White paper

Effective utilization of waste heat to provide affordable green heating

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The green transition's success hinges on cost-effective measures

Abstract

Utilizing waste heat through heat pumps offers affordable heating solutions. Over the past five years, numerous real-world cases have demonstrated the effectiveness of waste heat in district heating systems. A specialized software tool developed by Danfoss Climate Solutions predicts the feasibility of potential waste heat sources. This paper presents results from various installations in the MW range, serving as inspiration for heating plans under the Energy Efficiency Directive.

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Unleashing the Potential of Waste Heat

Waste heat is a largely underutilized resource. Significant amounts of heat are generated by applications such as data centers, supermarkets, food processing plants, industrial processes, hospitals, and wastewater treatment plants.

Integrating waste heat into energy systems can enhance their resilience and efficiency, creating a more interconnected and robust energy network.

By lowering the demand for primary energy sources and additional heating systems, energy costs and emissions will be reduced, making waste heat recovery and reuse a valuable asset for both consumers and the environment.

Figure 1: The interplay between consumers and providers of electricity and heating from a sector coupling perspective. Achieving the highest efficiency at the lowest cost depends on detecting and selecting the optimal heat sources.

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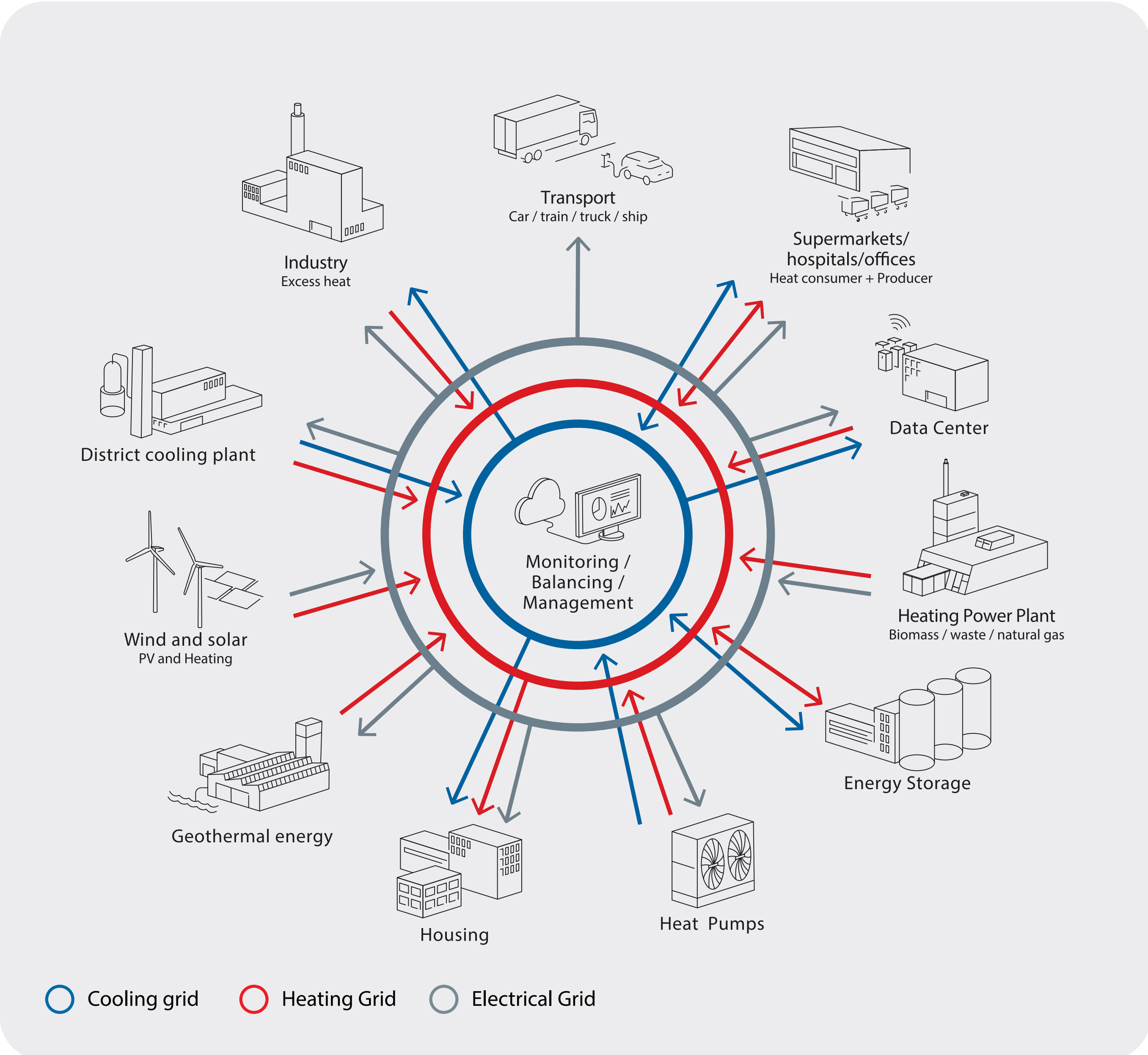


