The Mitsubishi Electric guide to

Data Centres:

Heat reuse for a low carbon future

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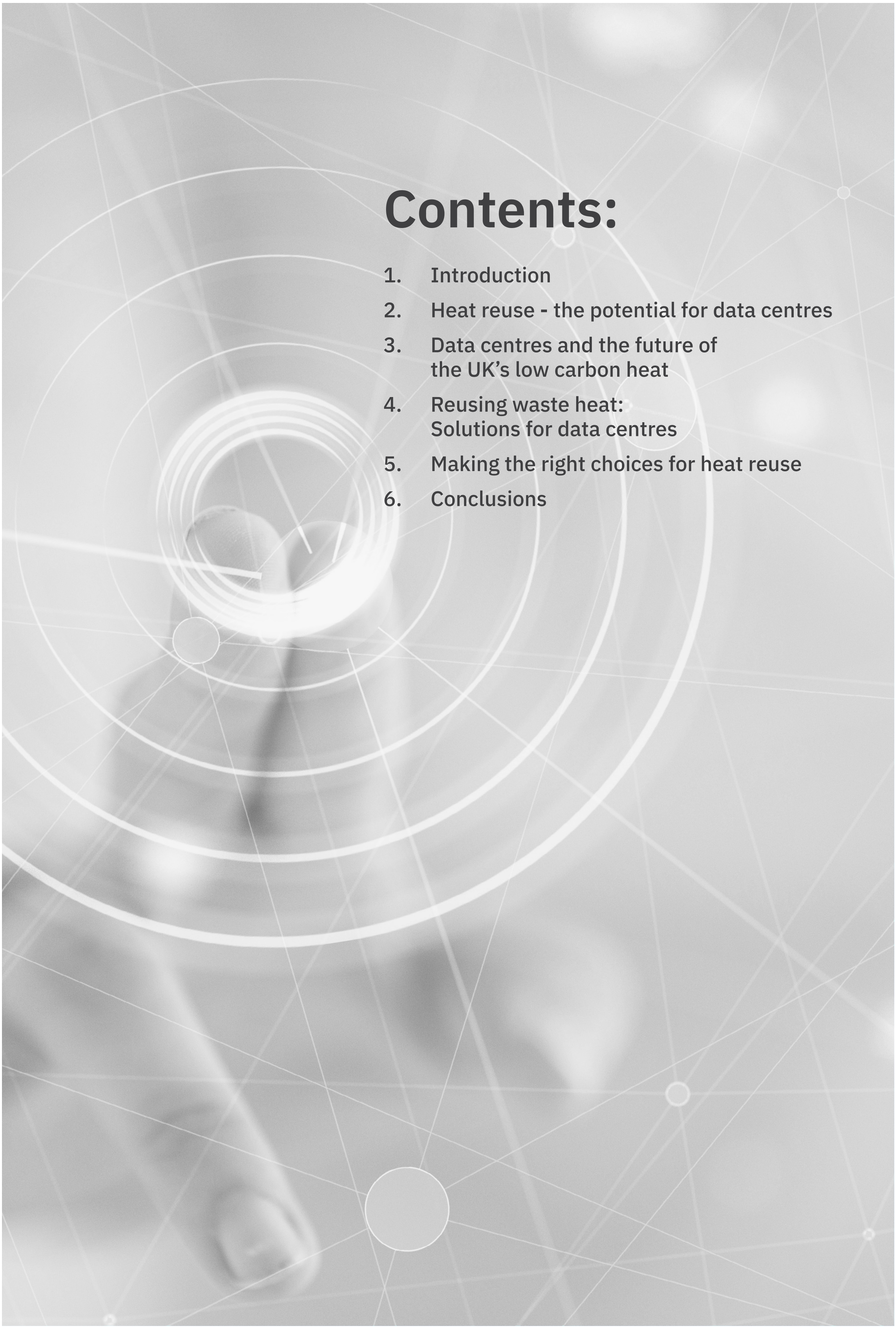

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Introduction

Data centres support the flow of information and communications that we rely on for almost every part of our lives - commerce, government, education and even entertainment. The technology used in data centres is advancing rapidly, particularly with the rise of artificial intelligence.

But data centres are significant energy users, and their impact on the global energy supply and the environment is a significant issue. Removing the heat produced during operation is a constant challenge and one that is becoming more complicated with new targets on efficiency and carbon emission reductions being set by governments and local authorities around the world.

These drivers include building regulations and local planning laws. Several countries have halted local data centre development due to their perceived impact on energy use and carbon emissions.

In addition, data centre clients are also increasingly concerned with the carbon footprint of their data use. They are therefore focused on working with providers in this field who can demonstrate low-carbon credentials. Overall, data centre developers and operators are under increasing pressure to provide robust, fault-free services while reducing energy use and emissions - a challenging balancing act.

There has been a great deal of focus on selecting cooling technologies to match building requirements while meeting energy-reduction targets. However, there is another way to approach this challenge: to view data centres as sources of heat energy that can be applied to other buildings.

Developments in heat pumps (which use low-grade heat as their energy source) and heat networks are making this scenario more achievable.

