Data Center Heat Reuse

Technology Innovation

Quick Insight

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The Heat Opportunity

Waste heat is a byproduct of many industrial processes, including power generation and manufacturing. Data centers generate significant heat due to the high energy and cooling demands of servers and equipment, often venting it into the atmosphere and missing opportunities for reuse. This brief outlines the potential for capturing and reusing data center waste heat, targeting data center operators, policymakers, and heat off-takers to drive energy efficiency and sustainability.

Data centers are high power density buildings where nearly all power is converted into heat that must be rejected, typically through active mechanical cooling (e.g., refrigeration or vapor compression) year-round. While the rise of AI (e.g., generative AI LLMs) is increasing total load and power density, non-AI growth also contributes to expanding data center operations. Capturing this rejected heat for beneficial reuse presents a significant opportunity, requiring collaboration among data centers, heat off-takers (e.g., district heating), and other stakeholders.

Maximizing the Heat Reuse Potential

Current Trends

- Immersion Cooling: Immersion Cooling: Expected to see expanded adoption in new data centers due to its high efficiency, despite higher costs. In this method, servers are completely or partially immersed in a dielectric fluid, which absorbs and dissipates heat, allowing for more effective temperature management compared to traditional air cooling systems.
- Direct-to-Chip Cooling: Growing rapidly with a 65% year-over-year increase, often integrated with heat reuse applications.
- Heat Reuse: Increasingly common, with data centers contributing to district heating systems and combined heat and power (CHP) projects.
- Market Growth: By 2028, DC Cooling Market could reach $16.8 Billion, growing at CAGR 18.4% between 2024-2028.

Who's Required

Addressing data center operators, regulators, and financial influencers is important. Operators are key in implementing and managing heat recovery systems. Regulators ensure compliance with environmental standards and provide incentives. Financial influencers fund these projects and assess their financial viability.

Why is this important

Heat reuse can enhance energy efficiency, reduce emissions, and promote sustainability in data centers. By leveraging innovative cooling technologies, they can achieve significant both environmental and economic benefits.

The Big Picture

Data centers are increasingly adopting advanced cooling systems and heat reuse strategies to improve energy efficiency and sustainability. In some jurisdictions, they might become mandated in the coming years. Heat Reuse can help reduce operational costs, lower carbon footprints, and comply with regulatory standards.

The Current Landscape & Feasibility

Current Landscape

- Large businesses, high-tech operations such as data centers, and governments are exploring innovative technologies to capture and reuse waste heat.
- Meta's data center in Odense, Denmark, has been operational since 2019 and uses heat recovery systems to capture approximately 100,000 MWh of energy annually, supplying 60°C+ water to a district heating network, enough to warm 6,900 homes(9).
- Stockholm, Sweden, integrates data center waste heat into a 3,000 km district heating network, with partnerships enabling recovery sufficient to heat 30,000 apartments annually. These systems are supported by advanced infrastructure developed since the 1970s(10).
- In the U.S., ARPA-E has funded numerous projects exploring novel waste heat recovery technologies, focusing on maximizing energy efficiency and enabling scalable applications across industries. From 2010 to 2015, ARPA-E funded projects such as General Motors' use of shape memory alloys to convert low-grade waste heat into energy and TEES's system to generate electricity from low-temperature heat streams. These efforts demonstrate ARPA-E's commitment to advancing scalable, data-driven waste heat recovery technologies(11,12,13).

Opportunity

- Studies indicate that up to 40% of DC energy input is lost as waste heat through exhaust gases, cooling water, and heat loss from equipment surfaces. Capturing and reusing this waste heat can significantly reduce primary energy consumption in industrial processes.
- The National Renewable Energy Laboratory (NREL) is developing the Urban Renewable Building and Neighborhood Optimization (URBANopt) platform to analyze the use of waste heat sources within geographically cohesive building districts. This tool facilitates the integration of waste heat into district energy systems, enhancing overall energy efficiency(14).
- Innovations in simulation-based design are enabling detailed analysis and optimization of waste heat recovery systems. These tools assist in identifying viable waste heat sources and designing systems for effective heat reuse(15).
- Innovative systems that simultaneously provide cooling and pure water production through condensate and waste heat recovery have been successfully designed and implemented, demonstrating practical applications of waste heat reuse(17).

