

Alternative heating sources of the heat hosts

When talking about heat reuse it is inevitable to talk about the alternatives to it. How is the heat host currently getting the heat? The most common ways of generating heat are:

- Biomass
- Gas boiler
- Diesel/oil/coal boiler
- Electrical heater
- Heat pump
- Nuclear energy

- Solar energy
- Geothermal energy
- Waste heat

Each one of these methods has an energy efficiency factor translating the needs of primary energy to get transformed into usable units of heat. It is crucial to know how much primary energy would be needed in order to quantify the avoided costs and CO2e emissions by using the waste heat. The alternative heat source for each heat host will also have investment and maintenance costs that will need to be considered.

Special considerations of machines, devices, needed for/to connect to the heat hosts

General classifications (locations, quantities, temperatures, seasonality)

	Industrial	Agriculture	Costal (Sea)	Costal (lake and rivers)	High Density Urban	Intermediate Density Urban	Low Density Populated Areas
Industry General							
Chemical Industry							
Paper Industry							
Metallurgy							
Machinery							
Plastic Industry							
Textile Industry							
Wood Industry							
Industrial Laundries							
Food & Drug Industry							
Green Houses							
Fish Farming							
Biomass Drying							
District Energy							
Swimming Pools							
Hospitals/Hotels							

Wastewater treatment							
Desalination							
Heat Storage in aquifer							
Cooling energy							

Direct usage at the data center

Sometimes the easiest way of making use of the waste heat can be to integrate it in the same data center area.

Data centers often have offices and meeting rooms and also need to maintain minimum temperatures, which can be challenging depending on the locations and insulation of the data centers. Waste heat from ITE can be employed for heating the space as well as the HVAC and power installations of the data center. Dehumidification at data centers is another application where the excess heat can contribute.

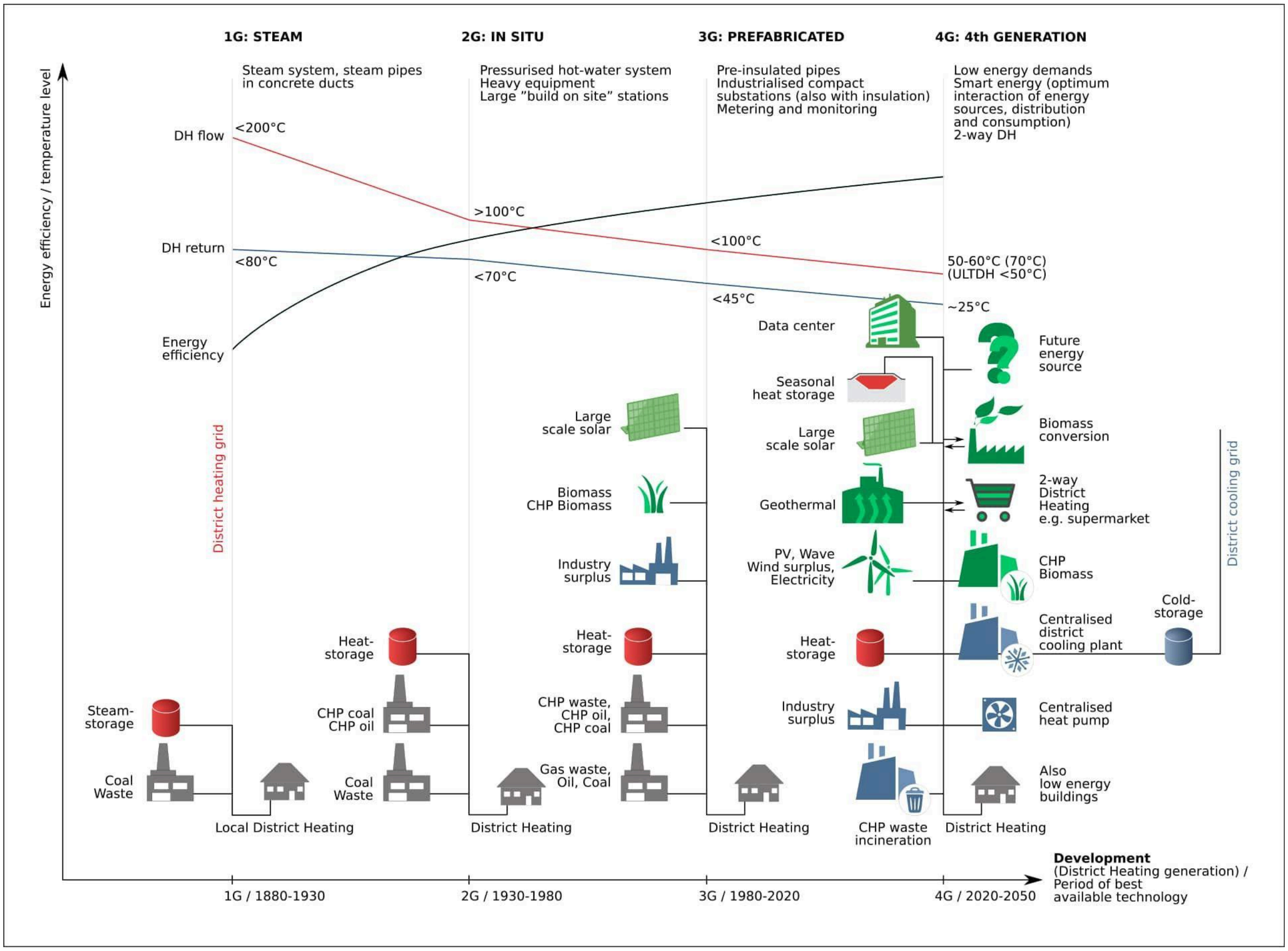
This should be the easiest way of considering the waste heat in the design of the data center, a way of utilize that excess heat independently of any external actor.