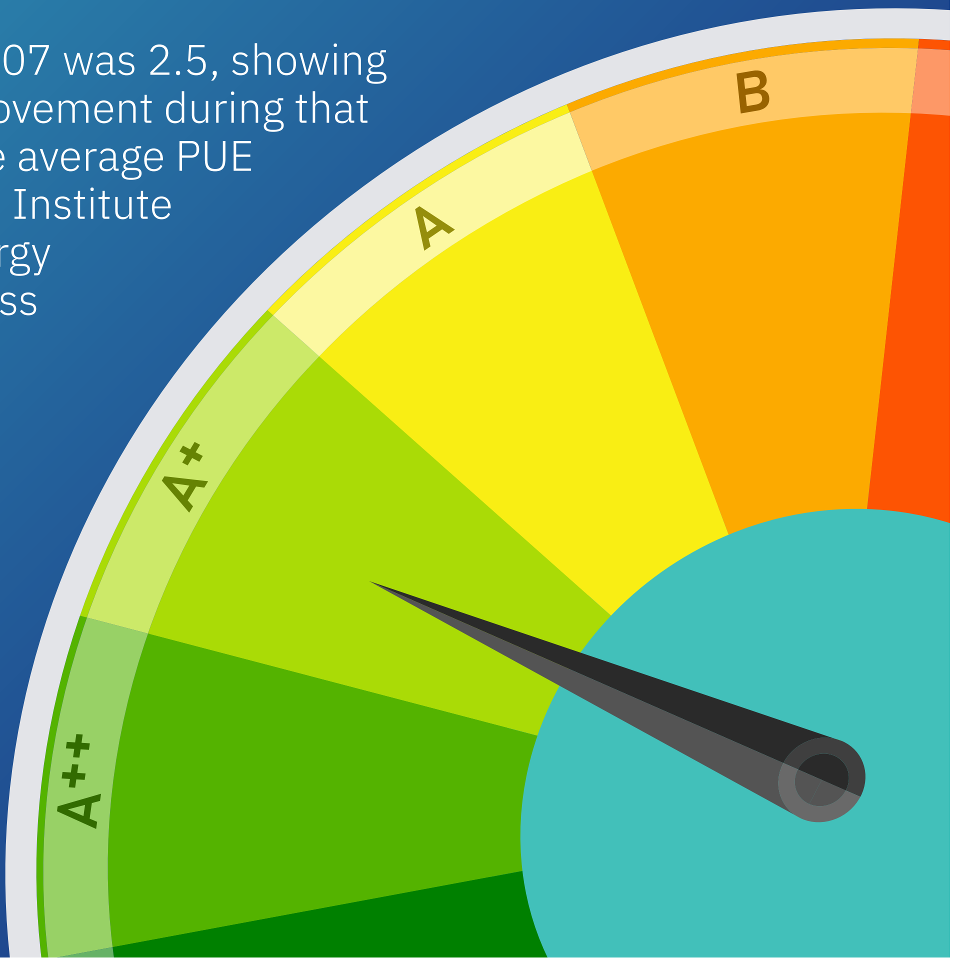
It's a method that has been adopted across northern Europe, and there is a growing opportunity to do so in the UK. By shifting the focus away from cooling and onto the reuse of heat energy, data centres have the potential to be a key factor in decarbonising UK heat.

Heat reuse - the potential for data centres

Data centre efficiency, commonly measured by power usage effectiveness (PUE). This is the ratio of the total energy used by a data centre (including IT load, cooling, lighting and other electrical systems) to the energy delivered to the computing equipment. The ideal PUE is therefore 1.0

However, the ability to continuously improve PUE is reaching its practical limits[1]. The Uptime Institute[2] 2022 global survey highlights that the average PUE in 2022 was 1.55.

The number in 2007 was 2.5, showing a significant improvement during that time. In 2021, the average PUE was 1.57, and the Institute notes that on energy efficiency, 'progress has slowed'.



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So, finding energy savings is becoming more challenging, even as global legislators expect continued improvements. In Europe, for example, the new Energy Efficiency Directive requires owners of data centres with a minimum capacity of 500kW to disclose energy performance[3]. There are also plans to introduce minimum sustainability performance standards for data centres by 2025. The objective is for data centres in the EU to be climate-neutral by 2030.

Germany is leading the way in acting on these targets. In September 2023, it introduced the Energy Efficiency Act with specific requirements for data centres in Germany[4]. For example, operational data centres must achieve a PUE of 1.5 or lower by 2027, and 1.3 or lower by 2030. Data centres which begin operations after 2026 must have a PUE of 1.2 or lower. Optimising efficiencies in cooling will be critical to achieve this level of improvement in data centre efficiency. However, reusing ejected heat is also being widely promoted as vital for the future of the sector as it aims to lower carbon emissions.

In the new German Energy Efficiency Act, the reuse of ‘waste’ heat is a requirement. This applies to all German business operations with an annual average energy consumption of more than 2.5 GWh. Data centres, in particular, will have to achieve 10% heat reuse from 2026, and 20% by 2028. This is measured as the Energy Reuse Factor (see below for more on ERF). There are exemptions to this rule, for example, if the data centre developer has an agreement with a local council for a heat network arrangement. At the wider European level, many data centre operators are adopting voluntary standards to help them achieve these ever-higher efficiency targets. The European Code of Conduct for Data Centres[5] provides insights for operators on improving energy efficiency in several areas.

