ENGINEERING
TOMORROW

Powering Big Data with **Sustainable** Cooling

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DATA CENTER COOLING:

EMERGING TECHNOLOGIES, TRENDS AND OPPORTUNITIES

Making the case for **data centers** as a **profit center**

Emerging technologies, trends and opportunities are impacting the way that data centers perform the urgent and often challenging task of cooling their servers and other IT equipment and, just as importantly, proactively managing the required investment to the satisfaction of upper management while also minimizing the Power Usage Effectiveness (PUE), the data center's primary measurement of overall data center efficiency, defined as the total amount of energy used by the data center facility divided by the power used by the IT equipment.

The investment in data center cooling can be significant, and the responsibility is daunting. It's a rare operation of any kind that isn't wholly dependent on its data management foundation and overheating—which can occur in a swiftly escalating domino effect at a second's notice—can bring an entire global operation to a halt, stranding and impacting the productive time of hundreds or thousands of users.

The demand for data processing and storage was growing at a fast pace already when COVID-19 dramatically changed everything, including the way we work, and the sudden, steep and unprecedented increase in people working remotely rapidly escalated digital demand to record-high levels. And, even as the world returns to a more normal state, a reduction to prior levels of remote demand is unlikely.

Emerging technologies offer new opportunities to lower cooling costs

Most commonly, the cooling strategy of choice for many data centers is similar to what has been used for decades— generating cool air to lower ambient temperatures using chilled, water-based computer room air handling (CRAH) units or computer room air-conditioning (CRAC) units. Yet, the technologies and methodologies to do so have progressed significantly in multiple directions.

For example, the cool air is often better focused, brought closer and closer to where it is needed— from room, to row, to racks and even semiconductors increasing efficiency as the cooling is more targeted to the servers themselves where the heat is generated, and less "wasted" on cooling ambient surrounding air. Over the years, computers and servers have become more tolerant of higher temperatures; thus, the equipment doesn't have to always be kept in the "human comfort zone," instead just cool enough to maintain effective operation. In order for the cooling system to fully benefit from this change, the cooling equipment must be able to achieve higher leaving water setpoints.

Some traditional chiller technologies, such as those based on screw compressors, are not able to do this effectively. New computer equipment designs can operate at higher space temperatures, enabling chillers to generate leaving water temperatures as high as 82°F, reducing compressor power consumption and helping data centers reduce operating costs. Additional technologies, such as oil-free compressors, have been introduced as well in order to realize the full benefits of this type of system.

This new chiller capability of handling higher leaving water temperatures is better enabled by the advent of oil-free compressors, which do not require oil for lubrication because the motor shaft levitates in a magnetic field. In addition to potentially providing several efficiency gains and reducing energy costs, this technology can also potentially reduce maintenance costs for the data center. For example, there is no need to periodically change the compressor oil and oil filter, and there is no mechanical wear to the system since there is no metal-to-metal contact. Operations using oil-free

compressors can reduce their maintenance costs some 30 percent or more over those using traditional fixed-speed positive displacement compressors with oil management systems.

Another advantage of oil-free compressors is there is no performance degradation over their operational life. Because oil and mechanical wear have been eliminated, the performance remains consistent over time. Traditional oil-lubricated compressors on the other hand, can incur significant performance degradation over time due to mechanical wear and excess oil in the system, in some cases as high as 26% after 15 years of operation.

Often, companies look to improve their energy performance for environmental reasons as well as financial ones and are delighted by the reduction in carbon footprint that often moves in lockstep with reducing energy consumption. With an average annualized PUE of 1.57, data center losses are currently adding about 60% to the energy use of IT, and while more and more new builds are designed with PUE's of 1.3 or less, it is not economically or technically feasible for many operators to perform the major overhauls needed for better efficiency in many older facilities.[1] However, there are easy gains to be had from better airflow management, optimized controls and replacement of aging equipment. Further improvements might require significant change, such as retrofits with highly efficient cooling systems that have been completed with relative ease, either with modular oil-free chillers or chillers with a significantly smaller footprint than that of their predecessors as they are designed using oil-free compressors that are lighter and more compact.

Similarly, a move to different compressor technology often allows a move to a more environmentally benign refrigerant. For example, screw and centrifugal compressors today commonly use R-134a which has a Global Warming Potential (GWP) of 1400. Users of oil-free compressors have many environmentally friendly choices, such as low GWP refrigerants R-513A and R-515B, or ultra-low GWP refrigerant HFO-1234ze.