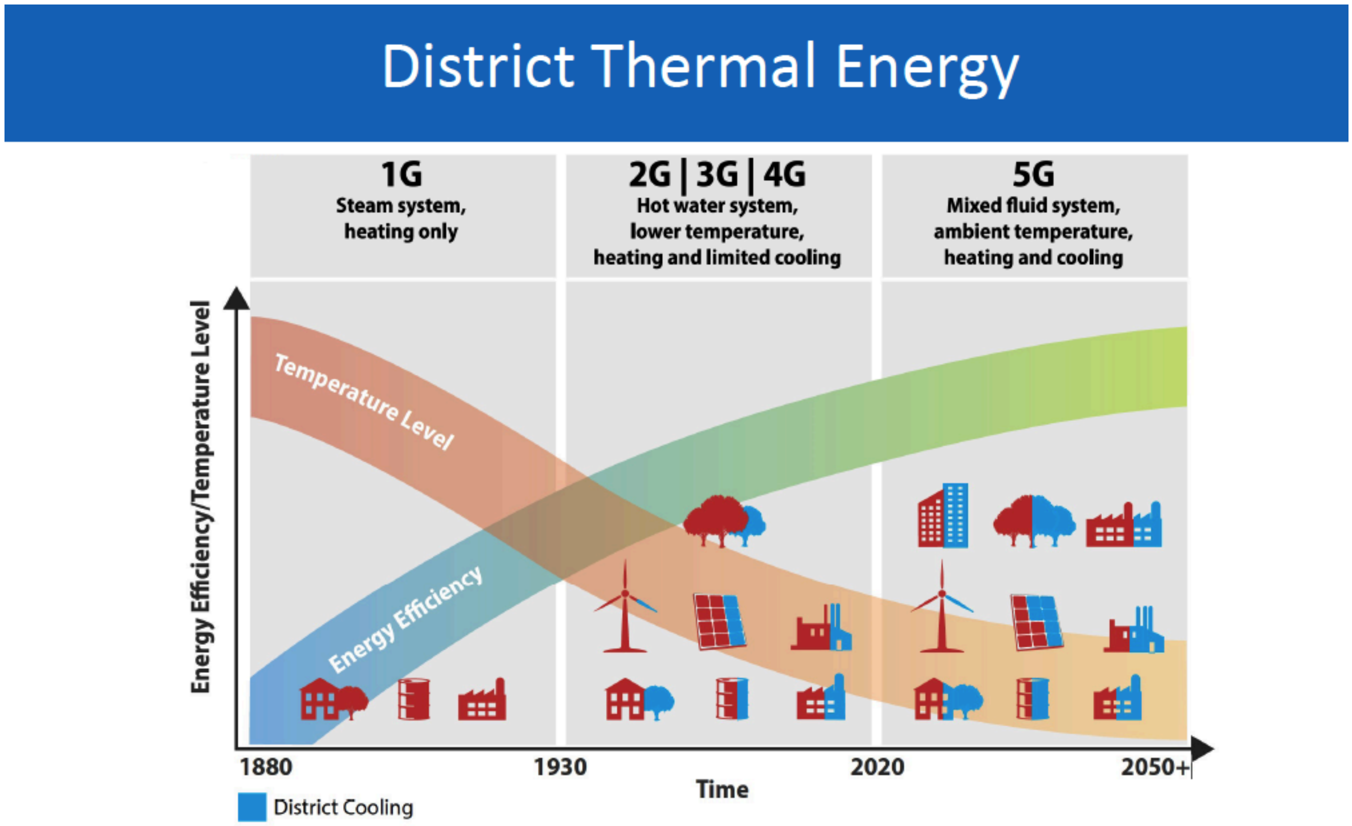
Main heat hosts

The following is a short description of the main potential heat hosts:

District Energy:

This is the most common used heat host. The main reason for it is that district energy uses a piping network to distribute the heat and even sometimes to gather the heat from generators and other industries that also need to give away their excess heat. Since district heating networks are already used to gather excess heat and are normally controlled by utilities, they are a good choice for the excess heat of data centers. The temperature levels of the networks are different depending on the generation of the district heating system:


1G: STEAM
2G: IN SITU
3G: PREFABRICATED
4G: 4th GENERATION
Steam system, steam pipes in concrete ducts
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
Energy efficiency / temperature level
DH flow
<200°C
>100°C
<100°C
50-60°C (70°C)
(ULTDH <50°C)
DH return
<80°C
<70°C
<45°C
~25°C
Energy efficiency
District heating grid
District cooling grid
Data center
Future energy source
Seasonal heat storage
Large scale solar
Biomass conversion
Biomass CHP Biomass
Geothermal
2-way District Heating e.g. supermarket
Industry surplus
PV, Wave Wind surplus, Electricity
CHP Biomass
Cold-storage
Heat-storage
Centralised district cooling plant
Steam-storage
CHP coal CHP oil
CHP waste, CHP oil, CHP coal
Centralised heat pump
Coal Waste
Gas waste, Oil, Coal
Also low energy buildings
Local District Heating
District Heating
CHP waste incineration
Development
(District Heating generation) / Period of best available technology
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050



District energy system evolution, from first generation to fifth generation.
Figure 22 from NREL: [A Guide to Energy Master Planning of High-Performance Districts and Communities]

Private District Energy, campuses (corporations, universities, hospitals…) are an alternative to the vast networks normally owned by utilities. These are local networks that are constrained to an area where data centers and heat users can be neighbors.

Seasonality and intraday variations: for district heating networks, seasonality is an issue since the heating demand is much lower in summer as in winter (80-90 % less). This situation invites to a correct dimensioning of the data center + district heating concept, where the data center permanently gives away the same quantity to the grid, independently of the season. To be connected to a grid with multiple heat generators and storage facilities can help to extract the highest potential from the data center excess heat. Specially for intraday variations are storage mechanisms very useful.

Industrial heating:

We will not describe each industrial process that needs heat and can profit from the excess heat of a data center but we will enumerate a list of fields and applications where the heat is needed.

Textile industry: coloring, washing, drying, whitening
Metallurgy industry: galvanizing, staining
Chemical industry: biochemical reactions, cleaning

Food industry: cooking, brewing, pasteurizing

The temperature levels of each process are different and for some applications (the less of them) under 40°C heat can be employed, otherwise, the temperature level will need to be increased and the excess heat of the data center will be used as a preheating process.

Industrial applications can be a good match for data center excess heat because the locations of the factories need industrial soil, which is also common needed for data centers. The deployment of a data center in an industrial area or adjacent to it, should lead to conversations with the surrounding industries to understand their heating needs. The usage of a district heating network to connect data centers and industrial applications can be sometimes the best option.

For a more detailed list of processes, see Annex C

Seasonality and intraday variations: many industries never stop producing and are constantly active, day, night, winter and summer and unless they processes do not rely on the weather conditions, they have a pretty constant need for heating energy. An industrial heat host can be a very suitable match for a data center excess heat from variability point of view.

Biomass drying

Biomass drying is the activity consisting in eliminating the moisture of biomass (usually wood, but also manure or green waste) mostly as fuel usage. This process can be done at low temperatures, depending on the degree of moisture and or type of biomass used.

Low temperatures can be used for longer times or as preliminary drying processes before going to higher temperatures.

https://bioresources.cnr.ncsu.edu/resources/effects-of-hot-air-temperature-on-drying-properties-of-biomass-brick-during-heat-treatment/

Biomass drying is typically done with hot air which enables a direct use of the hot air of a data center.

Seasonality and intraday variations: biomass tend to be more wet during rainy seasons, which are not always coincident with hot/cold seasons, depending on the geographical region. In any case, variations in the amount of heat needed exist but are more difficult to define in a general way.

(Herb Zien, John Gross, Sankar Padhmanbham, Tim Ashton)

Agro and Green Houses

Data centers in remote locations can take advantage of areas around the data center to be converted into greenhouses (not urban environments). Greenhouses that need to be heated typically use a floor heating system powered by gas boilers. For a floor heating system, low temperatures are required, which makes the direct use of the excess heat of a data center very suitable for it. If a greenhouse is heated with a hot air stream, the direct use of hot air from the data center could be considered.

Insect farms are becoming very popular as an alternative source of protein and, as we know, most of the insects like heat. In this case, similarly to the greenhouses, these farms need a heat input if located in cold regions. They will use a water-based floor heating system or a hot air flow, both at low temperatures.

Similar conclusions can be drawn for the usage of excess heat in a fish farm. These need also low-grade temperatures (less than 20°C) but, due to the medium they are based on, are better suited for an excess heat from the data center in a liquid form.

Seasonality and intraday variations: for these applications the variations are almost always very important. Life cycles of animals and plants are related to the sun hours and require different needs from day to night unless they are grown in a totally closed and opaque environment using artificial light. Unless growing tropical fruits in polar regions (as an example), plants do not require extra heating during summer. Seasonal variations of seawater or river water temperatures are not so high, which leads to a more constant need of heating for fishfarming all along the year

Singular heat hosts

Wastewater treatment/Desalination:

(Example David G wastewater → greenhouse)

Low Carbon Farming(UK) use 25℃ pure water from sewage stations in Norwich and Bury St Edmunds.