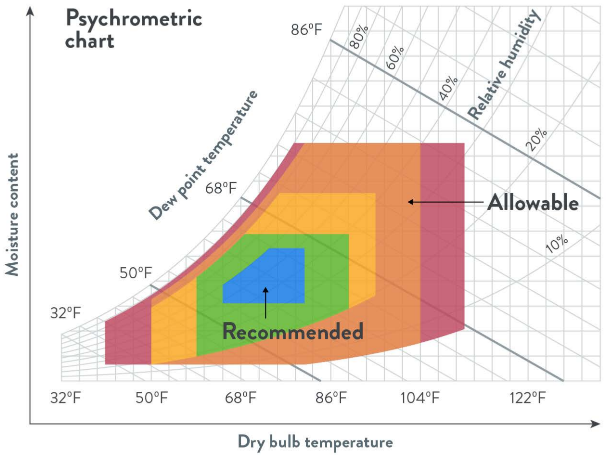
Background on Data Center Cooling Load

Data center cooling load refers to the amount of heat that needs to be removed from a data center to maintain optimal operating temperatures for IT equipment. Understanding this load is essential for designing efficient cooling systems and managing energy consumption. Cooling commonly represents 30-40% of data center energy consumption, in the United States. This percentage can vary depending on the type of data center, such as hyperscale, colocation, enterprise, location & cooling technologies used.

Factors Affecting DC Cooling Loads

- Servers & IT equipment
- Environmental Conditions
- Cooling System Efficiency
- Airflow Management
- Heat Gains – Latent (heat increasing moisture content) & Sensible (heat increasing temperature) heat gains
- Human occupancy (typically minimal)

ASHRAE Thermal Guidelines for Data Centers



Specialized Equipment for Data Centers

- **CRAC** (Computer Room Air Conditioner): Uses refrigerants and compressors to cool the air.
- **CRAH** (Computer Room Air Handler – Chilled Water): Uses chilled water to cool the air, often integrated with centralized chilled water systems.

Chillers (common for large data centers):

- **Air-Cooled Chillers**: Use air to dissipate heat.
- **Water-Cooled Chillers**: Use water, often with evaporative cooling towers, to dissipate heat.

Cooling Efficiency Considerations

Decrease in Chiller Efficiency with Increased Outdoor Temperature

- Chiller efficiency decreases as outdoor temperatures rise.
- The impact is less dramatic than in space conditioning because the cooling load in data centers remains relatively constant.

Economizers for Efficient Cooling

- **Types of Economizers**: Air-side, water-side, indirect evaporative, and pumped refrigerant.
- **Free Cooling**: Economizers enable "free cooling" when outdoor temperatures are favorable.
- **Climate and Indoor Conditions**: The number of hours of free cooling available depends on the local climate and indoor conditions.

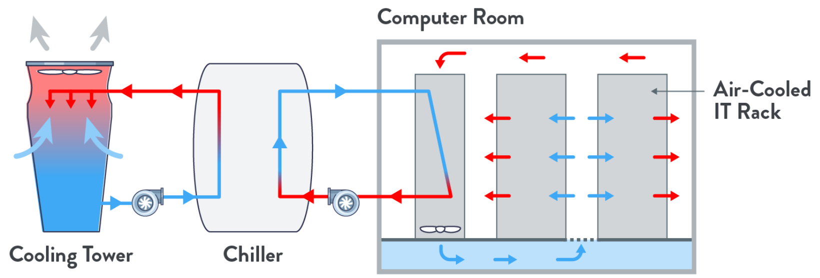
Standards & Guidelines

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) provides guidelines for safe operating temperatures and humidity levels in data centers. For most IT equipment, ASHRAE TC 9.9 recommends a temperature range of 18 to 27°C (64 to 81°F) and a relative humidity of up to 60%.

Example Large Data Center Cooling System

As AI increases power density and thermal loads, understanding the relationship between cooling methods and heat reuse becomes essential. Water-side cooling, with its higher efficiency in heat transfer, could expand effective heat reuse strategies in these high-density environments.

