ENGINEERING TOMORROW

US Delegation Visit

Nordborg, DK – June 25th

Decarbonizing Danfoss

We will become CO_2 neutral **by 2030**

All Danfoss factories shall be CO_2 neutral latest **by 2030**

All company cars shall be electric latest **by 2030**

Our 3-step approach to become CO_2-neutral latest in 2030

Step 1

Energy efficiency

reduce

Step 2

Energy recovery

re-use

Step 3

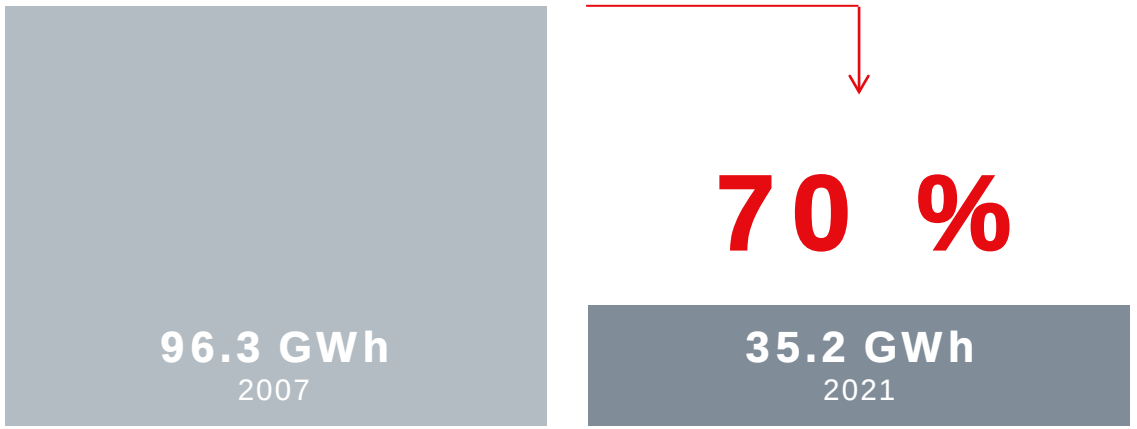
Source Renewable Energy

replace

Nordborg Campus

CO_2 neutral in 2022

Heating



1. Reduce
70 %

2. Re-use
15 %

3. Replace
15 %

Nordborg Campus

CO_2 neutral in 2022

Power

97.2 GWh
2007

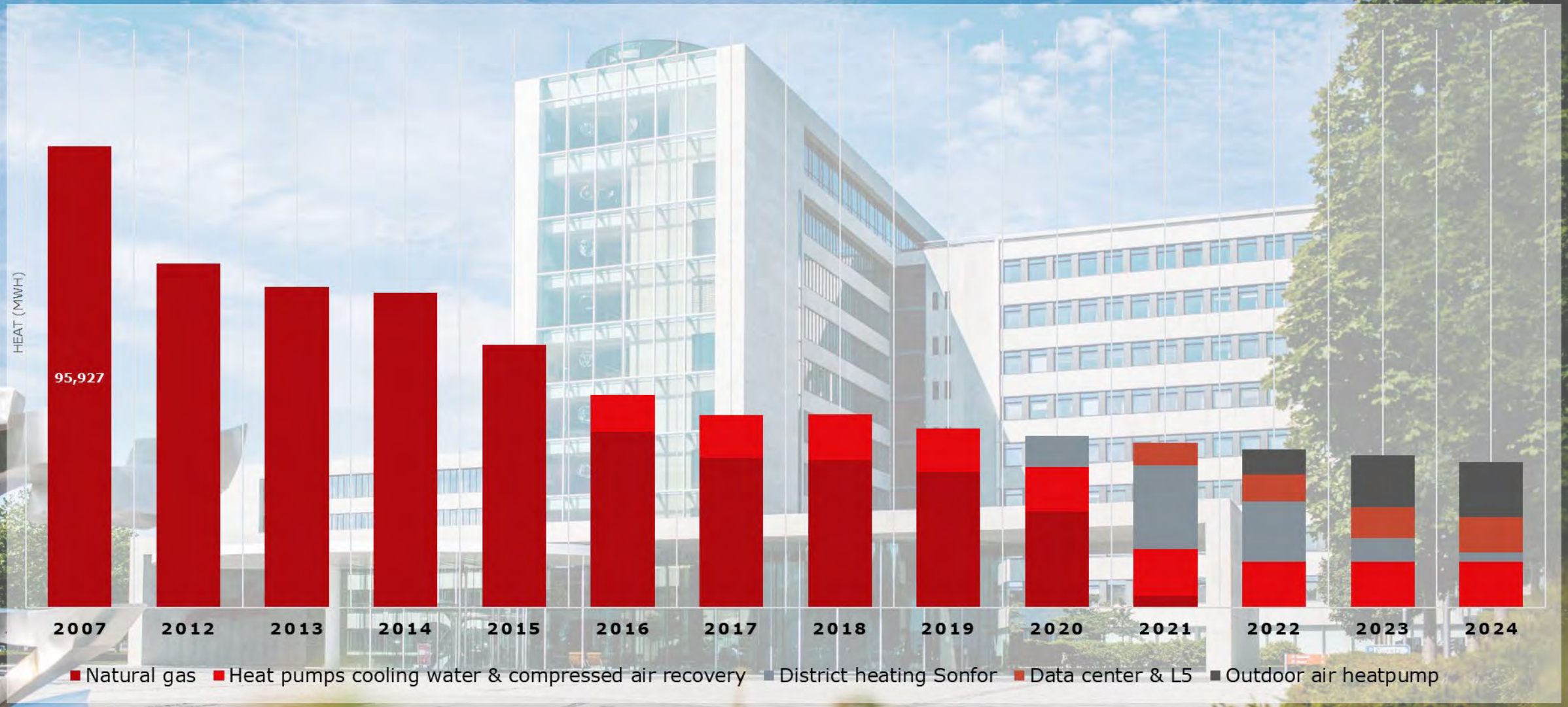
43 %

55.5 GWh
2021

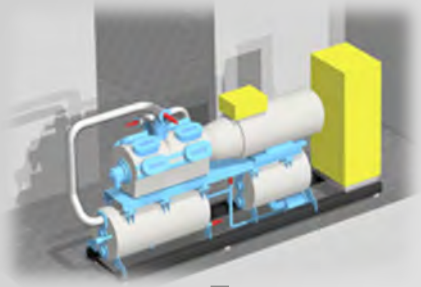
1. Reduce
43 %

3. Replace
57 %

Decarbonizing Danfoss HQs



Heat Pumps x 4



Compressed Air

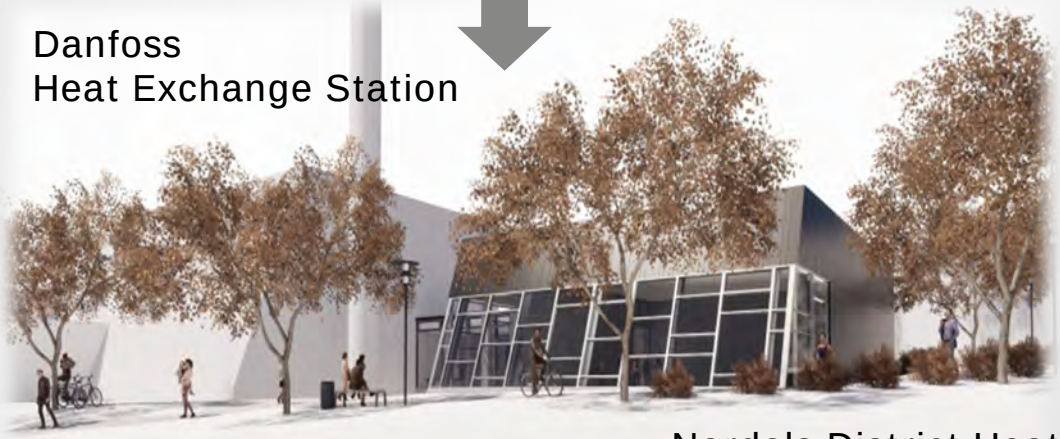