The Code of Conduct[6] includes details on the reuse of data centre waste heat (Section 5.7), noting: “As IT equipment utilisation is increased through consolidation and virtualisation, the exhaust temperature is likely to increase, which will provide greater opportunity for waste heat to be reused.”

Alongside PUE, the Energy Reuse Factor (ERF) is set to become a vital consideration for the design and operation of data centres. ERF is a measure of the amount of reused energy divided by the total amount of electrical energy supplied to a data centre.

A new standard[7] ISO/IEC 30134-6:2021 Information technology - data centres key performance indicators - Part 6: Energy Reuse Factor (ERF)[8] provides a method for data centres to measure their performance in this area. The Standard defines reused energy as: "The utilisation of energy used in the data centre for an alternate purpose outside the data centre boundary. Energy ejected to the environment does not constitute reused energy." Microsoft[9] estimates that it is possible to achieve an ERF range of up to 69% during winter months and 86% in the summer. Mitigating factors include the type of cooling system used in a data centre and ambient temperatures.

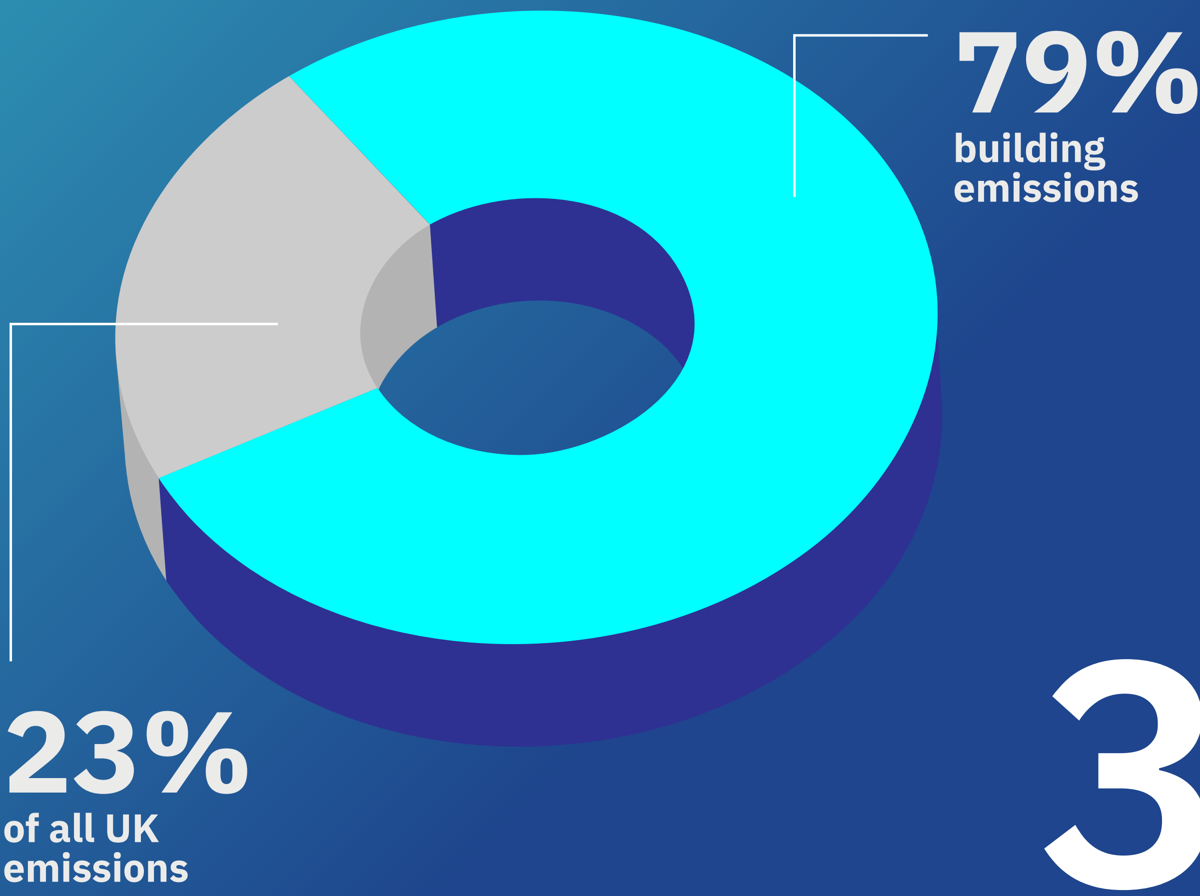
The World Economic Forum (WEF)[10] has recognised the significance of tapping into the heat produced by data centres. It estimates that the data centre heating market could be worth $2.5 billion by 2025. More importantly, data centres can help other buildings, including homes, become more sustainable by providing an alternative heat source. Leading data centre developers and owners are embracing the benefits of heat reuse, particularly in the Nordic region. In Odense, Denmark, Facebook's two 50,000m^2 data centres are linked to the local district heating scheme[11]. The data centre is powered by wind-generated electricity, making the heat entirely renewable. At full capacity, the system should recover 100,000 MWh of energy annually - enough to warm 6,900 homes.