CRAH with water-cooled chiller and evaporative cooling tower



https://www.energy.gov/femp/cooling-water-efficiency-opportunities-federal-data-centers

System Efficiency and Benefits:

- **Energy Efficiency**: Water-cooled systems consume less energy compared to air-cooled systems.
- **Ability to handle high heat loads**
- **Scalability**: Suitable for large data centers with high cooling demands.

Challenges:

- **Higher initial cost compared to simpler systems**
- **Complexity of the system requiring skilled maintenance**

Operational Considerations:

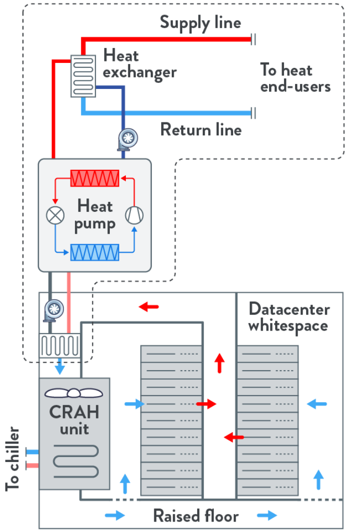
- **Maintenance**: Regular water treatment to prevent scale buildup and microbial growth.
- **Outdoor Temperature Impact**: Efficiency decreases with higher outdoor temps, but less dramatically than space conditioning due to constant cooling load.
- **Availability of Water:** The availability and quality of water are crucial for systems using water-cooled chillers and evaporative cooling towers. In regions with water scarcity, this can be a significant constraint. While liquid-cooled systems can be closed-loop, which minimizes water usage by recirculating the cooling fluid within a sealed environment, open-loop systems still rely on a continuous supply of water.
- **Water Sources:** Data centers can use potable water, treated effluent, or reclaimed/recycled water. However, the quality of water affects equipment longevity, with reclaimed water potentially causing more corrosion and scaling.
- **Water Usage Effectiveness:** Efficient use of water is essential to balance energy savings with sustainability goals. Metrics like Water Usage Effectiveness (WUE) help measure how efficiently a data center uses water relative to its power consumption for computation.
- **Environmental Impact:** Increased water usage can impact local water resources and sustainability objectives. It's important to consider the environmental footprint of water consumption in data center operations.
- **Regulatory Compliance:** Ensure compliance with local regulations regarding water usage and discharge. This includes adhering to guidelines for water treatment and disposal to minimize environmental impact.

Heat Recovery Configurations

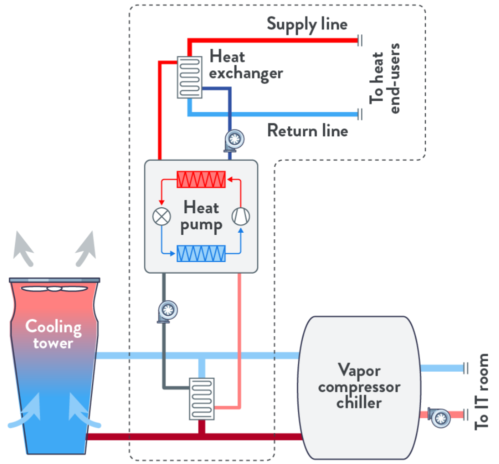
Air Side

- Widely applicable across cooling system types
- Performance limited by thermal capacity of air
- Direct heat exchange between exhaust and intake air
- Typically uses rotary heat exchangers or plate heat exchangers
- Can recover both sensible and latent heat
- Generally simpler to implement in existing facilities
- Efficiency can be affected by air quality and filtration requirements
- Well-suited for climates with significant temperature differentials
- Can be integrated with free cooling systems
- May require less pumping energy compared to water-side systems
- Potential for cross-contamination between airstreams
- Effectiveness can vary with humidity levels

