Data Center Cooling with Heat Recovery

Cost efficient and sustainable data center cooling

Data centers are estimated to represent between 1.5 and 2 percent of total global electricity consumption, corresponding to 400 TWh, or close to the total amount of electricity used in France (Corcoran & Andrae, 2013) (Shehabi, o.a., 2016).

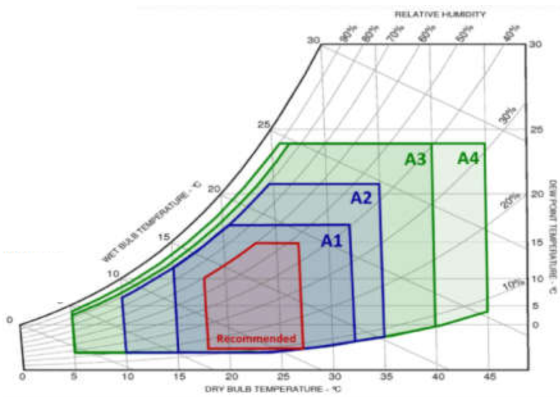
Imagine if there was a way to reuse the electricity deployed in the data servers. This White Paper examines how large-scale data center cooling with heat recovery is taking cost efficiency and sustainability of data centers to the next level.

Data center cooling standards

With increased CPU performance and power densities, higher equipment tolerance, new cooling technologies, increased cost consciousness and environmental concerns, guidelines and approaches for data center cooling have undergone significant development since the first introduction of the ASHRAE recommendations for “Thermal Guidelines for Data Processing Environments” in 2004.

The ASHRAE recommendations, now in their fourth edition and synchronized in 2008 with the corresponding Network Equipment-Building System requirements for telecommunications, are the de-facto standard for thermal management in the data center industry. Evolution of the guidelines has attempted to support a more energy efficient cooling of IT equipment, without compromising reliability.

Figure 1: ASHRAE Thermal Guidelines, 2015 4th Edition. Source: ASHRAE.



Ambient conditions in Stockholm

The choice of cooling solution is, of course, heavily dependent on ambient conditions where data centers are located.

The weather in Sweden varies significantly across the country and between seasons. In the capital Stockholm, the dry bulb temperature in northern Stockholm has been below 15 °C for 82.26 percent of all hours since 1 January 2001, and below 27 °C, (the ASHRAE recommended maximum for 99.63 percent, and below 32 °C, (the ASHRAE A1 maximum), for 99.998 percent of that period. The dew point temperature was below 15 °C, (the ASHRAE recommended maximum), for 96.98 percent, and below 17 °C, (the ASHRAE A1 maximum), for 99.19 percent, (Stockholm Luft- och Bulleranalys, 2016).

Cooling options in Stockholm

Stockholm offers a large number of potential cooling solutions for data centers. In this section, we outline the solutions that are most suited for the city's weather conditions.

Air based systems

Given Sweden's ambient conditions, direct and indirect air cooling systems represent two attractive alternatives. As of today, the experience of this building practice is, however, limited in Sweden.

The best example of a direct air implementation is Facebook's facility in Luleå, northern Sweden. There are no significant installations that employ a direct air solution in Stockholm. The reason for this may be concern over high filter maintenance costs in a city environment. The key advantage of this system is low PUE.

The most important issue with this solution, however, is the large amounts of valuable energy that is wasted as excess heat from data servers is simply rejected into the ambient air. However, direct air systems could be designed to reuse heat with the introduction of water-to-air heat exchangers. While conceptually feasible, such installations are still rare in the Nordic region except for Yandex's facility in Mäntsälä, Finland. Notwithstanding the favorable ambient conditions in the Stockholm area, a full-scale back-up cooling system would still be needed to manage the small number of hours of high dew point temperatures.

Indirect air systems perform air-to-air heat exchange where outside air is cooled with evaporative cooling. The efficiency of the method will depend on the wet bulb temperature of the outside air and will require mechanical top-up cooling to manage the small number of hours when relative humidity is too high for the evaporation process to work. The system has a low PUE, though typically higher than a direct air system.

As in a direct air system, excess heat is rejected into the environment. Unlike the direct air system, however, it is difficult to conceive an efficient design where heat recovery could be combined with an indirect air system.

Chilled water systems

The most frequently used systems rely on chilled water cooling with some sort of mechanical cooling, often in combination with a free air cooling mode for a significant period of the year. The system infrastructure is different from the air based systems in that energy is carried in a liquid in the data center, and cooling takes place through a liquid-to-air heat exchange in the data room.

Chilled water systems typically have a higher PUE than the air based systems. Chilled water systems tend, on the other hand, to allow for greater design flexibility, and require less space compared to indirect air systems.