The Heat Recovery Premise

Heat recovery can be implemented on-site or exported to a thermal grid. Data from over 120 projects carried out in cooperation with the Danfoss expert team show that heat pump Coefficient of Performance (COP) remains stable throughout the year, thanks to constant heat source temperatures. Different sources of waste heat have varying temperature potentials, but they all offer significant opportunities for energy savings.

Heat pumps play a crucial role. They capture and reuse waste heat, supplying it at higher temperatures to where it's needed. This makes them 2-4 times more efficient than traditional heating methods. For off-site use, waste heat can be a major alternative heat source for district energy networks, helping utilities move away from fossil fuels. On-site, waste heat can be reused within the same facility, such as in supermarkets, hospitals, breweries, and food processing plants. Integrating cooling and heating systems into a single, efficient setup reduces equipment needs, lowers costs, and offers a high return on investment.

Heat pump efficiency (COP – Coefficient of Performance) is directly linked to the energy consuming work of the compressor. The higher the temperature lift (ΔT) from heat source to heat consumer, the more work the compressor has to do. As a result, the COP will decrease or increase, depending on the ΔT. If the heat source is ambient water or air, the ΔT will vary over the year and so will the COP. If the heat source is waste heat generated by a process, ΔT and COP will be stable and high as the ΔT is lower compared to ambient sources.

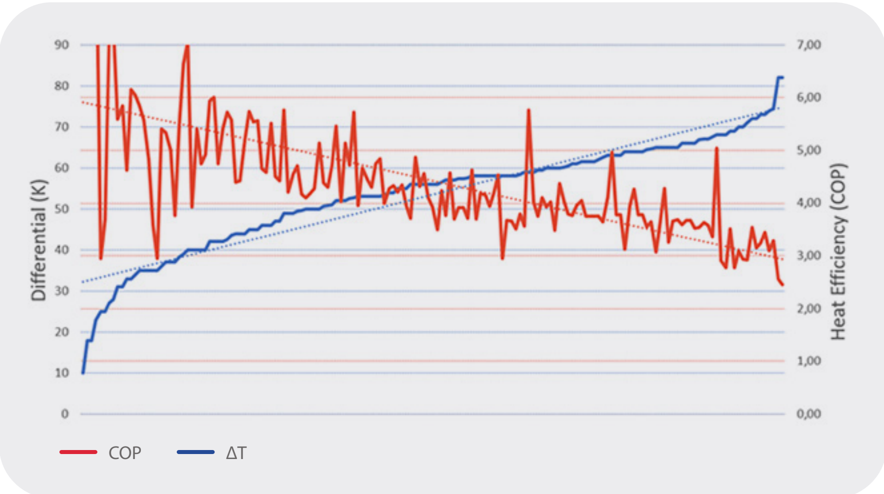
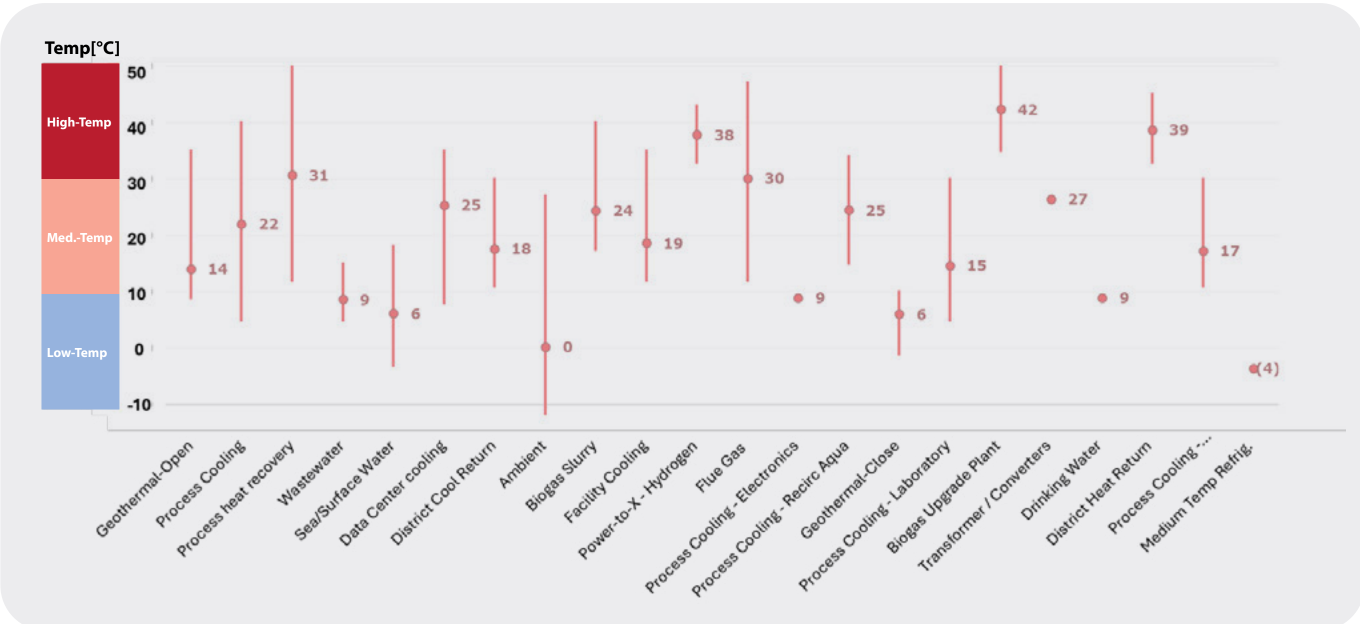