Schematics of waste heat recovery at air side for CRAH cooling technology



Schematics of waste heat recovery at condensate water side (applicable to air-cooled system e.g., CRAH, rear door cooling and in-row cooling, water cooled systems and two-phase cooled systems)



https://www.sciencedirect.com/science/article/pii/S0306261919317969

Water Side

- Higher efficiency
- Requires water-cooled chiller
- Uses a water loop to transfer heat from IT equipment to other applications
- Can utilize heat recovery chillers or separate heat exchangers
- Allows for more flexible heat distribution over longer distances
- Generally more efficient for high-density computing environments
- Enables easier integration with district heating systems
- Can provide higher-grade heat suitable for various applications
- Requires additional infrastructure (piping, pumps, heat exchangers)
- Offers better control over heat quality and quantity
- Less affected by outdoor air quality issues
- Can be combined with thermal energy storage systems

What fits your needs?

Aspect	Air-Side Heat Recovery	Water-Side Heat Recovery
Mechanism	Utilizes outside air to cool the data center by bringing in cooler external air and exhausting warm internal air.	Uses chilled water to absorb heat from the data center and dissipate it through cooling towers or heat exchangers.
Efficiency	Highly efficient in cooler climates where the outside air temperature is significantly lower than the indoor temperature.	More efficient in a wider range of climates compared to air-side systems.
Implementation	Easier to implement in regions with mild to cold climates. Requires proper filtration and humidity control.	Requires a reliable water source and proper water treatment to prevent scaling and corrosion. Suitable for large data centers.
Benefits	Lower operational costs due to reduced reliance on mechanical cooling. Can significantly improve Power Usage Effectiveness (PUE).	Provides consistent cooling performance regardless of outdoor air quality. Can offer cooling redundancy, reducing the risk of downtime.
Challenges	Limited effectiveness in hot and humid climates. Potential issues with air quality and humidity control.	Higher initial setup costs due to the need for cooling towers and extensive plumbing. Water availability and quality can be a constraint.
Climate Suitability	Best for cooler climates.	Versatile across different climates.
Energy Savings	Substantial energy savings by leveraging natural cooling.	Significant energy savings by reducing the load on mechanical chillers.
Operational Considerations	Requires careful air quality and humidity management.	Depends on water availability and treatment.

Aspect	Water-Side Heat Recovery	Air-Side Heat Recovery
Scalability	[green]	[red]
Energy Efficiency	[green]	[red]
Implementation Complexity	[red]	[green]
Heat Quality for Reuse	[green]	[red]
Maintenance	[green]	[red]
Climate Dependecy	[green]	[red]
Space Requirement	[red]	[green]
Flexibility	[green]	[red]
Initial Cost	[red]	[green]
Regulatory Compliance	[red]	[green]

Existing Technologies

Heat recovery chillers

- Dual-purpose machines: simultaneously produce chilled water and useful heat
- Efficiency: Can achieve combined COP (Coefficient of Performance) of 7 or higher
- Flexibility: Adjustable ratios of cooling to heating output
- Integration: Can work with existing chilled water systems
- Applications: Data center cooling + space heating, domestic hot water, or industrial processes

Thermal Storage

- Purpose: Balances intermittent heat production with constant demand
- Types: Water tanks, phase-change materials, underground thermal energy storage
- Benefits: Load shifting, peak shaving, improved system efficiency
- Scalability: From small buffer tanks to large seasonal storage systems
- Integration: Can enhance both cooling and heating capabilities of data centers

Thermal Energy Networks / Districts

- Concept: Distribute recovered heat to nearby buildings or facilities
- Scale: Can serve individual campuses or entire city districts
- Infrastructure: Requires insulated piping systems and heat exchangers
- Efficiency: Reduces overall energy consumption and carbon emissions
- Economic model: Potential new revenue stream for data centers

Synergies

- Heat recovery chillers can feed into thermal storage systems
- Thermal storage enables more effective use of thermal energy networks
- District systems can provide a consistent demand for recovered heat
- Combined approach maximizes energy efficiency and heat utilization

Challenges

- Initial infrastructure costs
- Coordinating supply and demand
- Maintaining water quality in storage and distribution systems
- Regulatory and contractual complexities in district systems

Planned Heat Reuse Demonstrations

The potential applications of heat reuse are vast and depend on the local climate. In cold climates, waste heat can be used for district heating, warming buildings, and even melting snow on roads and sidewalks. In hot climates, the heat can be absorbed to improve the efficiency of cooling systems or even to cool the data centers themselves. This not only reduces the energy demand of the data center but also reduces the need for additional cooling resources, leading to further energy savings.