A special version of chilled water systems is district cooling. In a district cooling solution, the same data center infrastructure is used, but cooling is provided as a service from the district cooling supplier. The supplier of the cooling service may use different methods for producing the chilled water, including seawater cooling, cooling machines and heat pumps. While not present in Stockholm, district cooling providers elsewhere are considering sorption based cooling.

One of the key advantages of chilled water systems is the opportunity to perform efficient heat recovery. In a conventional chilled water system, excess heat would be removed in a cooling tower.

However, in a chilled water system where the cooling of the data center is achieved with heat pumps, the temperature of excess heat may be raised so that the heat pumps simultaneously produce heating for residential and office needs via a connection to the district heating network. In a district cooling solution, where data center cooling is provided as a service, heat recovery is an inherent feature of the system where the return pipe carries excess heat from the data center to a production plant equipped with heat pumps and a connection to the district heating network.

With the advent of high performance computing, implementations of liquid cooling start to emerge. A liquid cooling solution requires no liquid-to-air heat exchange, and will be even more efficient for heat recovery with better heat absorption, higher temperatures and less need for mechanical assistance to reach temperature levels that work for residential heating.

Data Centers and Heat recovery in Stockholm

Stockholm is ideally suited for heat recovery. Many heat recovery projects performed elsewhere do not meet the prerequisites for successful heat recovery. The first challenge is the sheer quantities of heat that need to be managed. A 10 MW data center load corresponds to the heating needs of around 20 000 modern residential apartments (55 kWh/m^2/year). Thus, the option of fully reusing heat locally, or in the same building as the data center, is not feasible.

The other critical factor to consider is the risk for the data center of relying on a single building or limited residential area for absorbing data center heat.

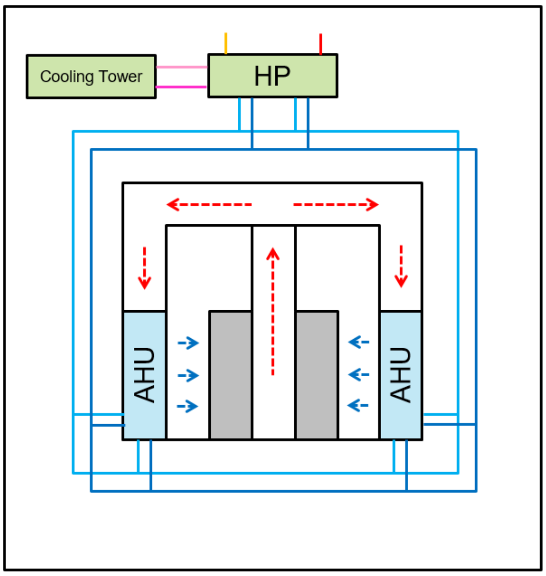
Only if the data center is connected to a vast network of buildings can heat recovery be performed on a sufficiently large scale and with reasonable risk. With Stockholm's 12 TWh/year district heating system, there is enough heat demand to accommodate heat recovery from data centers of any size (corresponding to close to 150 data centers with 10 MW load).

Fortum Värme has more than 25 years´ experience of recovering heat from data centers and transferring it to district heating networks, starting in 1989 when IBM began to provide heat from its Kista data center.

In addition to ordinary district cooling used by many smaller data centers, Fortum Värme has also developed a specific district cooling service with heat recovery which, for example, is used by Interxion's data center in Kista. At Interxion, a heat exchanger and a circulation pump is all that is required to cool the data center's internal chilled water loop. In this process, excess heat from the data center is recovered and returned to Fortum Värme where it enters large heat pumps that then provide district heating.

Fortum Värme has since developed a business model that allows any heat producer to interface with district heating systems and receive payment for supplying heat – Open District Heating. Using heat pumps specifically selected for heat recovery, the condenser side of the heat pumps perform a heat exchange with the district heating system, transferring heat there instead of dissipating it into outside air, which allows energy to be used twice – powering the servers and heating the city of Stockholm.

Figure 2: Illustration of a data center using heat pumps connected to the district heating network and a cooling tower in the event of the network becoming unavailable.



There are more than thirty data centers in Stockholm that are engaged in heat recovery.

Cooling as a Service (CaaS) with heat recovery

As outlined above, heat recovery can be conducted in one of two ways in Stockholm. Either data centers produce their own cooling with heat pumps, and reject excess heat into the district heating network at an appropriate temperature. Alternatively, Fortum Värme provides Cooling as a Service, (CaaS), where a data center's excess heat is carried to a production plant in a return pipe. At the production plant, excess heat enters on the evaporator side of large centralized heat pumps that generate heat for the district heating network.