With recent chip developments leading to CPU/GPU power consumptions of 300 and 600 W or more, respectively, the limits of air cooling are approaching. Though not new, the idea of focusing cooling "closer to the heat" is a logical solution and chills servers directly by means of a cold plate placed on the server and connected to a chilled water loop that carries the heat outside. Another alternative design concept is submersion, with specially designed servers submerged in dielectric cooling fluid that rejects the heat directly from the server to the fluid.

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Cooling as a profit center, not a cost center – **moving beyond PUE**

Data center HVAC systems have long been managed as a cost center with the focus upon continually reducing the operating costs through various efficiency improvements. However, many companies today are benefitting from an emerging solution that replaces the cost model with an entirely new paradigm by which the expensively removed heat is not dissipated into the air but is instead recovered and sold as a valuable commodity to those who need it at the time. Considering how much energy is spent to heat buildings from scratch this is obviously a need waiting to be filled—especially in colder and temperate climates.

The general concept is familiar to many industries; in fact, many industrial plants use their waste heat in a cogeneration model where heat removed from a process, rather than being released into the atmosphere, is instead disseminated to another area of the facility that demands heat, i.e. improving the comfort of the office environment, heating water and generally reducing the amount of energy that must be otherwise generated or purchased from utility providers.

Data centers, with their 24/7 operation and constant stream of heat, are ready-made as a de-facto highly consistent and reliable "generator." Once that paradigm shift is made, there are some upfront infrastructure costs, the concept can pay for itself and become a profit center fairly quickly based on recent demonstration projects. If the data center is close to a district heating infrastructure, which collects and generates heat for dispersion to a nearby campus or even to an entire municipality, the supply infrastructure is ready made, but it can also be cost-effective to create a new grid around many campus-like facilities such as colleges or business parks where heat must be provided to many adjacent rooms and buildings.

Hyperscale and colocation data center companies with their mega-scale facilities especially have the flexibility to locate in northern climates, which they have been doing over the last several years, creating the heat recovery scale needed for these district heating systems. The higher data center operating temperatures also means that the heat pumps applied to maintain the cooling while also recovering heat operate at optimal efficiency, lowering the resulting heat price and justifying base-loading the heat source. Additionally, the data center 'critical facility' onsite backup power means a constant supply of recovered heat under demand response or other power interruption scenarios.

Oil-free compressors can help with this shift through recent advances that have expanded the operating map to support heating applications. "High Lift" oil-free compressors have the ability to generate higher leaving water temperature for use in heating applications which in the past have commonly used traditional oil-lubricated positive displacement compressors. Using oil-free compressors for this application brings the benefits of reduced maintenance and no performance degradation over the life of the compressor.

In this model, the HVAC system becomes a revenue-generator for the enterprise and can ultimately provide an energy source that would otherwise be wasted into the environment. Finally, this model can go a long way in any organization's efforts to reduce their carbon footprint and contribute toward their decarbonization and net zero emissions goals. ■

[1] *Ascierto, Bizo, David, Lawrence in Uptime Institute Global Data Center Survey 2021. 4-5 (Uptime Institute, 2021).*

INERTECH AND **DANFOSS** INNOVATE **MODULAR DATA** CENTER COOLING

> **In fact, data centers use nearly 2% of the world's supply of electricity at any given time, and 37 percent of that amount is used to keep computing equipment cool.**

A lynchpin of our modern economy, data centers demand the highest levels of security, reliability, and uptime. Server rooms power small- to medium-sized businesses, enterprise data centers support major corporations, and server farms host cloud computing services. Keeping up with the explosive growth of digital content, big data, e-commerce, and Internet traffic is making data centers one of the fastest growing consumers of electricity in developed countries.

In fact, data centers use nearly 2% of the world's supply of electricity at any given time, and 37 percent of that amount is used to keep computing equipment cool. Not only is this a drain on the power grid, but it also taxes water supply. A 15-MW data center can use up to 360,000 gallons of water a day — more than half the water in an Olympic-size swimming pool.

Data center power consumption is on the rise, increasing 56 percent worldwide and 36 percent in the United States from 2005-2010. These substantial energy demands come at a price, and controlling operational costs in data centers has been a persistent challenge. IT systems are designed to ramp up and down based on a businesses' use, yet cooling systems in data centers were not previously designed to do that.

Traditional data centers can incur excessive energy expenses from four main cost drivers:

- Over-building a data center;
- Underutilizing the data center that has been built;
- Inefficiently using cooling technology.
- Cost-saving energy solutions

Aligned Energy, an integrated technology platform, has developed a solution that eliminates infrastructure complexity and waste, heightens visibility and control, and improves reliability in data centers. One of Aligned Energy's subsidiary companies, Inertech, set out to address the key drivers of cost in data centers. With 80 percent of a data center's costs going toward the electrical and mechanical systems, Inertech determined that the only way to effect real change is to drive down the cost of the cooling system and electrical blocks.