Several cities and companies around the world have already begun to harness the power of waste heat. Waste heat from data centers is being used to heat homes and businesses. Microsoft has implemented heat pumps in their data centers, leading to significant internal efficiency gains. Amazon has also made strides in this area, using waste heat to warm their office buildings. Furthermore, underground data centers offer a unique opportunity for heat reuse, as the stable year-round subterranean temperatures allow for efficient heat exchange.

Microsoft & Fortum – Helsinki, Finland

- A collaboration between Microsoft and Fortum, aims to capture waste heat from a new Microsoft data center to provide heat for 250,000 residents.
- The data center will consume 100% emission free electricity and will transfer the waste heat recovered from the servers through the connected district heating system. The operation would be the largest of its kind in the world.
- The effort aims to provide heat for homes, services including public buildings such as schools, hospitals, and office buildings and businesses.
- The collaborative effort will result in reduction of 400,000 tons of CO_2 by displacing fossil fuels for meeting up to 60% of the regions heating demands

Amazon – Dublin, Ireland

- A partnership between Amazon Web Services (AWS) & South Dublin County Council (SDCC) with an aim to recycle heat from AWS data center in Tallaght to provide low-carbon heat to the local community. The project will contribute to Ireland achieving its 2030 sustainability targets and Amazon being net zero by 2040.
- The heat from the data center is drawn from its hot aisles and run through a heat exchanger. The heat exchanger heats up water that is delivered to a nearby heat pump.
- The system will initially heat 47000 m^2 of public space, 3000 m^2 of commercial space and 135 rental apartments. This will result in reduction of 1500 tons of CO_2 and supply low-cost low-carbon heat to Tallaght town center. AWS will be providing the heat free of charge for this scheme.

Heat Reuse from the Facebook Datacenter in Denmark

The Facebook data center in Odense, Denmark, is demonstrating today how waste heat can be repurposed to benefit the local community.

Project Highlights:

- Heat Recovery Process: Hot air from the servers is directed over water coils to heat water, which is then used in a district heating network.
- Renewable Energy: The data center is powered by clean and renewable wind energy, further enhancing its sustainability.

Emissions Avoided:

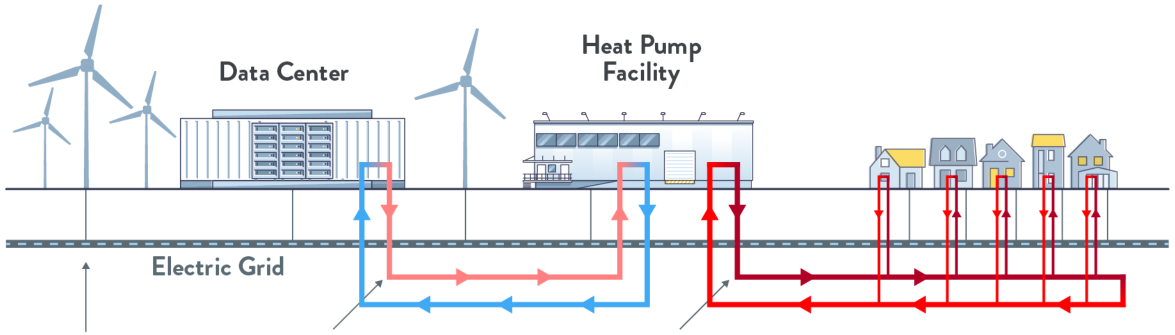
- The emissions avoided are due solely to heat recovery efforts, not including wind power contributions.

Heat Reuse Applications:

- District Heating: The data center's waste heat is used to warm nearly 7,000 homes in the local community.
- Environmental Impact: This initiative helps reduce the city's carbon emissions by utilizing 100,000 MWh of excess heat annually.