Danfoss Data Center

Danfoss Supermarket

Danfoss P2X Station

Danfoss Integrated Energy System

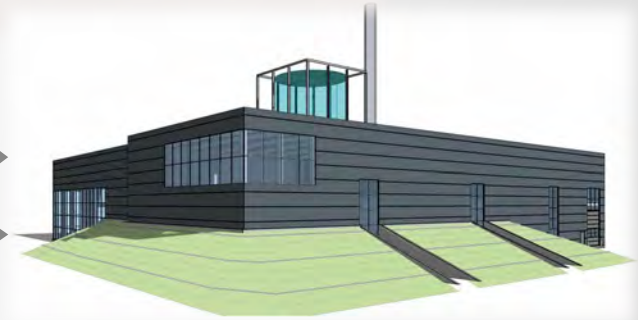
Danfoss
Heat Exchange Station



Nordborg City

Danfoss Headquarters

Nordals District Heating Plant



ENGINEERING TOMORROW

Sønderborg Hospital & District Heating | The future of integrated systems

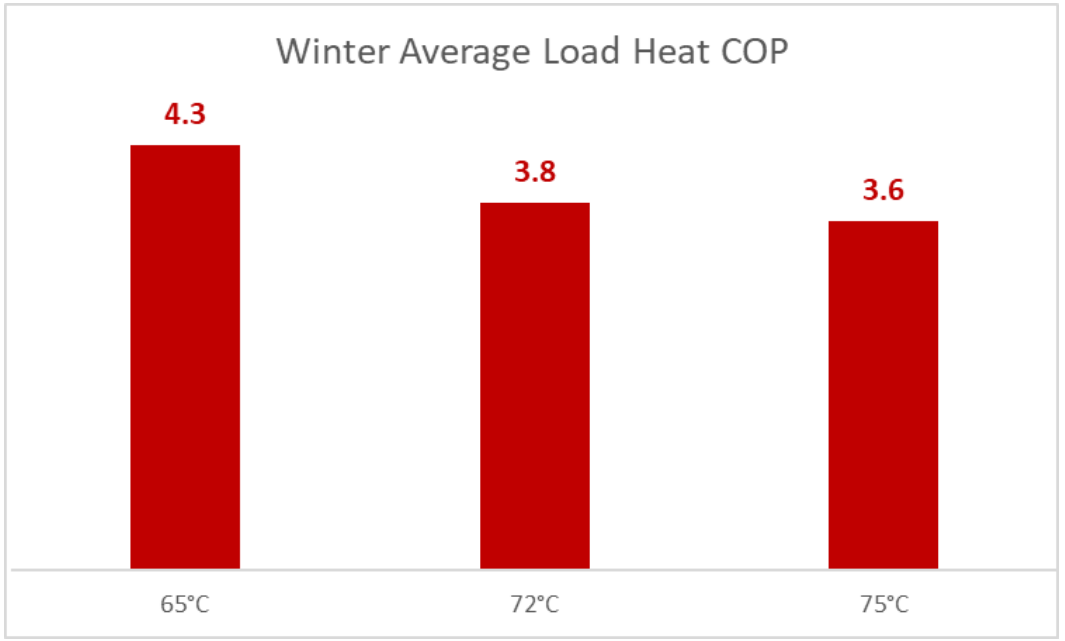
Danfoss Sector Integration

”Sonderborg Denmark is the global capital of energy efficiency” – Fatih Birol, IEA Chief

Sønderborg Hospital – Lighthouse Project

Performance summary

Cooling & Heating Plant Performance	Cool kW	Heat kW	Cold Temp °C	Hot Temp °C	Cool COP	Heat COP
Summer	2,000	2,737	8	72	2.7	3.6
Winter Peak Load	1,578	2,176	8	72	2.6	3.6
Winter Average Load	1,000	1,369	8	72	2.7	3.8



Total Efficiency Ratio (symbiosis) = (Heating + Cooling Capacity) / Power Input