Figure 2: Efficiency data from more than 120 projects where the temperature lift is a boundary condition for the heat pump operation. Source: Danfoss.

Figure 3: Typical heat source temperature levels. When the heat source temperature is constant, the COP of a heat pump in heat recovery operation often becomes seasonally independent.



The Predictive Tool: A game changer

To offer quick preliminary assessments of waste heat opportunities, Danfoss Climate Solutions developed a predictive tool that combines thermodynamic data with financial metrics to evaluate the feasibility of potential projects.

The Heat recovery tool is designed to provide fast, initial analyses, it can trigger more detailed evaluations. The tool is versatile, catering to different levels of detail, and helps stakeholders make informed decisions about waste heat recovery projects. Input parameters include thermodynamic boundary conditions combined with financial parameters to evaluate the business case.

Existing legislation, such as the Energy Efficiency Directive (EED), mandates heat mapping for municipalities and requires consideration of waste heat potentials in cost-benefit analyses, further emphasizing the importance of tools like this.

Try out our new Heat Recovery Tool that analyzes your heat source and consumption. The tool links data with current energy prices to provide tailored recommendations for your operation.

Heat recovery tool

01

Input

Heat demand temp. profiles
- › Heat sink
- › Heat source

Capacity available

Direct heat recovery or heat pump

Energy prices
- › Electricity
- › Heat to be exported
- › Heat source to be substituted

02

Output

Energy production
- › Heat sink
- › Heat source (seen as cooling)

CO_2 reduction

CAPEX

OPEX

SCOP (seasonal COP) or COP

Pay back time

Figure 4: Input and output parameters for the calculation model

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Real-world success stories

The Danish municipality Sønderborg offers several real-world examples of waste heat recovery, each with a payback time of three years or less. These cases demonstrate a highly attractive business case while also showing that the electricity:gas price ratio needs to be below 2.0 to fully realize this potential.

Heat recovery case	Heat capacity [MW]	Heat production [GWH/year]	Temp: Cold [in/out] Heat [in/out]	COP [Heat/Cool] Total	Pay back [years] with electricity Heat price ratio [1.5-2.0]
Hospital	2	18	[12/8] [40/70]	2.7 / 3.6 / 6.3	2
Data center	0.5	5	[27/19] [43/68]	2.7 / 3.6 / 6.3	3
Food processing	2.6	19	[12/8] [45/75]	3.0 / 4.0 / 7.0	Depreciation over 10 years
Brick yard	4.7	30	[20/10] [45/85]	3.0 / 4.0 / 7.0	Under commissioning
Material processing	1.2	9	[26/18] [45/60]	3.9 / 4.9 / 8.8	2.5
Grain drying	1.1	6	[15/10] [40/72]	3.0 / 4.0 / 7.0	1.7

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The table shows six cases that are currently operating or being commissioned. Their accumulated heat production of 87 GWh per year is equivalent to 5,000 family homes, or about one third of the municipality's total residential heating demand. All systems are water-to-water based, use the ultra-low GWP refrigerant R1234ze, and employ a mix of centrifugal and reciprocating compressors.

Hospital
Hospitals need temperature-controlled environments for equipment, processes, and comfort. By installing a simultaneous heating and cooling system, one hospital was able to export excess heat to the district heating system. This pilot project was so successful that a larger project is now underway in a neighboring municipality.