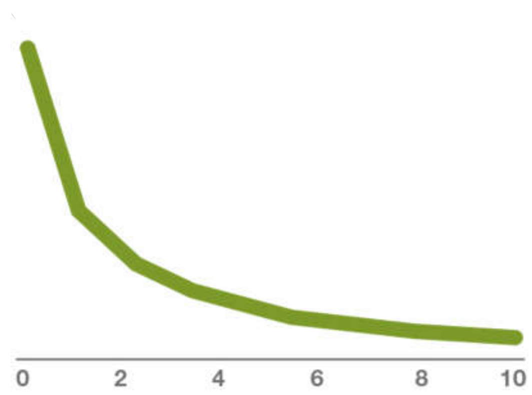
In Stockholm Data Parks, Fortum Värme welcomes both solutions. To achieve and share economies of scale, Fortum Värme has developed – and is proposing – an enhanced CaaS offering targeting data centers that expect to reach computer load in excess of 5 MW. By using larger machines, and connecting heat pumps in series, COP can be increased, and electricity consumption decreased compared to a local heat recovery solution, often in a parallel configuration.

Each Data Park, (at different locations in Stockholm), will contain a dedicated cooling plant, where large-scale centrifugal, (instead of scroll or screw), chillers provide CaaS for data center cooling with heat recovery for the entire park.

From the data center perspective, the delivered service is chilled water through a pair of distribution connections to a standard chilled water system, allowing the full range of design flexibility that such a cooling system offers. The data center chilled water distribution system interfaces with the CaaS system through a heat exchanger where ~20 °C water is provided on the delivery side, allowing ~22 °C water into the CRAH units. The hot return water travels back to the CaaS plant where it enters heat pumps that produce 68 °C water to the district heating system, depending on heating needs.

In Stockholm Data Park Kista, the price (SEK/MWh) of the cooling services declines with the load, reflecting the increased benefit of heat recovery as the volume increases. In the offering, chilled water cooling will be provided free of charge in exchange for the excess heat for data centers with a cooling load just north of 10 MW.

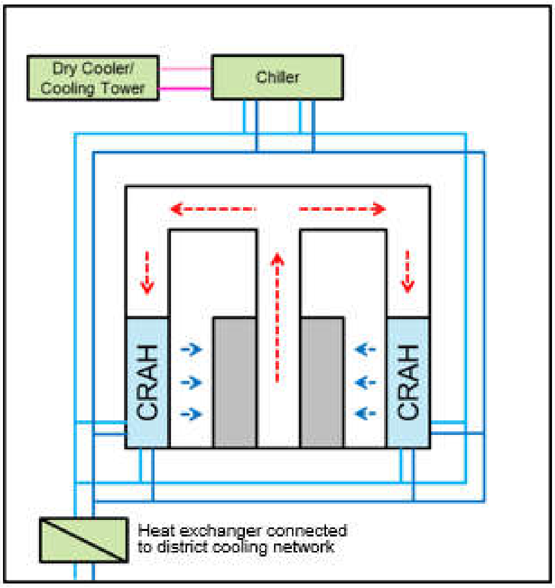
Figure 3: Stockholm Data Park Kista price model.



Similar to how the power supply through a public connection is considered a way to reduce OPEX compared to using a data center's own electrical system, the heat recovery system can be thought of as a way to reduce and eventually eliminate OPEX for cooling. With this offering, Fortum Värme proposes to run the CaaS for 8,030 hours per year, with 99.7 percent availability, allowing for revisions and maintenance to be performed.

The offering, again similar to the power set up, envisages that the customer will complement CaaS with low CAPEX chillers for redundancy, and to cool the data center when CaaS is not provided. The data center operator may choose the backup cooling system with minimal attention to OPEX, considering the low amount of estimated usage. With less than 730-hour yearly usage of the backup system, and the simplicity of the primary system, required maintenance is also reduced. The water distribution infrastructure of the data center is shared by the two systems.

Figure 4: Illustration of a data center using CaaS with an integrated backup cooling system