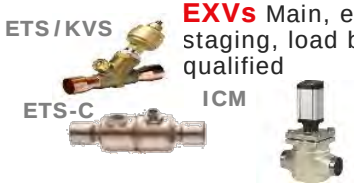
$$= \frac{\text{2,000kW Cooling + 2,737kW Heating}}{\text{750kW power draw}} = 6.3 \text{ COP}$$

Application knowledge taken to the next level

Danfoss has a wide range of products which fits in this field

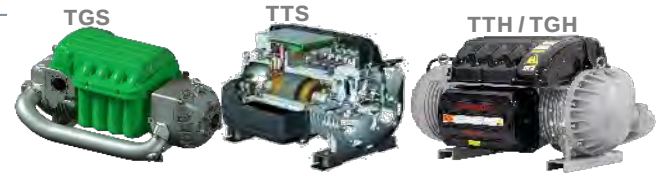
Danfoss offering

EXVs Main, economizer, staging, load balance. Oil-free qualified



Sensors & System Protection Temperature & pressure sensors, switches, transmitters & relief valves

High efficiency Turbocor© oil-free centrifugal compressors: standard and high lift, optimized for HFC & HFO



Microplate heat exchanger (MPHE), for modular and/or economizer. Medium pressure refrigerant-optimized and low approach

Electronic controls Subsystem and unit-level with pre-configured application code

Check & Ball valve Isolation & prevent backflow. Oil-free qualified, minimized pressure drop