In Helsinki, Finland, Microsoft[12] is working with heat network specialist Fortum to supply waste heat from its data centre to an existing network. This data centre also uses 100% emission-free electricity. The heat network serves businesses and homes on a 9,000 km network of pipes, making it the second-largest heat network in Finland. For data centre operators based in the UK, there are very few examples of data centres reusing heat at this scale. Our history with heat networks is limited when compared to northern neighbours, but changes in legislation are underway that will make both heat networks and heat recovery more achievable.

Data centres and the future of the UK's low carbon heat

The government's Heat and Buildings Strategy[13] points out that UK buildings are responsible for around 30% of national greenhouse gas emissions.

The vast majority of these result from heating: 79% of building emissions and about 23% of all UK emissions. Our reliance on fossil fuels for heating, particularly gas and oil, means that decarbonising heat is a top priority if we are to reach Net Zero greenhouse gas emissions by 2050. And data centres can play an important role in this low-carbon future for heat.



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In its Heat and Buildings Strategy, the government highlights two main technologies it regards as critical for this objective: heat pumps and heat networks. As we will see later, these technologies can successfully be used in tandem to provide low-carbon space heating and hot water for a range of building types.

Heat pumps are particularly useful for making the most of waste heat. Data centre output heat is around 30ºC to 35ºC. Heat pumps can use water at this temperature as a heat source, topping up the temperature to 70ºC to 80ºC. This heat energy can be used in the data centre building (or nearby buildings) for general heating. It can also meet domestic hot water (DHW) demand in washrooms and showers, for example. Alternatively, it can be used on a wider scale in heat networks.

The Climate Change Committee (CCC)[14] estimates that 18% of UK heat could come from heat networks by 2050 (up from 2% today). The government's Energy Bill factsheet[15] describes heat networks as: "A proven, cost-effective way of providing reliable, efficient, low-carbon heat... They are uniquely able to unlock otherwise inaccessible larger-scale renewable and recovered heat sources such as waste heat."

This final point is very important for data centre developers. Most of the UK's current 14,000 heat networks' primary fuel source is gas[16] – that must change. There is an opportunity to switch the perception of data centres as large energy users to significant sources of low-carbon waste heat.

UK heat networks - bringing down the barriers to development

Historically, the UK has not developed heat networks at the same scale as other northern European countries. This has made data centre connection to networks less likely, and perhaps more challenging to manage.

However, the UK's Net Zero 2050 objective is changing that, and new legislation will remove many of the barriers to entry for the development of new heat networks. This is already being recognised in the data centre sector. Research in 2023 by digital built asset specialist BCS[17] noted that more data centre developers are discussing the utilisation of waste heat and that the level of concern about its viability had fallen 15% year-on-year.

The increasing optimism about this approach is supported by the introduction of the Energy Act, which came into force in October 2023[18]. It brings heat networks, currently unregulated in the UK, under the control of Ofgem, making heat networks a regulated utility like gas and electricity.

The government is set to invest over £350 million in to scale up low carbon heat network deployment. This includes establishing heat network zones around the UK where connection will be mandatory for some buildings, and highly recommended for others.

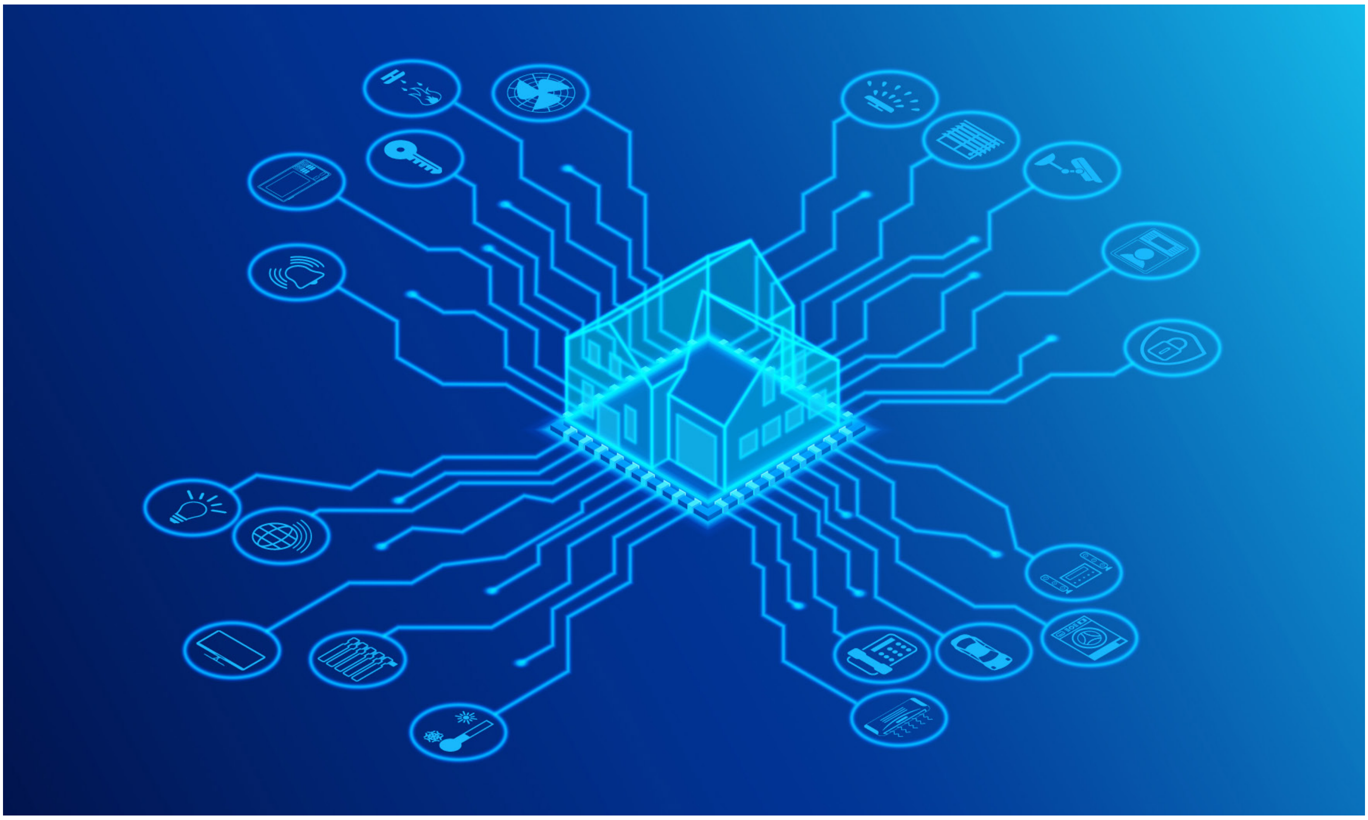
Heat recovery from industry (and data centres) will be encouraged, and there will be carbon emission limits set for heat networks to encourage the use of low-carbon heat sources. In addition, existing heat networks will be required to decarbonise by reducing their reliance on fossil fuels as heat sources.