Using Danfoss' portfolio of products and application expertise, Inertech was able to develop a solution for scaling mechanical and energy infrastructure directly to servers and storage use, which has yielded enormous savings in water and electricity costs.

Evaluating cost drivers

One of a data center's major upfront cost is in building chilled-water-based cooling infrastructure. The average data center is constructed to a "perceived build" based on the anticipated IT capacity. Companies try to predetermine the size of chiller plants needed to support IT; however, these calculations are highly complex and difficult to accurately predict. Often, companies significantly overbuild data centers from day one, unnecessarily inflating their capital costs.

Operators of existing data centers working under this model were spending nearly 85 percent of their capital expense upfront, but they were applying this capital toward equipment that was going unused. These operators would start up their IT operations and realize that they were running a much lighter load than they had built for.

Earl Keisling, CEO of Inertech, explained that, "IT systems are designed, like in the financial industry, to 'follow the sun around.' These systems are designed to support very high loads in a given area, whether it be Hong Kong or the London stock exchange, but have to be able to support low loads as well. The problem with the original technology is that they only work well when they're fully loaded, because that's what they were designed for."

Keisling added that when data centers are operating, they never draw more than 60 percent of the wattage listed on the server name plate. "Therein lies the problem — that you designed a system for servers, and your utilization is only a fraction of what that name plate is."

If companies overbuild their cooling systems or install products they aren't using, it is both operationally and fiscally inefficient. The lack of a supply chain model that scales products to requirements has fueled the perpetual repetition of this costly practice.

Click here to watch our video.

Collaboration between Danfoss and Inertech **yields innovative solution**

Using Danfoss products, Inertech's patented model has been able to reduce 80-85 percent of the cost of starting a data center on day one. On the operational side, because Inertech's cooling systems are 90 percent more efficient than a traditional chiller plant, it is able to drastically cut the electrical infrastructure that supports that data center for its customers.

Inertech did this by building a platform of small modular cooling blocks that can be scaled to actual IT use. It worked with Danfoss to identify critical components of the Danfoss portfolio that would enable Inertech to maximize efficiencies for energy and water use. The system design supports data center needs in a much more cost-effective delivery model than a traditional chiller plant, as the smaller platforms can be installed exactly when they are needed, or 'just-in-time,' without interrupting IT online operations. ■

Originally published in 2016

A QUEST FOR **PERFECTION** IN **DATA CENTERS**

NEXTDC is a market leader enabling business transformation through innovative data center outsourcing solutions, connectivity services and infrastructure management software. It provides enterprise-class colocation services to local and international organizations. In July 2012, its M1 Melbourne data center — a 15MW hyperscale colocation facility — went live.

NEXTDC is committed to sustainability and renewable energy, so it was no surprise when the M1 data center received a 4.5-star NABERS (National Australian Built Environment Rating Systems) rating in 2016 for incredible building performance. This excellent rating was reflective of NEXTDC's decision to install Smardt Chillers using Danfoss Turbocor® oil free compressor technology.

But that wasn't enough. They improved their systems even more, receiving a 5-star NABERS rating in 2019. The M1 data center became the first to ever receive 5 stars in Australia. Because of this reputation, maintaining and continuing its sustainable, efficient systems are essential to upholding its core business values and maintaining its 100% uptime guarantee for its customers.

Yet, that begs the question — how can you improve something that's already top-rated?

Test for the best

NEXTDC consulted with the Smardt Chiller Group, a longtime OEM partner of Danfoss, to help them further improve the efficiency of their cooling system. When they expanded in 2016, they added three more Smardt chillers to maintain maximum efficiency of their M1 Facility. In applications like data centers, the cooling system typically has a high number of run hours in order to protect the servers that generate quite a bit of heat on a 24/7 basis. This is quite different from traditional cooling applications for office buildings and schools, the system may only run 50% of the year. Therefore, any improvements in efficiency in the cooling systems in data centers can create major annual energy savings.

In recent years, data centers have been utilizing various technologies to cool their equipment in the most efficient way possible. Furthermore, they are pushing the operating envelope in the server rooms by operating at higher temperatures. This enables the chiller to consume less power but also challenges the compressor operating map. In response, Smardt collaborated with Danfoss to expand the operating map of their oil-free Danfoss Turbocor® compressors in order to allow it to operate at the higher water temperatures while also enabling operation at lower ambient conditions.