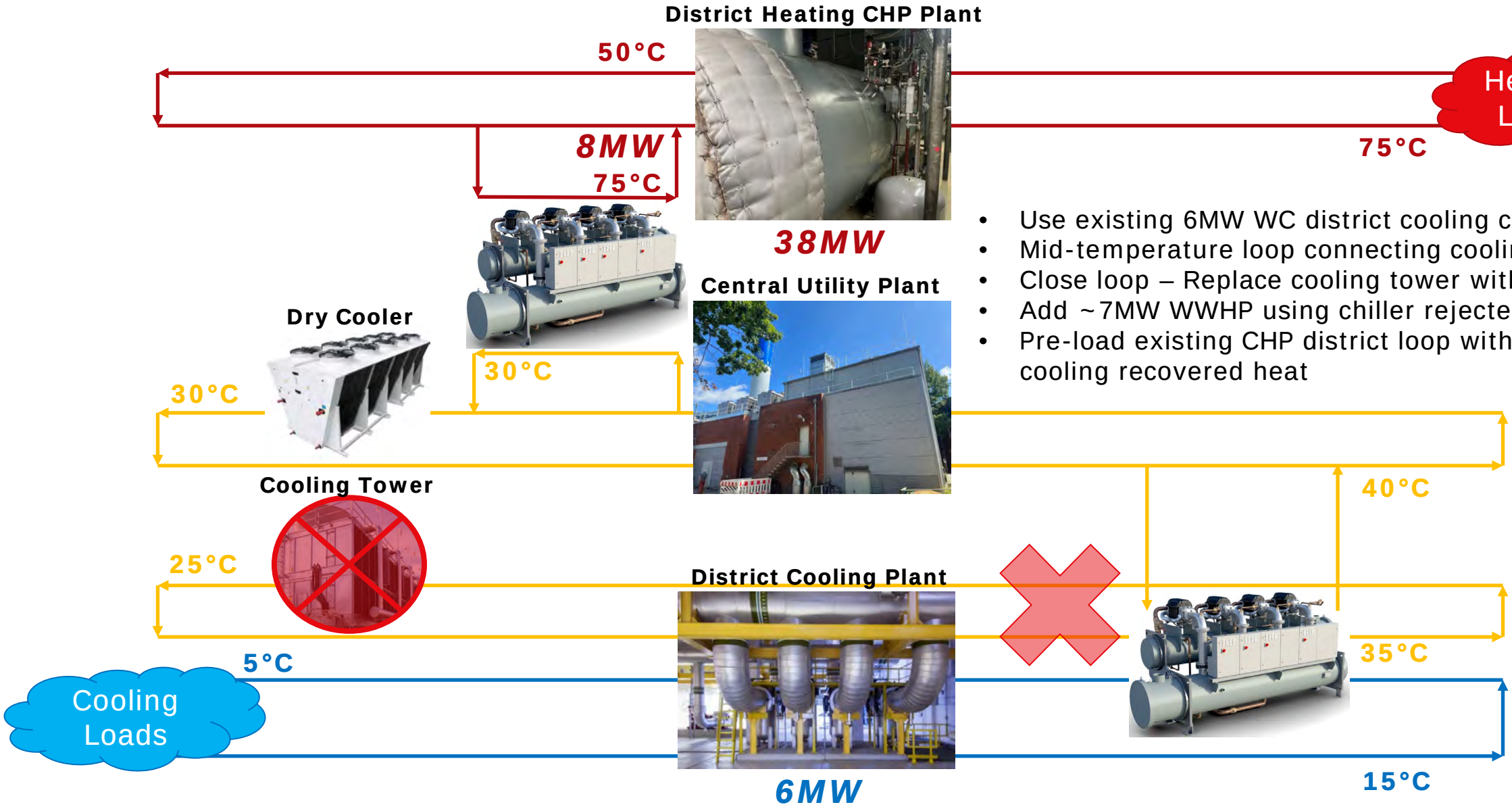
Solenoid valve Liquid line shut off. Oil-free & medium pressure refrigerant-qualified

Filter Drier / Sight Glass Safe operation with all refrigerants

Level Sensors Accurate liquid level measure. Oil-free qualified

Inverter Drives Integrated compressor & standalone hydronic and fan control

Hospital Electrification Retrofit



- Use existing 6MW WC district cooling chillers
- Mid-temperature loop connecting cooling & heating
- Close loop – Replace cooling tower with dry coolers
- Add ~7MW WWHP using chiller rejected heat
- Pre-load existing CHP district loop with ~8MW cooling recovered heat