Another factor making data centre connection to heat networks more viable is geography. London dominates the UK's data centre sector, and the city is now the largest market in Europe, with a capacity of over 1GW[19]. The London Plan 2021[20] includes a note (9.4.4) on future district heat networks in the city using heat from waste heat sources "such as building cooling systems".

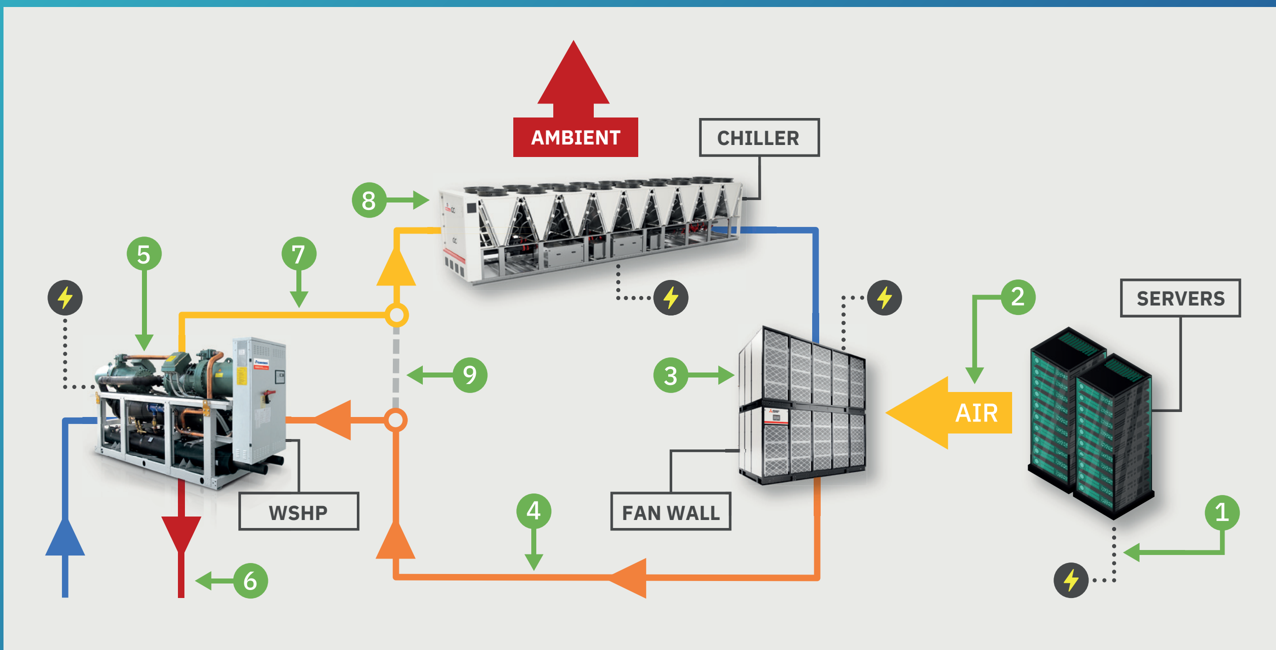
The London Plan also requires all major building projects to achieve carbon reductions of 35% below those required by the Building Regulations (Part L). Data centres must include emissions associated with the IT[21] process load in that measurement, adding to the challenge for designers and operators.