“Our first two locations will create 360 permanent new jobs in Norfolk and Suffolk. The 70 acres of greenhouses will be capable of producing 12% of the UK’s tomatoes with a 75% reduction in carbon footprint.”

YouTube BBC

Cooling:

Cooling energy can be generated with heat, using two processes:

Absorption cooling and adsorption cooling.

Electricity generation

Organic Rankine cycles

Fuel cells (see comment below)

Thermoelectric generators (small scale so far)

Using heat to deform the material and get it back when needed

In-between equipment for heat transformation

The excess heat from a data center does not fulfill the requirements of the heat host for heat, its seasonality, its temperature level. The excess heat from the data center might be transformed to bring more value to it. This will depend on the needs of the particular heat host receiving the excess heat.

Heat pumps

Consider as well solar or whatever heat source adding thermal content to the excess heat.

Storage mechanisms

Desalination machines

Cooling machines (adsorption, absorption cooling)

Electricity generators

Water usage reductions

Consider water footprint

Water scarcity footprint

Efficiency of greenhouse farming in terms of water usage

Metrics used

The Green Grid and ISO/IEC have defined data center heat reuse metrics.

- ◦
- ERE energy reuse effectiveness Formula <NREL & LBNL, TGG WP#29>
- ERF Energy Reuse Factor Formula <link ISO/IEC 30134-6>

ERE/ERF metrics can be improved by maximizing compute leaving temperature to maximize energy reuse.

-

The Green Grid has passed the ownership, development, standardization, and dissemination of PUE, WUE, and CUE to ISO/IEC JTC1 SC39 WG1 several years ago – as mentioned in the Guide to Environmental Sustainability Metrics for Data Centers White Paper 67 by Schneider Electric.

NREL's Key Approach to Sustainable Data Centers

1. PUE: Reduce energy use by making systems as efficient as possible.
    a. ***Maximize compute entering temperature to maximize energy efficiency!***
    b. "Free" cooling to reduce or eliminate compressor (chiller, DX) based cooling:
        i. Install direct liquid cooled computers that use warm water
        ii. Capture as much heat as possible directly to the liquid cooling system
    c. Optimizing fan/pump speeds and UPS
2. ERE: Reuse waste heat – achieve as low an Energy Reuse Effectiveness as possible
    a. ***Maximize compute leaving temperature to maximize energy reuse!***
3. WUE: Reject as much remaining heat to dry coolers as possible
    a. ***Maximize compute leaving temperature to maximize heat rejected dry!***
4. CUE: Maximize energy from renewable systems (RE) onsite or within region.
    a. ***With the goal of 100% RE 100% of the time***

How can the PUE be affected by heat reuse?

Some data centers fear that the usage of heat pumps to elevate the temperature or other machinery to adapt the excess heat to the need of its heat host can affect the PUE. Actually, if these machinery and installations belong to the heat host or are used by the heat host to take advantage of the excess heat they should not be accounted for in the PUE calculation.

We can compare heat reuse to free cooling. If a data center is using the natural available cooling to cool down its ITE and is giving the excess heat directly without transforming it to the ambient, the data operator is just employing auxiliary power to circulate that heat to the outside of the data center. In this case, the PUE is affected positively because there is no need for chillers, only pumps and fans to extract and reject the heat..

In the case this heat is reused instead of rejected, the interface of the data center should end there and anyone who is taking care of that heat should be in charge for transforming it to fulfill their needs. If the heat is of a low quality, the heat host will pay less for it because they will invest more to take advantage of it, but still is taking advantage. The data center operator will reduce the PUE in this case by using less dry cooling power to reject the heat in the ambient.

~~Values of carbon usage effectiveness (CUE) and water scarcity usage effectiveness (WSUE) encompassing only operations are fairly straightforward to calculate. The CUE is calculated as the product of the PUE and a carbon emission factor (CEF) that depends on the method of power production. Values of CEF are generally based on location and are published through the EPA eGrid. Recently, methods to update CEF values that incorporate electricity transfers within the electric grid have been proposed. In addition, data centers with power purchase agreement (PPA) contracts have CEF values that correspond to the terms of the PPA, enabling data centers to have lower emissions than they would otherwise have based on the CEF corresponding to their physical location.~~

~~The WSUE is calculated as~~

$$WSUE = A_{CF} \cdot WUE + SWI \cdot PUE$$

~~where A_{CF} is the AWARE-CF local water scarcity metric, WUE is the water usage effectiveness, and SWI is the scarce water index. The first term on the right-hand side of the above equation is due to on-site water stress, whereas the second term is due to the water stress associated with power production to support the data center. The AWARE-CF factor is defined as the ratio of a reference water availability-minus-demand (AMD) divided by the local AMD, with bounds at 0.1 (low water stress) and 100 (high water stress). The SWI tracks water scarcity through the electric grid and is therefore, like CEF, distributed based on location.~~

Stakeholders involved

Directly involved: Data center operators, heat hosts (industries, companies, institutions, particulars, etc.), utilities, heat grid owner, authorities (municipalities, regional and national governments),

Indirectly involved: digital service providers and users, power grid owner, ISPs, authorities (municipalities, regional and national governments),

Regulations and subsidies

Trends and opportunities

The European Energy Directive 2022 in Annex VI mentions the Data Centre Performance indicator Waste heat utilization.