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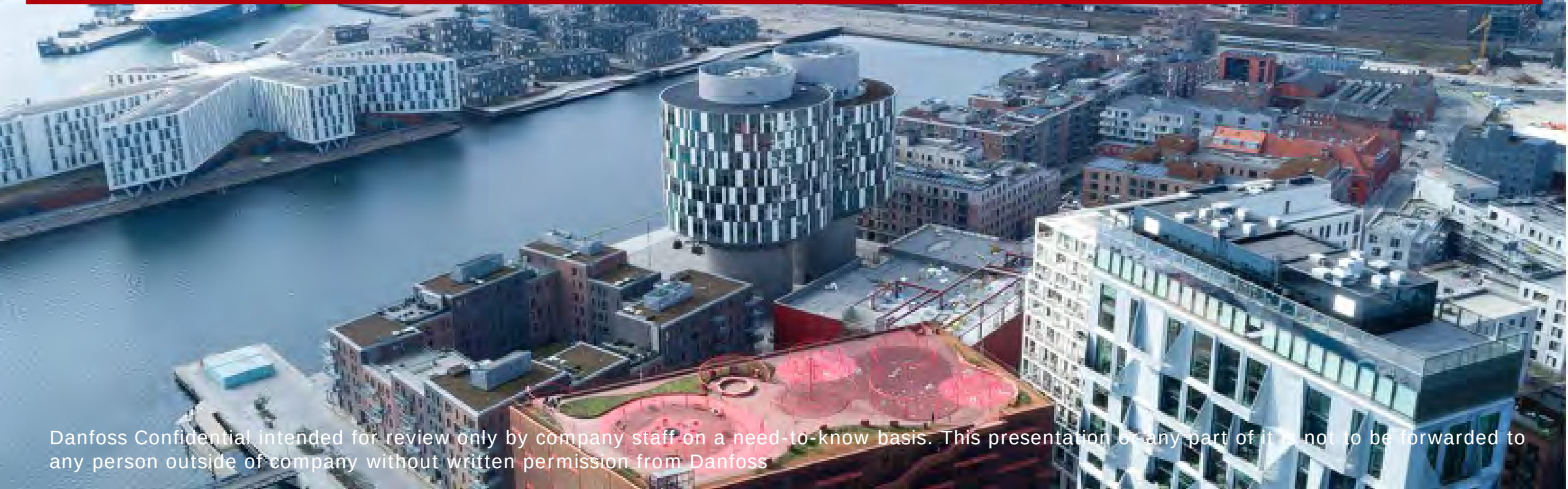
TOMORROW