Other areas of the UK are also seeing growing interest as potential sites for new data centres. This is particularly focused around Manchester, Leeds and Cardiff, cities which have their own Net Zero targets, which are likely to influence future decisions around heat network use.

These sites correspond with the government's Opportunity areas for district heating networks across the UK[22]. The colocation of high heat demand (a critical factor for successful use of data centre waste heat) and cities with requirements for data handling points to a future where data centres could become low-carbon heat sources across the UK.



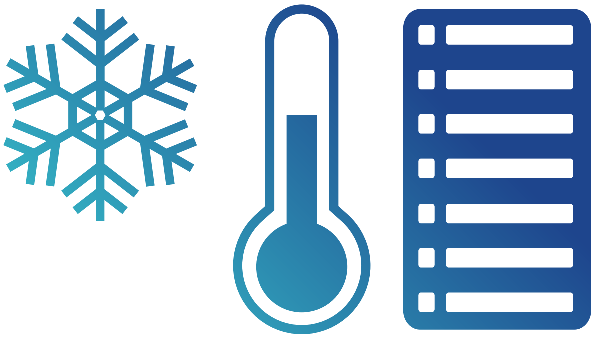
Reusing waste heat: Solutions for data centres



Reuse of waste heat from a data centre is theoretically straightforward, with several tried-and-tested technology options on the market.

1. Electricity that is provided to operate the servers gets turned into heat.
2. The fans on the servers reject the generated heat into the air.
3. This heat is captured by the fan wall's heat exchangers and is transferred into the data centres' hydronic circuit.
4. The captured heat travels through the hydronic circuit, aggregating together if there are multiple fan walls.
5. The WSHP* takes the heat from the hydronic circuit, enhances/boosts it before transferring it to the heat network.
6. This heat is sent to the local or district heat network for comfort or process heating.
7. Any heat that could not be used by the heat network (e.g. low demand in summer) continues in the data centres' hydronic circuit to the chiller.
8. The chiller then rejects all remaining heat to the atmosphere. It has the capacity to reject up to 100% of the heat produced by the servers, if required to do so.
9. A bypass for the WSHP is installed to enable service & maintenance and/or to control flowrate through the WSHP.

* Water Sourced Heat Pump



Several approaches to heat recovery can be applied, depending on a data centre's heat output and location. It is important to analyse the local heating load requirements in order to optimise the use of waste heat from a data centre. For example, it may not always be possible to connect a data centre to a heat network, but there are options for reusing rejected heat on-site.

For example, simultaneous heating and cooling chillers are particularly useful in data centres where there are coincidental heating and cooling loads. The heat extracted from areas that require cooling can provide heating to occupied spaces in or close to the data centre, such as offices. It can also boost the temperature of hot water to reduce the load on chillers that supply hot water for washrooms, showers or on-site restaurants.

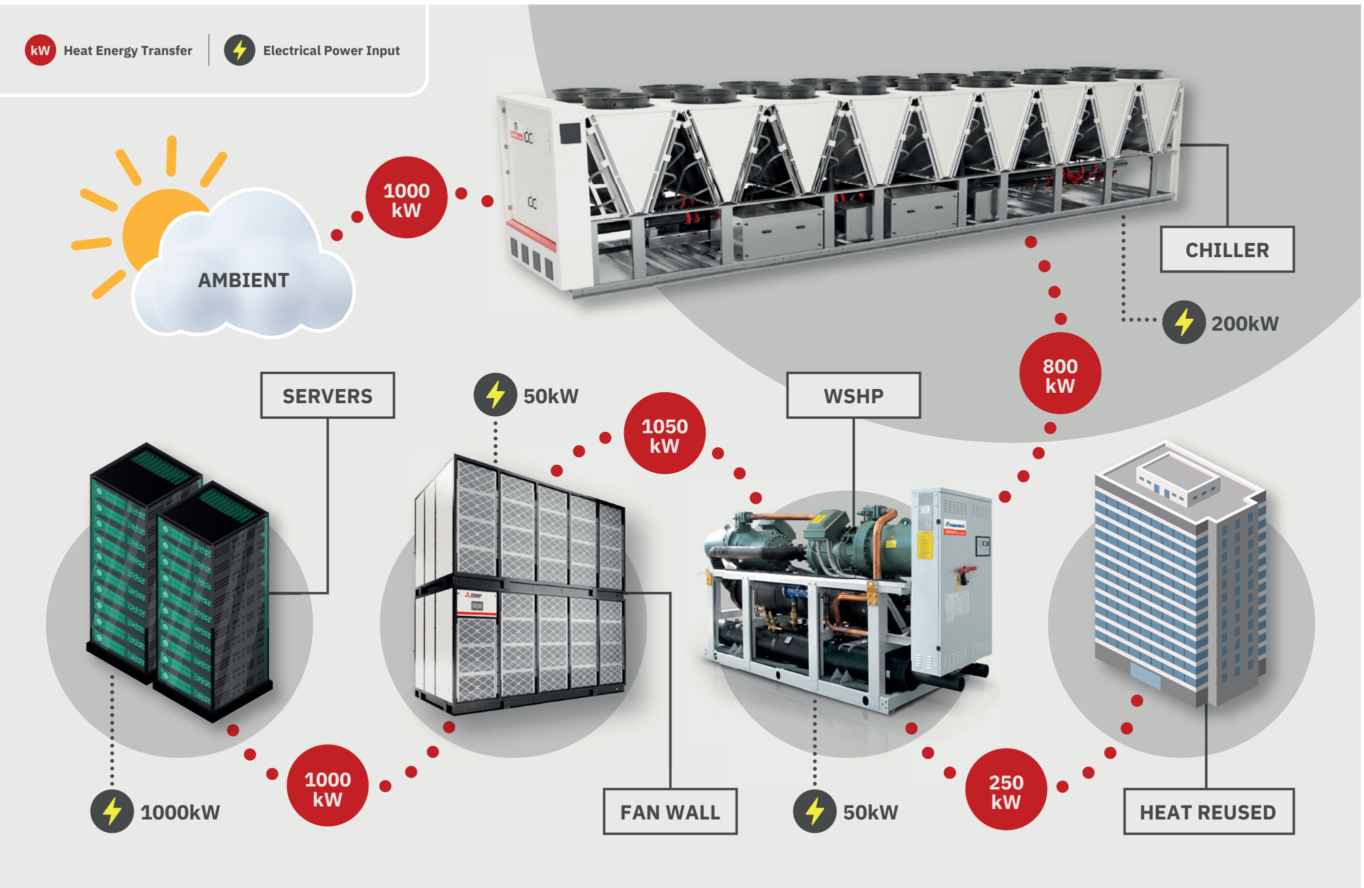
It is also possible to use a dedicated water source heat pump that uses the condenser water or return chiller water from the data centre cooling system as its energy source. It is an excellent approach for large, water-cooled chiller applications that improves the performance of large-capacity chillers and dedicated plant, enhancing the ROI of capital expenditure and improving long-term performance.