In part (d) in article 24 mentioned:

*a data centre with a total rated energy input exceeding 1 MW level, to assess the cost and benefits of **utilising the waste heat** to satisfy economically justified demand, and of the connection of that installation to a district heating network or an efficient/RES- based district cooling system. The analysis shall consider cooling system solutions that allow removing or capturing **the waste heat** at useful temperature level with minimal ancillary energy inputs.*

Also, many of the heat reuse projects in Europe are financially supported by local authorities and financial institutes.

Environmental impact and communities perception (water, energy and carbon)

Nowadays new data centres construction are banned in Ireland, Netherlands and Singapore. Moreover, in Ireland people are protesting its construction as they take up to 14% of the country's energy grid without social benefits. With heat reuse approach data centres can be reliable source of energy (Uptime 99,99%) based on renewable source of energy (wind, solar, hydro) integrated with energy storage can provide significant social and environmental values:

- Heavily reducing fossil fuel burning for house heating
- Decarbonise the district and individual heating systems
- Stabilize the country energy grid
- Increase the utilization of renewable sources of energy

Monetization

After reviewing in the section “Alternative heating sources of the heat hosts” the different options for heating of the heat hosts, we can proceed to evaluate the monetization of the excess heat at a data center.

Each one of these methods has an energy efficiency factor translating the needs of primary energy to get transformed into usable units of heat. It is crucial to know how much primary energy would be needed in order to quantify the avoided costs and CO_2e emissions by using the waste heat. The alternative heat source for each heat host will also have investment and maintenance costs that will need to be considered.

The following is a formula for calculating the costs of heating a heat host:

Cost of heating per kWh of heat = **primary energy needs for a kWH of heat (efficiency factor)** x **cost of primary energy** + **maintenance costs per kWh** + **investment costs per kWh (assuming a certain lifetime)**

A similar formula can be suggested for CO2e emissions (see Annex B Carbon footprint considerations).

Please note for your evaluations that the price of electricity and fuels can strongly differ from place to place and time to time.

When heating with waste heat, the cost of the primary energy can be considered as zero but not the maintenance and investment costs. A similar conclusion can be drawn for the CO2e emissions (see Annex B Carbon footprint considerations).

If the data center operator wants to monetize the waste heat, its price cannot obviously exceed the cost of the alternative heating method of the heat host or the purchase price of the alternative if the heat host is not generating it itself.

Price of waste heat < **Cost/price of alternative heat source heating** - **maintenance costs of waste heat solution** - **investment costs of waste year solution per unit of waste heat**

Should the heat be used as an intermediate good for generating another one (such as cooling energy, clean water, electrical energy), the comparison for costs and CO2e emissions should be done considering the energy input using the alternative methods for generating those goods.

For generating cooling power with heat we can consider two methods: adsorption and absorption cooling. The most common alternatives of generating cooling power are:

- Compression cooling
- Adiabatic cooling
- Free cooling (using air, water, snow…)

All of these methods are driven by electrical energy and some of them require water usage (see Metrics used). The costs of these alternatives will be related to the price of the electrical energy, depending on the way this is generated and where this is happening. A similar conclusion can be drawn to the CO2e emissions associated to it.

When considering water treatment the most common methods for doing it are:

- Reversed osmosis (for desalination)
- Boiling
- Filtration
- Distillation
- UV sterilization?

All of these methods are driven by electrical energy as well and some of them require water usage (see Metrics used) so the same considerations have to be taken into account.

Generating electricity can be done in several ways. Comparing waste heat electricity generation to the mix of the power grid would be the simplest way of doing it but if the alternative in place is an off-grid method, the comparison should reflect that situation.

In any case, the usage of waste should also reflect the amount of waste heat that can be directly used without any other transformation or storage system which could increase costs and emissions.

Who is paying what is a crucial decision/factor when considering waste heat reuse from data centers. Each use case will be different and each heat host will have different financial strengths and motivations. The criticality of the service at the heat host will define the investment as well in a backup system which could cover partially or totally its needs. If the heat host relies on the data center excess heat, it could be the one investing almost exclusively in the connection from the data center and, if applicable, the machinery needed to increase the temperature level or transform the heat into something else.

Terms of contracts

duration and commitment, Long term, constant flow, constant temperature, seasonality

Intersectoral agreements and business opportunities (Edo Energy)

Calculations for exemplary use cases of data center heat reuse

We need to quantifiy:

CAPEX, OPEX of the installation needed for a heat reuse project

Calculation of the above mentioned metrics and CO2 emissions.