Integrated Systems

Trends/drivers, example applications and enabling technologies

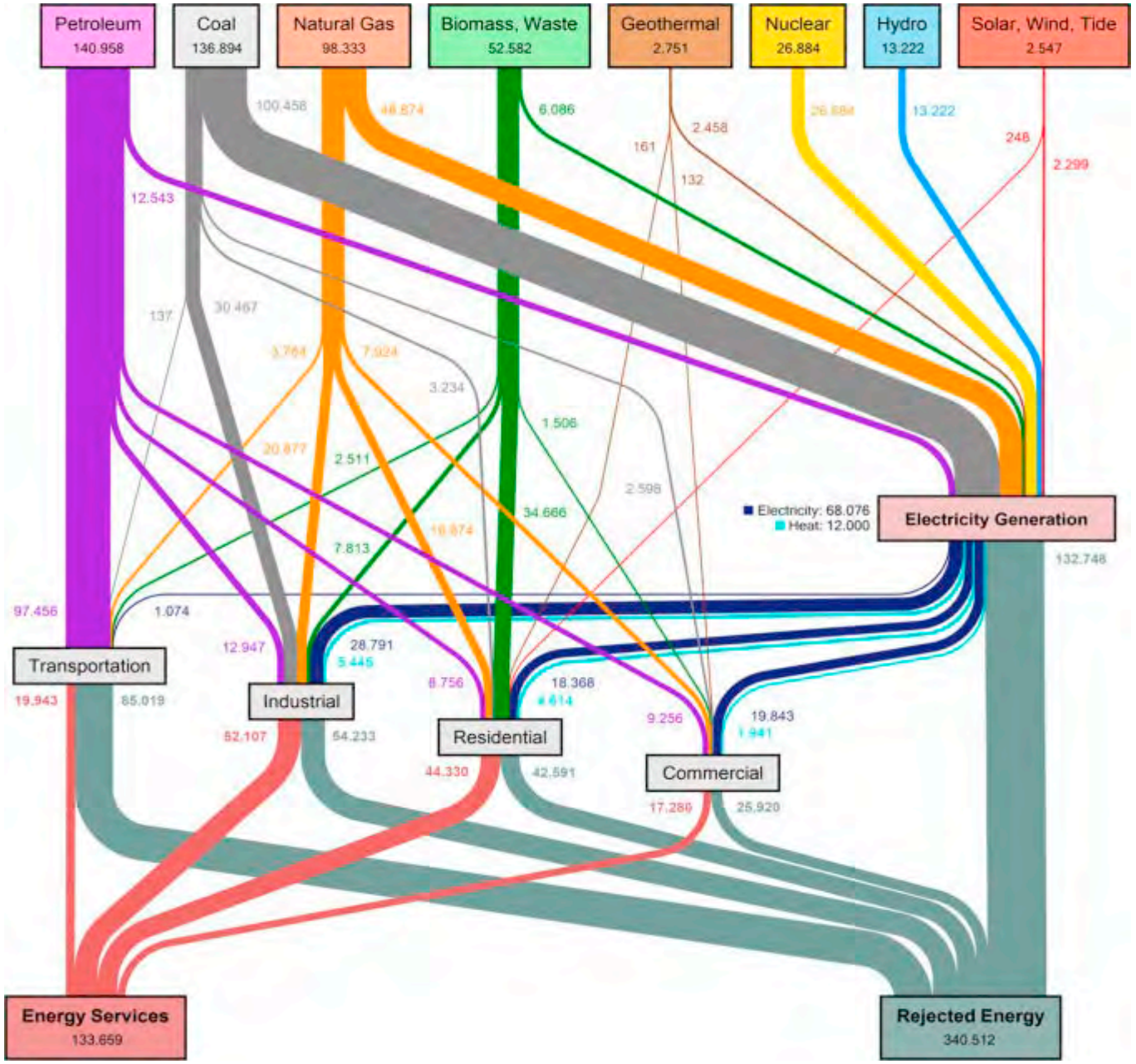
Danfoss Sector Integration



The Waste Heat Opportunity

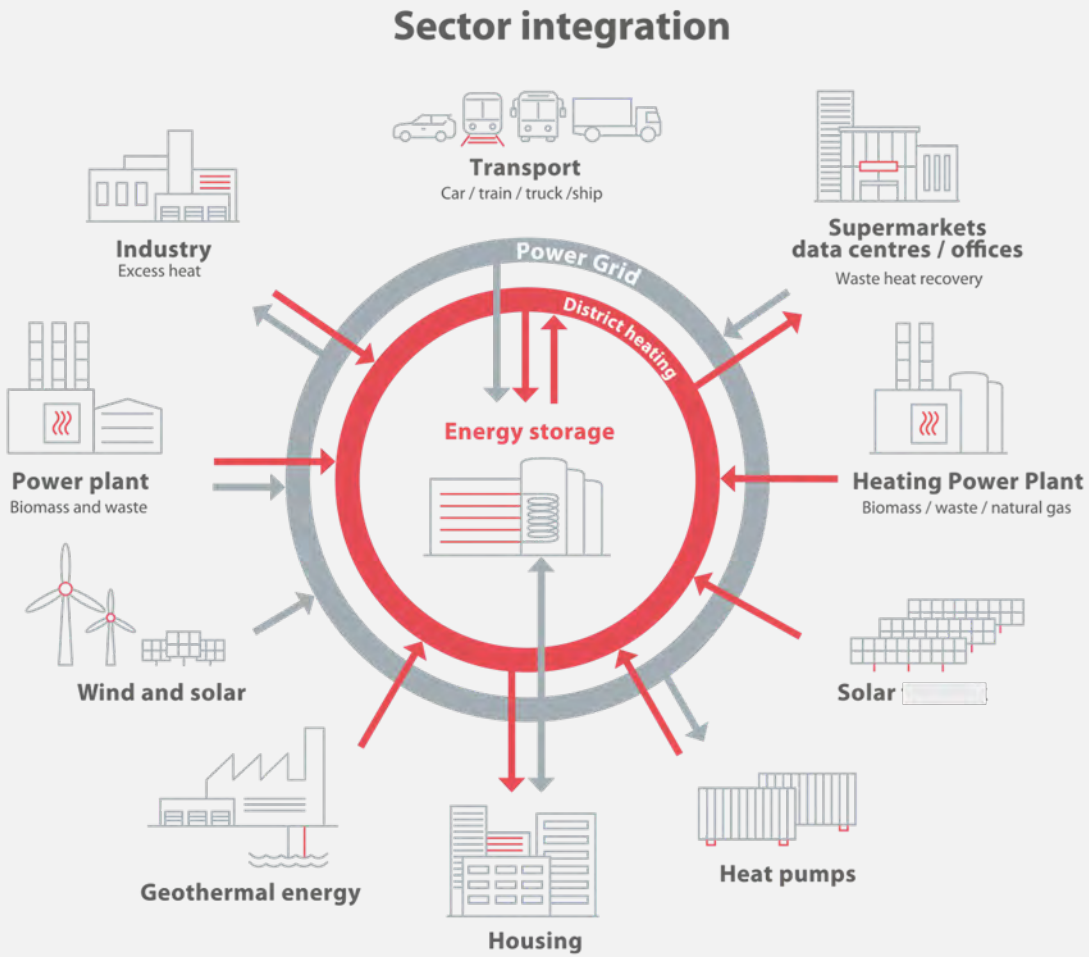
”72% of the global energy input (consumed primary energy carriers) is currently lost after conversion. The problem we're trying to solve here is a lot smaller than primary energy use might suggest. The good news is that the future energy system will look radically different and use a lot less primary energy for the same and even more energy services. Such a system will be characterised by:

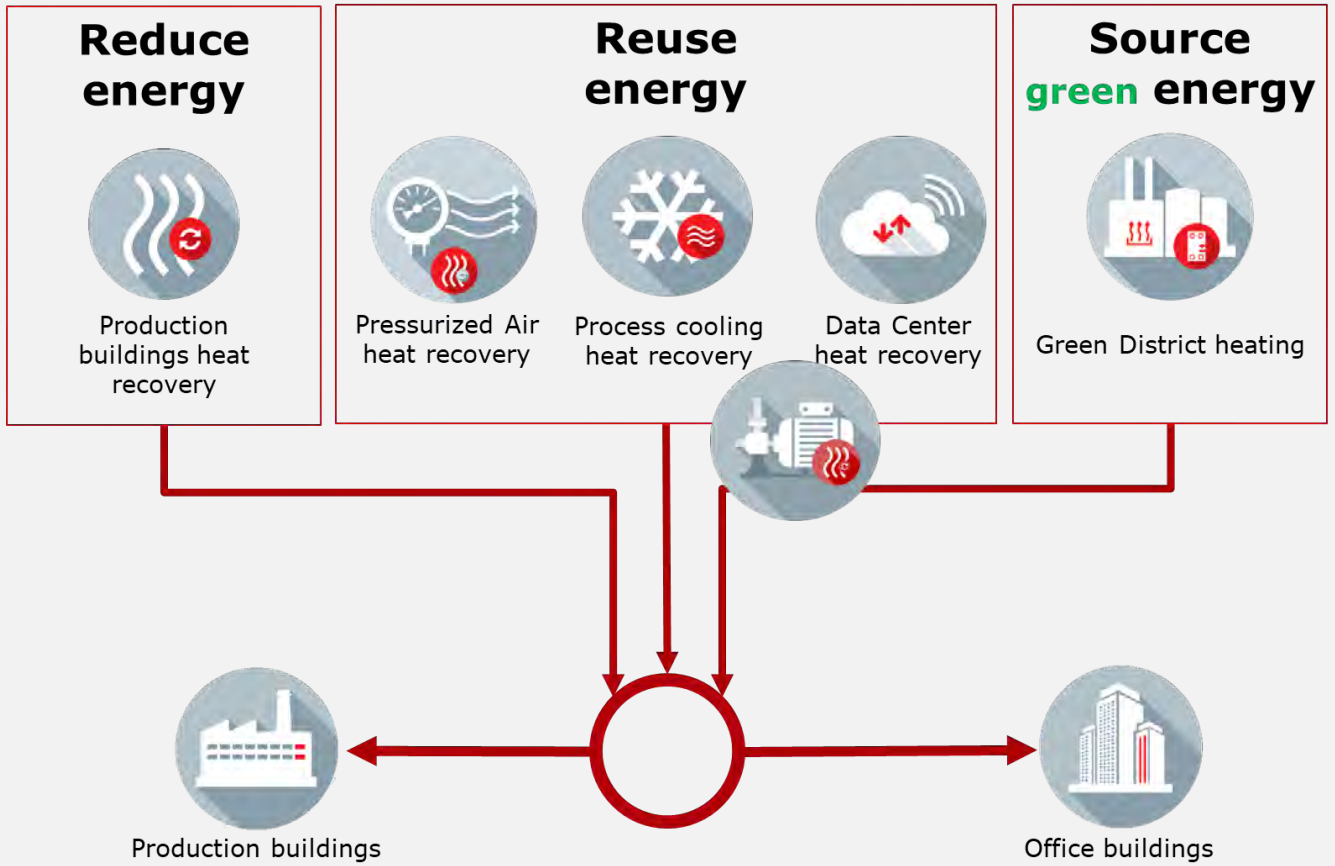
a) "electricity-only" renewables (mainly solar and wind),
b) electrification of many end uses that currently rely on burning fossil fuels,
c) reusing unavoidable waste heat,
d) much improved end-use efficiency
e) enhanced flexibility”