Brick Yard
Brick yards are energy-intensive, using gas to heat furnaces and dry bricks. The humid exhaust air from the brick drying cellars is cooled and the heat from the furnace's exhaust gas is recovered and used to preheat the air before it enters the gas heating furnace, significantly improving efficiency.

Data Center
Data centers produce significant amounts of heat and are required under EU law to report on heat recovery. The case for recovery is straightforward: all electricity consumed by a data center is ultimately converted into heat that must be transferred to a heat sink. At Danfoss HQ, a small 0.5 MW heat pump was installed in series with the existing chillers to capture and reuse this heat, maximizing efficiency.

Food Processing and Grain drying
Food processing often uses air frying to process and dry food. The hot and humid air contains a lot of energy and is a perfect heat recovery asset. Grain drying is another example which is very similar to food processing.

Materials Processing
Most materials processing requires cooling of the machining tools, such as plastic molding or metal forming. Instead of releasing the heat to the ambient, the chiller can recover it by controlling its head pressure.

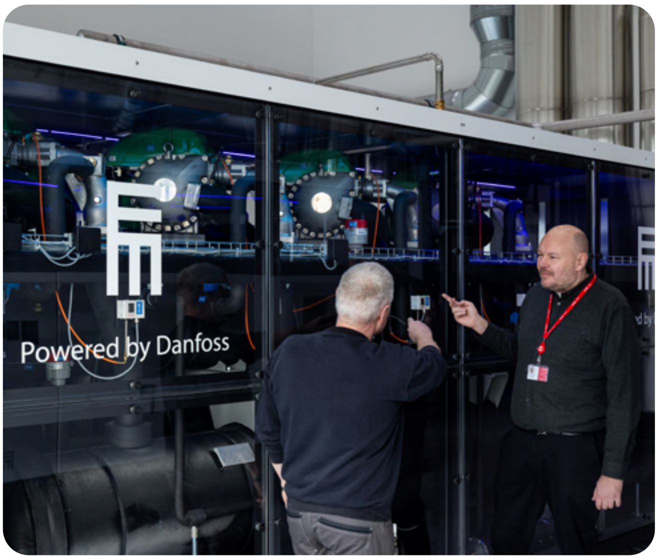
Overcoming barriers and seizing opportunities

Despite its massive potential, waste heat recovery still faces several challenges that hinder its adoption.

- **Lack of awareness:** Many installers and end users are unaware of the potential of waste heat recovery, the attractiveness of the business case, and the legal opportunities that come with mandatory heat planning.
- **High electricity prices:** Electricity costs can pose a significant barrier, especially compared to gas prices, as they negatively impact the OPEX of systems integrated with heat pumps.
- **Operational inefficiencies:** In some cases, expected efficiencies are not fully realized in practice.
- **Shortage of skilled workforce:** There is a lack of trained engineers and technicians available to install, commission, and maintain the systems.

However, existing and new policy frameworks combined with technological progress are creating significant opportunities within:

- **Existing policy:** The EU's Energy Efficiency Directive (EED) and Renewable Energy Directive (RED III) offer major opportunities to tap into the potential of waste heat recovery and reuse. This includes mandatory heat mapping for municipalities with populations over 45,000; the gradual decarbonization of district energy grids where waste heat recovery can serve as an energy source to achieve this goal; the consideration of waste heat recovery within mandatory cost-benefit analyses for heating and cooling; and the possibility to count waste heat toward renewable energy targets.
- **Policy improvements:** Existing policy can be further improved, for example, with comprehensive EU-wide guidelines for waste heat recovery; an expanded definition from off-site waste heat recovery to include on-site waste heat recovery; an obligation to act combined with incentives if opportunities arise from heat mapping and cost benefit analysis.
- **Technological advancements:** Advanced heat pumps and integrated systems can maximize efficiency and return on investment.



Conclusion

Waste heat recovery and reuse, in combination with sector integration and heat pumps, is a powerful tool to increase resilience, save energy and cost, and reduce emissions.

The case studies presented here demonstrate the variety of applications and the substantial benefits of waste heat recovery. Very attractive payback times are evident, and to date, the projects deliver up to one third of the municipality's residential heating demand.

The new Danfoss heat recovery tool offers a simple and fast way to assess the business case. With the right policies, incentives, and technologies, the full potential of waste heat can be unlocked, driving a green and resilient transition forward.

Explore our solutions
danfoss.com

"Waste heat is a massive, untapped resource that can drive the decarbonization of buildings and industry. The EU's Clean Industrial Deal and the upcoming Heating and Cooling Action Plan present a unique opportunity to unlock this potential, making waste heat recovery a cornerstone of a cleaner, more resilient energy system."

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