Notes: (Usage of a heat pump for the exemplary use case (Bryan from Carrier))/ Use Rolf’s tool, “Joules calculation”

Conclusions

ANNEX A – AVAILABILITY CONSIDERATIONS

Redundancy is a mechanism of mitigating potential risks and assuming other ones. At many data centers, risks cannot be tolerated at all (such as critical data from financial institutions, defense or health systems), others are more tolerant against downtimes. At many heat hosts the same happens (hospitals, residential heating) but others resist a period without heating or might not be as indispensable. The synergies between data centers and heat hosts can generate some opportunities "from scratch" where a trade-off of risks are considered and calculated in the business plan.

Criticality of data centers

"Step down of data centers in some parts of the world"

Data center redundancy is almost universally required, depending on the heat reuse redundancy at the heat user level is preferable but not always required. In most cases heat reuse will be a pre heat opportunity, in case the pre heat opportunity is down, the heat user will have to face higher costs, but not an interruption of the services/operations they manage.

Depending on the nature and size of the heat host, a heat host can be either comparable to the power grid, or it would require a backup cooling system as if the heat host didn't exist. More generally speaking, a "regular" cooling system backup is advisable, especially if a data center wants to comply with certain existing certifications.

Owning the cooling source (being at the same time data center provider and heat host) can reduce the need of back-up cooling at the data center.

Some data centers do not have any redundancy measure in place. This is the case of some legacy data centers, some HPC data rooms or other non-critical applications that decide to stay in a low-cost range assuming that they can be rescheduled. This is as well the case of all of the cryptomining farms. (Hyper)Edge data centers are becoming more common and due to the lack of space and in some cases to the non-criticality of the IT loads, do not incorporate the redundancy of a hyperscaler data center.

The usage of an external reliable source of cooling (such a district heating network) can increase the reliability of all this kind of data centers.

Criticality of heat hosts

From a heat host point of view a data center is probably one of the most reliable sources of heat possibly available. Nevertheless, some heat hosts need to ensure no matter what the supply of heat and will have a heating backup in presence but maybe will not incorporate a second back-up (e.g. a critical heating host heating with gas might have an electrical or diesel boiler as back-up but if the waste heat of data center is incorporated, one of the above mentioned heating systems might be enough).

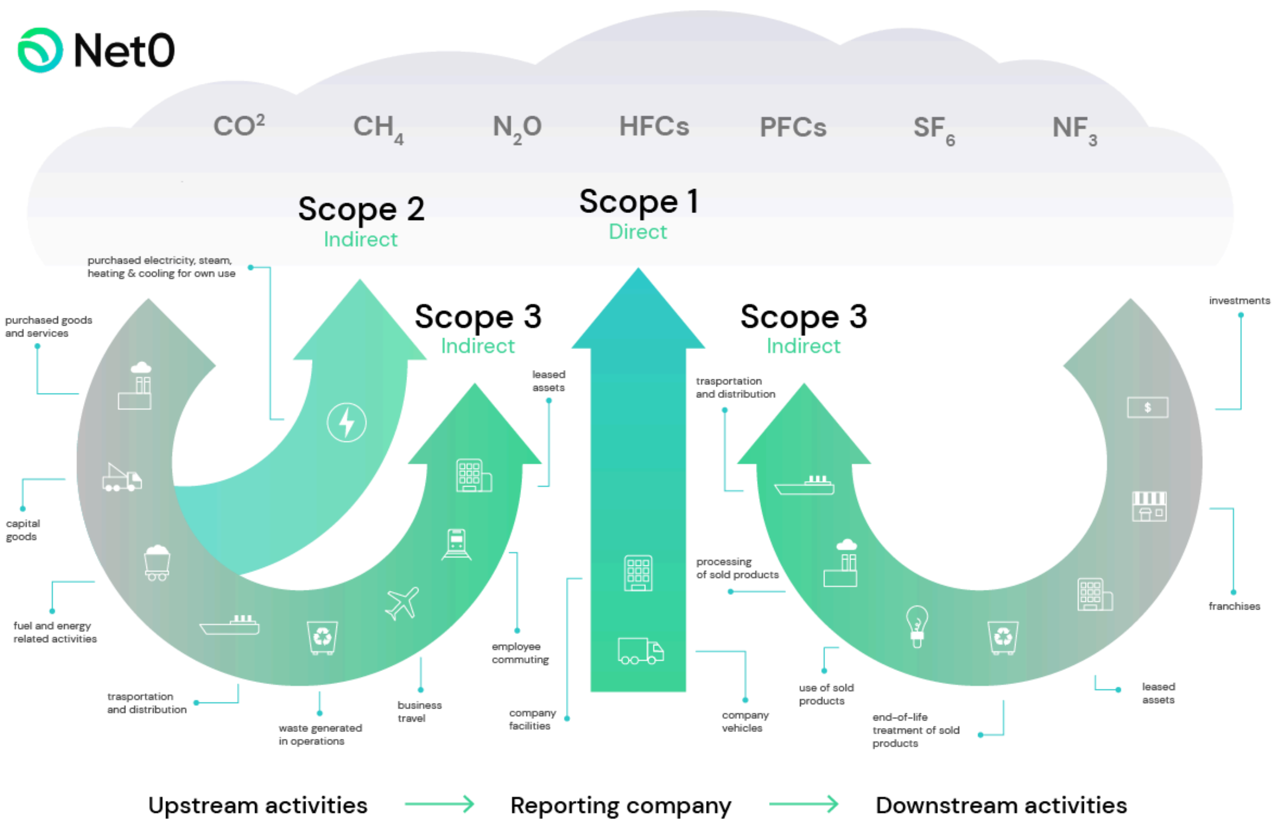
In any case, for the data center to be offline a major catastrophic event needs to happen, which would hamper the ability of the heat host to keep operation running. On top of that a heat storage system could mitigate the effect of short, temporary interruption of the heat source from the data center (usually maximum a couple of hours per year).