Compressors operating in these two areas, high chilled water temperatures and low ambient conditions, run at low compression ratios or "low lift." Operation in this area offers significant energy savings but requires some changes to the compressor. Smardt and Danfoss engineers overcame these challenges by developing a technology which implements software changes and other improvements needed to allow the oil-free centrifugal Danfoss Turbocor® compressor to run at low lift. The Smardt team then developed the software to optimize the operation in these low lift conditions.

Low-lift, high reward

With NEXTDC, Smardt piloted this new low-lift configuration, SmardtLift™, which was installed on one of their Smardt chillers at the M1 data center facility. The pilot proved that the chiller could run quite efficiently during low-lift scenarios. This means that it will activate when the ambient temperature of the data center is within an optimum threshold of what the cooling system requires. This method significantly cuts energy costs of the chillers — by 31% (depending on the ambient conditions)! This validation of savings paves the way for upgrading the remaining chillers and creating even greater savings for the facility as a whole.

This low-lift operation produces the highest efficiency possible today for oil-free chillers. Oil-free chillers also mean there is no performance degradation over time, where oil-based chillers typically lose 10-30% of their capacity and efficiency over the life of the chiller, mainly caused by oil coating the heat exchangers and acting as an insulator which inhibits optimum heat transfer (see ASHRAE 601 paper for more details).

The Danfoss Turbocor® compressor also provides improved reliability due to multiple compressor chiller configuration versus single compressor oil-based chillers.

Plus, because there is no oil system which hinders fast startup times, Smardt chillers powered by Danfoss Turbocor® offers 30-second fast re-start — the shortest restart time in the industry.

The solution has performed so well at the M1 Melbourne plant that NEXTDC has decided to roll out the SmardtLift™ low-lift chiller configuration across its fleet of data centers — improving their efficiency across the board.

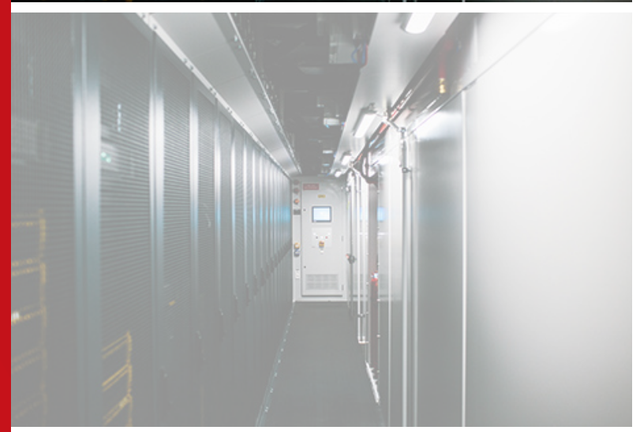
Total solutions provider

Not only were Danfoss and Smardt able to engineer a solution that can operate efficiently in low-lift conditions, but they also collaborated closely to validate this new solution. In this world class plant, the large heat exchangers and the variable-speed drives that were needed to complete the hydronic system were also manufactured by Danfoss. This demonstrates Danfoss' understanding of the total cooling system.

The solution has performed so well at the M1 Melbourne plant that NEXTDC has decided to roll out the SmardtLift™ low-lift chiller configuration across its fleet of data centers — improving their efficiency across the board.

Who knew that the trick to improving the most well-oiled machine was a customized oil-free chiller? ■

DANFOSS **DECARBONIZES** BY BUILDING **GREEN DATA** CENTERS



Data centers, the brains and beating hearts of the internet, are consuming vast amounts of energy. Energy to supply servers with power, but also to cool down server rooms and remove the huge amounts of heat they generate. It is estimated that 2% of all electricity is used within the IT ecosystem. This makes reducing the climate impact of digitalization a high priority.

In response to the exponential growth of data-center energy consumption, Danfoss decided to build a modular containerized data center that will be an example for future climate-friendly designs. Danfoss has the technologies to cool data centers in a greener way, to reduce energy consumption within them, and to reuse the excess heat for other applications.

> **"We cool our data centers in a very energy-efficient way, and we recover and reuse the excess heat produced within the data centers. This is what we consider green digitalization."**
>
> ***Sune T. Baastrup,*** *Senior Vice President and CIO of Danfoss Group IT*

Data centers as **power plants**

The technologies include chillers and heat pumps featuring Danfoss Turbocor® technology that allow data centers to be cooled up to 30% more efficiently and to recover excess heat generated by the data centers.