One of the primary benefits of using heat in this way is that no gas boiler is required since the system provides cooling and space / hot water heating.

In the diagram below we see an example calculation of our circuit diagram at the start of this chapter. In this setup, we are using a small Water Sourced Heat Pump (WSHP) to recover 250kW of heat, from the 1MW of electricity that is being provided to the servers. This heat could be used for the datacentre itself - and potentially reducing its overall PUE - or it could be used by other buildings or a district heating system.

It is significant because recovering the heat allows for an alternative energy consumer to be reduced or replaced - meaning that this system is giving 2 outputs; maintaining the servers performance, and providing heat, which in turn will improve the efficiencies of both outputs. If the heat being supplied is replacing a boiler’s output - then it is reducing direct emissions.

This scenario is described as partial heat recovery, however, it is feasible to design a system to perform total heat recovery. In that scenario all heat generated by the servers is recovered for alternative purposes and the chiller is on standby, with the capacity to reject all the heat in case of redundancy.



Example: Finland - A data centre at the heart of a carbon-neutral district heating scheme

Fortum, a Finnish energy company, is capturing the waste heat from a data centre to supply its heat network. The data centre has effectively become a heat production plant, with Fortum managing the cooling and heating process, leaving the data centre owner Ericsson to focus on its core business.

By using heat pumps, the same equipment can provide cooling for the data centre while also capturing 'waste' heat for the network. The system is based around two Mitsubishi Electric Hydronics and IT Cooling Systems (MEHITS) FOCS2-W heat pumps with 1 megawatt each of cooling capacity. These units have the additional benefit of using low GWP refrigerant (HFO 1234ze), which reduces the equipment's embodied carbon.

The heat pumps take heat extracted from the data centre and increase the temperature to 70ºC. This enabled Fortum to connect the data centre directly to the district heating system. The data centre currently delivers 2,200 GWh of heat annually, serving 7,000 customers on the network.

The data centre originally generated around 10,000 to 15,000 megawatt hours of waste heat annually. This has grown as the data centre IT load has increased over time. The heat pumps replaced an older cooling system which could not meet the increased cooling requirements.

Example: Tallaght - The Republic of Ireland's first low carbon district heating network

Another example of heat pump technology at the heart of a heat network that captures waste heat from a data centre to benefit local householders and larger buildings.

The system is based around two MEHITS FOCS2-W heat pumps by MEHITS, which use low-GWP refrigerant (HFO R1234ze). During normal operation, the heating demand from the network is fully covered by the data centre's ejected heat, while peak requests in winter are satisfied by dedicated heat pumps and a heat pump module, supplied by Mitsubishi Electric partner Nohewa.

The system is 1.5km long and will initially be heating 32,800m^2 of public sector buildings, while in 2024 133 rental apartments will be added to the network, and more public buildings will be connected in the years to come. The network is estimated to reduce pollutant emissions in the South Dublin County area by nearly 1,500 tonnes per year.