Failure modes while using heat reuse

Maintenance

ANNEX B – CARBON FOOTPRINT CONSIDERATIONS

Carbon emissions are classified depending on the scope they consider (scope 1, scope 2, scope 3).



https://net0.com/blog/scope-1-2-3-emissions

The implementation of heat reuse at data centers can impact in various ways the carbon footprint of the activities but we will focus here:

- on the effects on the emissions associated with the operations of a data center linked to the energy used for cooling and the effects on the carbon footprint associated with the materials employed for its cooling system
- on the effects on the emissions associated with the operations of a heat host linked to the energy used for heating and the effects on the carbon footprint associated with the materials employed for its heating system

Please note that the carbon emissions are actually carbon equivalent emissions, which are accounting emissions of other GHG and normalizing them to the warming potential of CO2 emissions. For sake of simplicity we will spare the word “equivalent” each time we talk about emissions.

For data centers

Data centers tend to be “greener” in the last few years. Some companies are pushing for net zero policies, which start at the supply of the power and its sustainable origin, the building materials for the construction and the used machines. Heat reuse implementation can also impact the carbon footprint of data centers.

There are three ways how a heat reuse concept can impact the carbon footprint within a data center:

a) If the implementation of heat reuse concepts directly impacts the energy consumption of the cooling facility (e.g. less usage of chillers), this lower consumption will have a lower carbon scope 2 footprint associated.
b) Following the discussion about potential consequences in the simplicity of the redundancy at data centers, if the heat reuse connection can lead to a simplification of the cooling system the spared materials will inevitably lead to a scope 3 carbon footprint reduction.
c) If the cooling facility is at the same time a heating facility supplying heat to third parties and this facility belongs to another company (for example a utility), the associated scope 3 emissions to this facility would be accounted for the utility and not the data center.

For heat hosts

Heating generation, such as many other industries, is looking to reduce its carbon emissions. More efficient processes and machines and being supplied by renewable energy sources are the main actions for it. The usage of a waste heat from another facility is a perfect option for the carbon reduction: since this energy has been already used for one purpose its energy factor is 0 and hence its carbon footprint, independently on how this power was originated.

There are four ways how a heat reuse concept can impact the carbon footprint within a heat host:

a) When we talk about carbon reduction, we state that the carbon emission has been avoided in comparison to a case without heat reuse (see Current sources of cooling for data centers). 100% of the heating energy supplied by the data center to the heat host will be then carbonfree (scope 1 or 2).
b) Following the discussion about the usually high reliability of a data center and the unusual offline periods (meaning unusual periods without waste heat transferable to a heat host) we can assume that the heat host will not implement any redundant heating system to counter the eventuality of a black-out unless the heat host as a higher level of criticality or needs higher reliability than the data center. If then the usage of the waste heat incurs in an absence of some machinery needed for heating, the carbon footprint of the heat host will be respectively reduced (scope 3).
c) If the cooling facility is at the same time a heating facility supplying heat to third parties and this facility belongs to the data center operator, the associated scope 3 emissions to this facility would be accounted for the data center operator and not the heat host.
d) If the heat is used to fix carbon from the environment.