Benefits:

- Energy Efficiency: Reduces the need for additional heating sources, lowering energy consumption.
- Environmental Impact: Decreases carbon footprint by utilizing waste heat to offset fossil fuel use (reducing Odense’s coal use by up to 25%).
- Cost Savings: Potential revenue by selling waste heat to district heating systems.



https://sustainability.fb.com/wp-content/uploads/2020/12/FB_Denmark-Data-Center-to-Warm-Local-Community.pdf

Challenges with Heat Recovery & Reuse

Data centers require reliable cooling (24x7x365) to prevent overheating and ensure continuous operation. However, with the use of economizers, the heat output of data centers can be quite variable, especially when external temperatures are low. This variability poses a challenge in finding heat reuse applications that match the timing of heat output. When heat reuse applications cannot meet the demand, a primary heat rejection system is necessary to handle the entire load. Additionally, data center waste heat is typically low temperature and may require heat pumps to boost it to useful temperatures for industrial applications. Thermal storage or other technologies may be needed to manage mismatches between heat output and reuse demand.

Infrastructure Investments

Data Centers have faced high initial costs to integrate heat recovery systems into the existing infrastructure. This included installing heat exchangers and connecting to the district heating network.

Regulatory Frameworks

Data center operators had to navigate complex regulatory requirements to ensure compliance with local environmental standards and obtain necessary permits for heat reuse projects.

Technological Challenges

A data center in Frankfurt encountered difficulties in optimizing heat exchangers and heat pumps to efficiently capture and transfer low-grade heat, which required advanced engineering solutions.

Economic Consideration

In Paris, data centers had to justify the economic feasibility of heat reuse projects to investors, balancing the high upfront costs with long-term savings and potential revenue from selling excess heat.

Collaboration

A data center in Amsterdam struggled with coordinating between multiple stakeholders, including local governments, utility providers, and community organizations, to establish a successful heat reuse initiative

Seasonal Variability

In Copenhagen, data centers experienced fluctuations in heat demand throughout the year, leading to challenges in managing oversupply during warmer months. They implemented seasonal thermal energy storage solutions to store excess heat for use during colder periods

Heat Storage and Transport – Challenges & Technology Innovations

Challenges:

Storage of Heat: Data centers generate a continuous demand for cooling, and effectively reusing waste heat requires balancing this steady output with variable external heating needs. Thermal energy storage (TES) systems offer a solution by storing excess heat when demand is low and releasing it during peak periods, ensuring efficient utilization of recovered energy. While water is a widely used and effective medium for TES, its application in data centers can be limited by the large storage volumes required, which may be impractical in space-constrained environments. Advanced TES solutions are needed to optimize heat storage in data centers and align constant heat output with fluctuating external demand.

Transportation of Heat: Efficiently transporting waste heat from data centers to locations where it can be reused is challenging due to heat losses during transmission. To mitigate these losses, innovations in insulated piping systems and the development of heat transfer fluids designed to operate at higher temperatures are essential. These technologies aim to minimize energy loss and maintain higher efficiency over longer distances [*Current, Projected Performance and Costs of Thermal Energy Storage, MDPI*].

Geographic Proximity: The effectiveness of waste heat recovery in data centers is often constrained by the need for close proximity between the data center and heat users. This geographic limitation restricts the range over which waste heat can be effectively transported and utilized. Developing decentralized thermal energy networks that connect multiple data centers and users can distribute heat more effectively, overcoming the limitations imposed by geographic constraints [*Waste Heat Recovery, Energy.gov*].

Technology Innovations:

Phase Change Materials (PCMs): PCMs can enhance the heat storage capacity of data centers by absorbing and releasing heat during phase transitions. This technology allows for more compact and efficient thermal storage, suitable for data centers where space is at a premium. Despite their cost, PCMs provide a high energy density solution, making them effective for applications where rapid temperature regulation is required [*Latent thermal energy storage technologies and applications: A review, ScienceDirect*].

Localized Thermal Grids: Creating localized thermal grids specifically for data centers can facilitate the efficient redistribution of excess heat within a confined geographical area. These grids utilize insulated pipeline technologies to connect nearby facilities that can benefit from the waste heat, such as office buildings or industrial sites, minimizing energy loss and optimizing heat use [*Industrial Thermal Energy Storage, ScienceDirect*].