Decarbonization of data centers starts from the cooling side. Danfoss has a wide portfolio and expertise to reduce direct and indirect CO_2 emissions with lower-GWP refrigerants and energy-efficient solutions. Danfoss technologies are also optimized for operating conditions at higher temperatures to enable less need for cooling, thus naturally reducing the power consumption used for cooling.

In addition, Danfoss has innovative solutions for heat recovery. Excess heat is generated by server equipment as part of data center operation and is discharged into the atmosphere. Utilizing this excess heat for use in heating applications, instead of allowing it to escape, represents a massive opportunity for Danfoss to provide an environmentally friendly solution that will help the company reach complete global decarbonization by 2030.

> **"Data centers, with their 24/7 operation and constant stream of heat, are ideal as a highly consistent and reliable generator, while there are some upfront infrastructure investments, recent projects have indicated that the concept can pay for itself quickly."**
>
> ***Michael Strouboulis,*** *Director of Business Development for Critical Infrastructure at Danfoss North America*

The Danfoss **decarbonization**

An example of this concept is Danfoss' headquarters in Nordborg, Denmark. In 2015, it was heated 100% by fossil fuel. In 2022, it will be CO_2 neutral. And, in 2024, reused excess heat from Danfoss data centers will provide 25% of the overall heat supply for the 250,000 square meter of factories and offices.

Location plays a key factor to optimally utilize excess heat. The data center will be near the location of data use and where the local area can benefit from the excess heat. This provides the opportunity to use oil-free heat-pump systems to transform the data center into a heat source. The excess heat from the data center can then be distributed to a local neighborhood, helping to reduce the data center energy costs, and lowering greenhouse-gas emissions.

"The data centers of the future will be hybrid data centers where we combine the best of two worlds: the cloud and the on-site data center. And we utilize the excess heat in the energy grids close to where it is produced," Baastrup says.

Danfoss is on a digital transformation journey, consolidating 20 global data centers and 135 server rooms into a handful of data centers, which will all be built utilizing Danfoss green technologies.

> **"We put words into action. We have managed to build our own climate-friendly data centers, effectively in less than half a year. We want to show that digital transformation and green transition go hand in hand."**
>
> ***Sune T. Baastrup,*** *Senior Vice President and CIO of Danfoss Group IT*

CRUSHING THE DATA CENTER CHALLENGE

Data centers currently use nearly 2% of the world's electricity - as much as Great Britain - and emit as much CO_2 as all the world's airlines combined. We have the technology to cut down data centers' electricity consumption and use their surplus heat for heating homes.

The global need for data storage and processing is snowballing – from 1 zettabyte in 2010 to a projected 44 zettabytes in 2020. By 2025, global demand will be an estimated 180 zettabytes – the equivalent of every single person alive today needing 48 laptops for data storage.

Seen from a climate and energy point of view, the main challenge is cooling, since around 40% of a data centers power is used to cool its servers. And luckily the solutions are already at hand. Using technologies that are on the market, Danfoss helped Facebook make its data center in Luleaa, Sweden, the cleanest and one of the most efficient of its kind in the world.

High-pressure Danfoss pumps with capacities of 13,000 l/h cool Facebook's servers using mineral-free water that guarantees 100% sanitization – which is good for both employees and data. This system already saves Facebook 50% on costs. The data center is also solely hydro-powered and emits no CO_2.

In the U.S., Danfoss' compressors, heat exchangers and drives have helped Lenovo cut 90% of the electricity consumption in two of their data centers.

And another world-leading company estimated that for every 100 W used to power servers at its 40-building campus in San Diego, another 50 W were needed to cool them. With Danfoss' help, a 700-ton chiller was replaced by a new 1400-ton chiller with Turbocor® compressors that cut annual compressor energy costs by more than 30%.

But data center solutions can – and should – go way beyond cooling. In district heating systems – such as those that cover 64% of Denmark and are mainly based on renewable energy - we already have the technology to use surplus heat from data centers for household heating. As an example, Apple and Facebook's two data centers planned for construction in Denmark will be able to provide heating for 40,000 homes.

The US Department of Energy estimates that energy-efficiency improvements in data centers could save up to 33 billion kWh annually by 2020 - representing a 45% reduction compared to current efficiency trends. And that is only for the US. Globally, there are 8.6 million data centers.

We are already able to save up to 90% of the energy those data centers use for cooling. We can supply them with carbon-free, renewable energy and in some cases, use their surplus heat to keep households warm. These are all real solutions we can start implementing right now to crush the snowballing data center challenge. ■

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