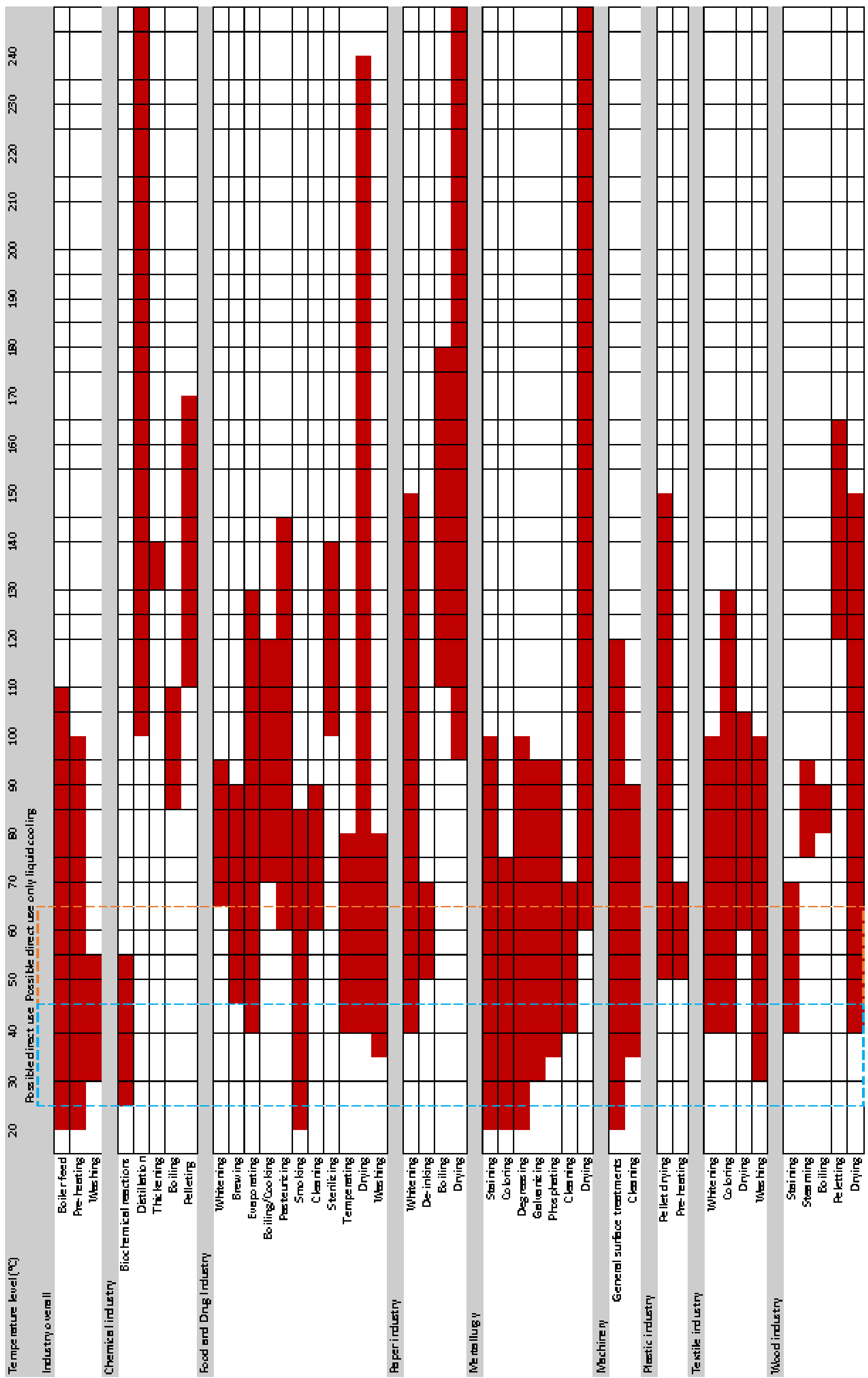
Combined

Which facility can account which emissions' reductions or avoidances? From a combined point of view, the union of these facilities lead always to a scope 1-2 carbon emissions avoidance and most probably also to a (rather small, if applicable) scope 3 carbon emissions avoidance.

A way of seeing this situation is to pose the question: what would be the alternative? The alternative of the data center would be to employ energy to extract that heat from the ITE, but the energy to run the ITE has still to be sourced and is not somehow avoided. The alternative of the heat host would have been to employ another source of energy, pollutant or not. Even if the data center is contributing to reducing the overall carbon footprint via sourcing a waste heat to the heat host, they cannot account for the reduction associated with this (unless they own the heat host) and can only account for the carbon emissions' reduction within the data center. An equivalent reasoning happens when referring to the carbon emissions of the heat host.

Having said that, another discussion would be if one party asks for a retribution to the other party for the avoidances generated and if they artificially share these avoidances by monetizing them. In any case, both parties will be interested in publicly showing the effect of the sinergy and use it for image or to comply with internal policies.

ANNEX C – HEATING AT INDUSTRIAL PROCESSES



Source: Das Potential solarer Prozesswärme in Deutschland, Teil 1 des Abschlussberichtes zum Forschungsvorhaben „SOPREN – Solare Prozesswärme und Energieeffizienz" Förderkennzeichen: 0329601T

Authors: C. Lauterbach, B. Schmitt, K. Vajen, Institut für Thermische Energietechnik, Universität Kassel

Abbildung 6-2: Geeignete Prozesse zur Einbindung solarer Prozesswärme (Aidonis et al., 2005, Müller et al., 2004, Schweiger et al., 2001 und eigene Recherchen)

Translation and adapted for the OCP workstream Heat reuse