Innovative Heat Transfer Enhancements: Innovations like microchannel heat exchangers and the use of nanofluids in data center cooling systems can significantly enhance heat transfer efficiency. These technologies enable more effective heat removal and transfer in compact spaces, reducing the energy required for cooling and allowing for more efficient waste heat recovery and reuse within or near data centers [*Micro/Nanomaterials for Heat Transfer, Energy Storage and Conversion, MDPI*].

Sustainability & Financial Opportunities of DC Heat Reuse

- ***Improved Energy Efficiency:***
  - Heat reuse can lower overall energy demand by capturing waste heat for external use. While cooling systems are typically required to recover heat, optimized designs — such as heat exchangers or direct recovery systems — can offset the energy consumed by cooling, improving Power Usage Effectiveness (PUE). Waste heat recovery significantly reduces non-IT energy consumption, improving overall efficiency
  - Combined with renewable energy, recovered heat can help data centers achieve energy-neutral or energy-positive operations
- ***Circular Economy Integration:***
  - Transform an unused byproduct into a resource to supports external heating needs.
  - Create closed-loop systems within the data center facility
- ***Water Conservation:***
  - Reduce water consumption for cooling towers by reusing heat for on-site purposes
  - Potential for water recycling in heat recovery systems
- ***Carbon Footprint Reduction:***
  - Lower greenhouse gas emissions by reducing reliance on external energy sources
  - Potential for carbon credits or offsets through heat reuse initiatives
- ***Biodiversity Support:***
  - Excess heat can support on-site greenhouses or biodomes designed for biodiversity-focused projects, such as research into resilient plant species or seed banks for preservation efforts.
  - By creating controlled environments tailored for diverse flora, data centers can contribute to conservation initiatives rather than conventional agricultural use, promoting local or endangered plant species.
- ***Thermal Management Innovation:***
  - Drive development of more efficient heat capture and transfer technologies
  - Encourage integration of phase-change materials for thermal management
- ***Operational Resilience:***
  - Reduce dependence on external energy sources for heating needs
  - Improve ability to operate in various climatic conditions
- ***Sustainable Building Design:***
  - Integrate heat reuse into the architectural design of data centers
  - Create multi-functional facilities that showcase sustainable practices
- ***Environmental Compliance:***
  - Meet or exceed environmental regulations and standards
  - Position for future carbon taxation or cap-and-trade systems
- ***Sustainable Cooling Alternatives:***
  - Enable use of higher temperature cooling methods, reducing refrigerant use
  - Facilitate transition to natural refrigerants or refrigerant-free cooling systems
- ***Heat-Driven Dehumidification***
- ***Thermal Energy Storage Integration:***
  - Implement on-site thermal storage to balance heat production and utilization
  - Enhance overall energy system flexibility and efficiency

Financial Opportunities in Heat Reuse

- ***Revenue Generation:*** Data centers can monetize waste heat by selling it to nearby facilities or integrating it into district heating networks. For example, in 2020, data centers in Germany consumed approximately 16 TWh of electricity, with a significant portion dissipated as waste heat. If 50% of this waste heat were recovered and sold at €50 per MWh, it could generate around €400 million annually. This potential is expected to increase as data center energy consumption rises, presenting significant future revenue opportunities.
- ***Cost Considerations***: Implementing waste heat recovery systems, such as Organic Rankine Cycle (ORC) technology, involves initial investments. Studies have shown that ORC systems in data centers can achieve payback periods ranging from approximately 4 to 7 years, depending on factors like system design and scale. Considering that both data centers and ORC systems have operational lifespans of around 20 years, these systems can generate net revenue after the payback period.
- ***Regulatory Compiliance:*** Some regions mandate heat reuse; for example, Germany's Energy Efficiency Act requires data centers to achieve 10% heat reuse by 2026 and 20% by 2028. Such regulations can enhance the financial viability of heat recovery projects.