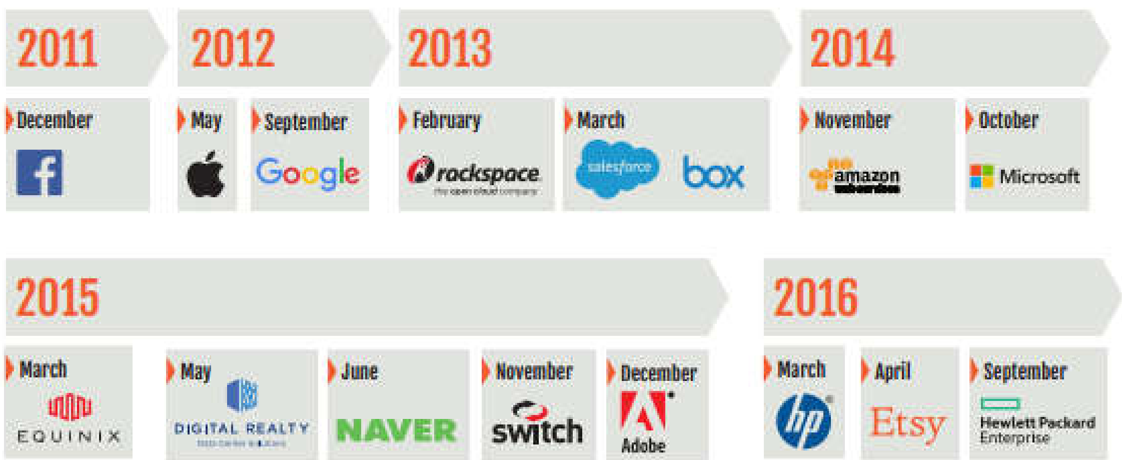


Should a fully redundant CaaS solution be preferred, a structure with two separate feeds could be provided, however impacting the pricing model.

Efficiency and the environment

PUE is a common metric to measure data center efficiency. It has become increasingly popular primarily due to its simplicity. But PUE has also been criticized as it fails to provide a full view of the efficiency and environmental impact of a data center.

Figure 5 – ICT companies that have made 100% Renewable Energy Commitments (Cook, 2017).



Fortum Värme believes that green data centers of the future will source sustainable electricity to minimize environmental impact. Several major players have already made commitments to this effect and are moving ahead with investments in additional, renewable electricity, predominately with wind power (Cook, 2017). In December 2016, Google announced that it planned to run its entire company on renewable electricity as of 2017.

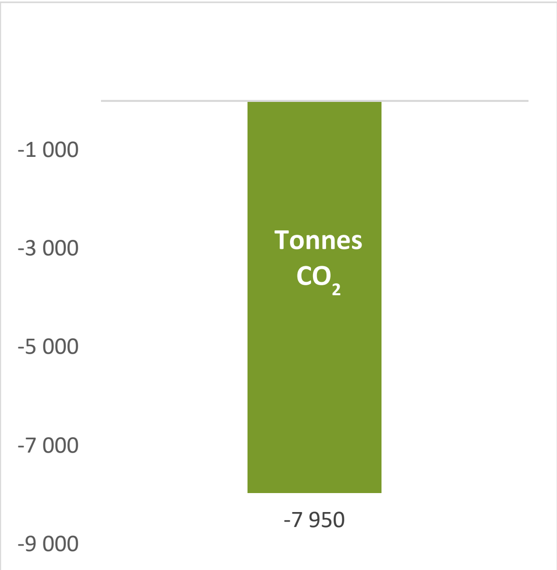
In this transition, Fortum Värme is making the same commitment as the major data center players, adding renewable capacity to the system for its electricity use in Stockholm Data Parks.

With a data center load of 10 MW in Stockholm, around 20 000 modern residential apartments could be heated, fuel resources used for incineration can be conserved and CO_2 emission reduced.

Deploying heat recovery, a green data center can become net climate positive. In Stockholm, a 10 MW data center load could reduce CO_2 emissions with close to 8 000 tonnes.

Whichever way you assess the impact of heat recovery in Stockholm Data Parks, it will always be better for the environment than competing cooling solutions. A data center without heat recovery can go from being climate negative to climate neutral, but never become net climate positive.

Figure 6 - Net CO2 tonnes of a 10 MW data center load with renewable electricity and Cooling as a Service with Heat recovery



Conclusion

With data centers enabling nearly all aspects of modern societies and their ever-increasing demand for energy, we need them to be not only cost efficient but also smart, sustainable and ideally part of fighting climate change.

The Stockholm Data Parks initiative contributes to phasing out fossil fuels in Stockholm. By 2040, the City targets to be fossil fuel free.

Joining Stockholm Data Parks and employing heat recovery, you make a significant contribution to reducing global CO_2 emissions. We offer a pricing model with zero OPEX for large data centers, and help you to make your data center truly green – even net climate positive.

References

Cook, G. (2017). *Clicking Clean: Who is winning the race to build a green internet?* Greenpeace.

Corcoran, P., & Andrae, A. S. (2013). *Emerging Trends in Electricity Consumption for Consumer ICT.* ResearchGate.

Shehabi, A., Smith, S., Sartor, D., Brown, R., Herrlin, M., Koomey, J., . . . Lintner, W. (2016). *United States Data Center Energy Usage Report.* Ernest Orlando Lawrence Berkeley National Laboratory.

Published January 2017.