Making the right choices for heat reuse

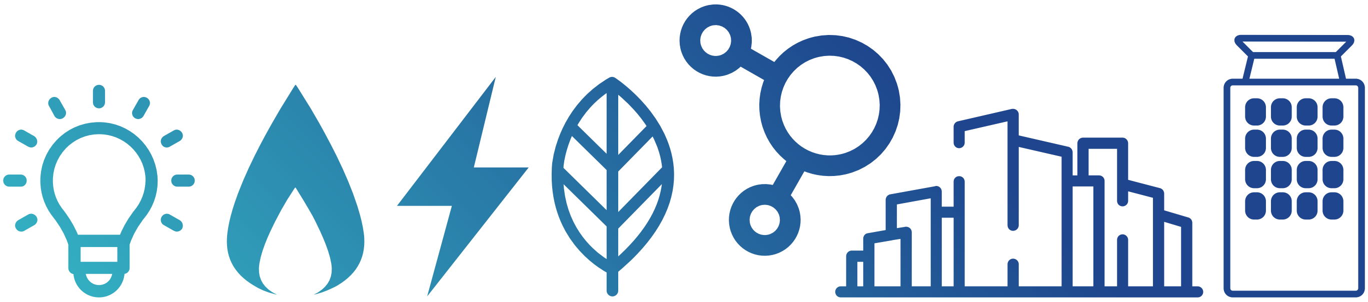
When considering heat reuse as an option for a data centre, there are several issues to address from the earliest stages of design and specification. For example, The European Code of Conduct for Energy Efficiency in Data Centres[6] includes advice on factors to consider around heat recovery (Section 5.7)

Each activity has been assigned a qualitative value to indicate the level of benefit to be expected from an action and the relative priorities that should be applied to them. These values are from 1 to 5, with 5 indicating optimum value.

These can be summarised as:

ACTIVITY	DESCRIPTION	EXPECTED	VALUE
Waste heat reuse	Evaluate the possibility of providing grade heating to industrial space or to other targets such as adjacent office space fresh air directly from heat rejected from the data centre. This does not reduce the energy consumed by the data centre itself but does offset the total energy overhead by potentially reducing energy use elsewhere.	In new-build and retrofit projects	4
Heat pump assisted waste heat reuse	Where it is not possible to directly reuse the waste heat from the data centre due to the temperature being too low it can still be economic to use additional heat pumps to raise the temperature to a useful point. This possibility should be evaluated and can potentially supply office, district and other heating needs.	In new-build and retrofit projects	4
Use data floor waste heat to warm office, generator and fuel storage areas	Evaluate reducing or eliminating the electrical preheat loads for generators and fuel storage by using warm exhaust air from the data floor to maintain temperature in the areas housing generators, fuel storage tanks and office areas.	Optional	2
Energy reuse metrics and reporting	The opportunity for the reuse of waste heat from data centres is referenced by the Energy Reuse Factor (ERF) and Energy Reuse Effectiveness (ERE) from The Green Grid) and should be used currently for reporting the use of waste heat, however as standardised metrics in this area continually develop. This is referenced by ISO/IEC 30134-6 Information technology - Data centres - Key performance indicators- Part 6: Energy Reuse Factor (ERF)	Optional* (This may be a requirement, depending on location of data centre and regional requirements for reporting)	1
Capture-ready infrastructure	Consider installing 'Capture Ready' Infrastructure to take advantage of, and distribute, available waste heat during new build and retrofit projects.	Optional	1

Table from 2023 Best Practice Guidelines for the EU Code of Conduct on Data Centre Energy Efficiency, section 5.7 on reuse of waste heat



Mitsubishi Electric has been involved in data centre waste heat use in heat networks across the world. Our experience has given us some useful insights. Our first advice when considering linking the data centre to a new or existing heat network is to ensure that there is a need for the waste heat a reasonable distance from the data centre - or that there is an existing heat network that can use extra capacity.

A successful match of data centre heat output and local heating requirements is what designers will look for when setting out these projects. Buildings which are close to the data centre, for example nearby offices or public buildings may not have high heat requirements, for example. However, heat networks which supply domestic customers have higher and more predictable heat demand profiles. Buildings such as hospitals, schools and leisure centres area also sources of heat demand to consider. Heat mapping is an important part of this, and the UK government has undertaken extensive research to identify areas where there is significant potential for heat networks.

It's then vital to understand what the cooling demand of the data centre is across the year, and to size and specify cooling equipment. The ideal solution is a water-to-water heat pump, or a heat pump chiller. The heat output of the heat pump can then be calculated to establish the annual heat output profile. It will be helpful to consider future data centre growth and how that could impact cooling requirements. It's also important to consider client goals for carbon footprint reduction. Consideration must be given to the embodied and operational carbon of equipment. Embodied carbon in products such as heat pumps is impacted by the type of refrigerant used. For instance, hyrdofluoroolefins (HFOs) have the lowest GWP (Global Warming Potential) on the market and are used in several Mitsubishi Electric heat pump options.

Conclusions

There is significant potential for data centres to adopt heat recovery solutions and become part of the UK's drive to decarbonise heating. It's already happening, as we saw in November 2023, the UK government awarded £36 million to a district heating system in West London which will share data centre waste heat with up to 10,000 new homes[23].

Framing the data centre sector as part of the solution for our decarbonised future, rather than simply an energy user, has clear benefits for future development and growth. However, heat networks are a relatively new approach to low carbon heat in the UK, so it is vital to work with partners who have experience of these projects at scale.

At Mitsubishi Electric, we have been working with data centre partners for decades and can bring unique insights into heat recovery and heat pumps from global projects.

6

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