Regulatory Environment

	DENMARK	NORWAY	NETHERLANDS	GERMANY
Regulatory initiatives and proposals	Removal of tax on excess heat New price regulation on excess heat	Requirement for planned data centers above 2 MW to assess the potential to utilize excess heat	Data centres must explore the use of excess heat for heating nearby homes	Draft of the Energy Efficiency Act: Mandatory reuse of 30% and (later) 40%
Political focus on excess heat	✓	✓	✓	✓
Proposed DC heat recovery regulation	✗	✓	(✓)	✓
Example of excess heat recovery	Meta's data center in Odense is supplying excess heat to 7,000 households	Excess heat recovery and use in Hima Seafood's trout farm (world's largest trout farm)	NorthC data center south of Amsterdam	Pilot project on excess heat recovery in Frankfurt to supply 1,300 apartments

EU INITIATIVES

Energy Efficiency Directive (EED): Mandates energy efficiency improvements, including heat reuse from data centers

Renewable Energy Directive (RED): Encourages the use of renewable energy sources and supports the integration of waste heat into district heating systems

Energy Performance of Building Directive (EPBD): Promotes the use of waste heat in building heating systems

National Programs

Denmark: Requires data centers to donate a portion of their surplus heat to district heating systems

Finland: Offers tax incentives for data centers that implement heat reuse technologies

France: Local governments provide grants for infrastructure projects that integrate data center waste heat into municipal heating networks

Germany: Regional initiatives support the development of heat reuse projects through subsidies and technical assistance

U.S.: 48C Manufacturing Tax Credit Offers up to 30% tax credit for investments in advanced energy projects. This can be utilized by data centers to implement heat recovery systems, promoting sustainable heat reuse and reducing operational costs.

INDUSTRY STANDARDS & GUIDELINES

Open Compute Project (OCP): Provides guidelies and best practices for data center heat reuse

European Data Centre Association (EUDCA): Offers resources and advocacy for regulatory frameworks supporting heat reuse

Advancing Heat Reuse Practices

Enhancing Heat Reuse in Data Centers Through Strategic Initiatives

To accelerate the adoption of heat reuse practices, data centers can focus on the following key strategies**:**

- **Initiate Pilot Projects:** Design and implement targeted heat reuse pilots tailored to data center environments to evaluate feasibility and scalability.
- **Foster Partnerships:** Collaborate with local facilities, district heating networks, and industries to integrate waste heat into broader energy ecosystems.
- **Drive Technological Innovation:** Invest in advanced heat recovery systems and operational strategies optimized for data center applications.
- **Operational Optimization**: Integrate heat reuse into data center design and operations through advanced thermal management, predictive analytics, and dynamic load balancing.

By implementing these strategies, data centers can reduce operational costs, lower carbon emissions, and contribute to sustainable energy ecosystems.

Research Questions Focused on Data Centers

- **Overcoming Market Barriers for Data Centers**: Further research and development are needed to address specific market barriers that limit the adoption of heat reuse technologies in data centers, such as high initial costs, infrastructure constraints, and regulatory challenges.
- **Identifying Optimal Applications for Data Center Heat Reuse**: Research should focus on identifying the most suitable applications for heat reuse in data centers, such as integrating with nearby district heating networks, providing heating for adjacent buildings, or supporting other local industries.
- **Developing Advanced Heat Reuse Technologies for Data Centers**: There is a need for the development of advanced technologies specifically designed for data center applications, including high-temperature heat pumps, compact thermal storage systems, and integrated thermal energy networks that can efficiently capture, store, and redistribute waste heat.
- **Field Demonstrations in Data Center Environments**: Conducting field demonstrations in real-world data center environments will be essential to validate the practicality and effectiveness of heat reuse technologies. These demonstrations should test various configurations and integration strategies to optimize performance.
- **Performance Testing and Long-Term Reliability**: Ongoing testing and verification are required to assess the performance, efficiency, and reliability of heat reuse technologies in data centers over the long term. This will provide crucial data to support wider market adoption and inform future technology development.

By focusing on these areas, the data center industry can enhance its contribution to sustainable energy practices and set a precedent for integrating advanced heat reuse solutions into modern digital infrastructure.

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