Estimating the global waste heat potential - ScienceDirect

Danfoss Sector Integration –
What We Do





Sector Integration Introduction Video

Heat Sources – Sector Coupling Projects Through 12/2023

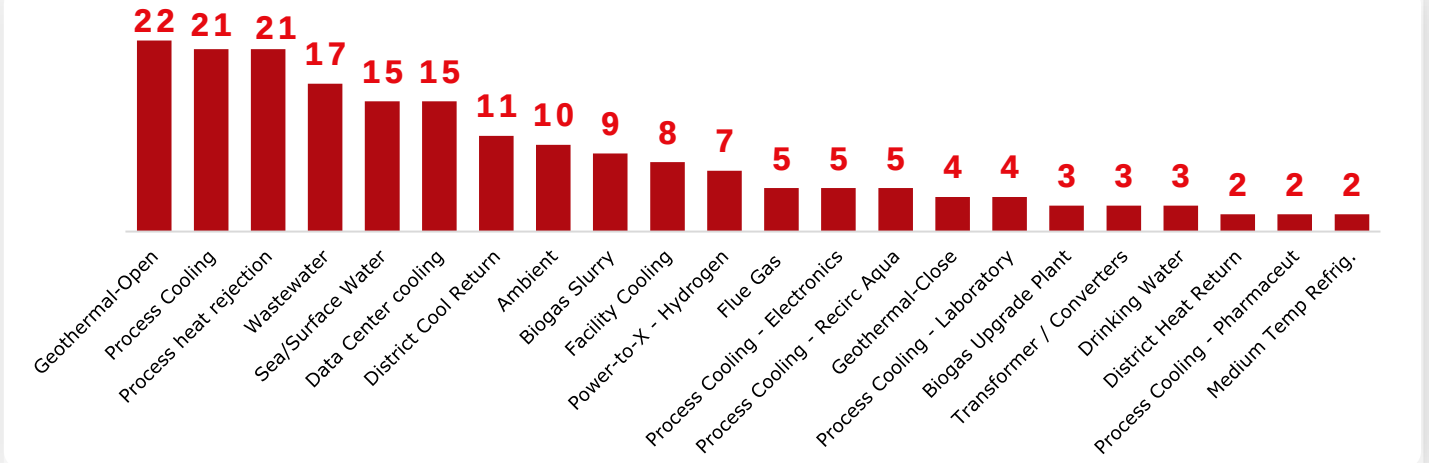
The most prevalent heat recovery heat sources

- Process, Wastewater, district and data center cooling / heat recovery = 52%
- Geothermal total = 13%
- Biogas total = 7%

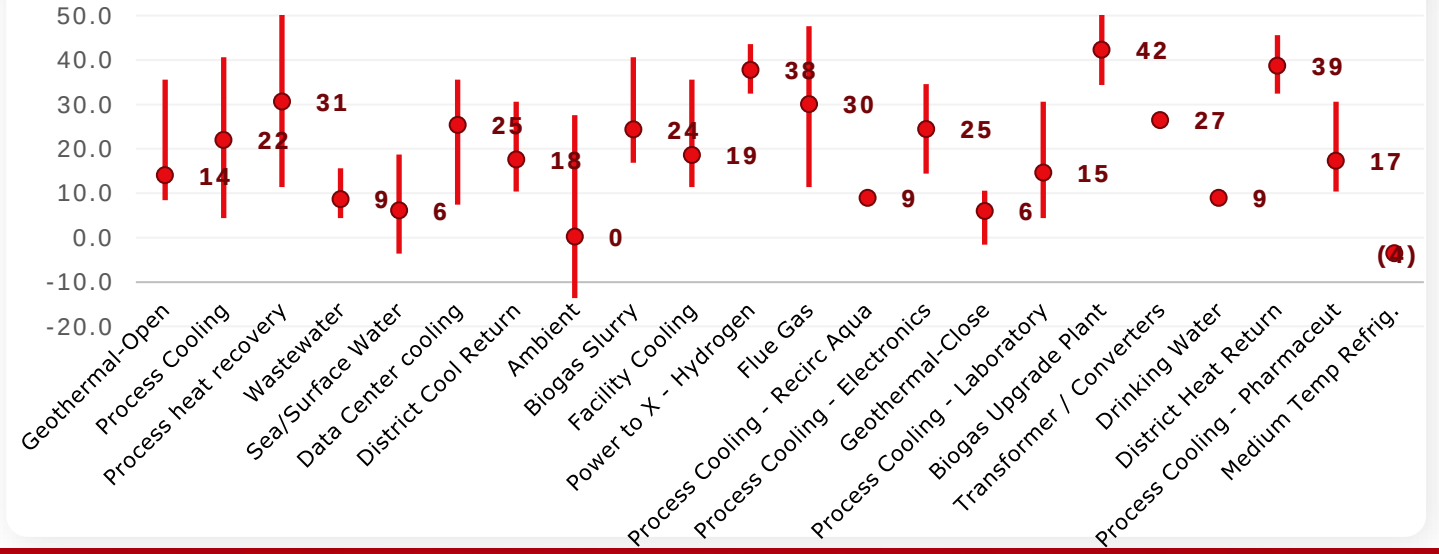
- Target the most consistent availability and highest temperature heat sources

- To drive…
  - highest operating hours
  - best efficiency
  - lowest resulting heat price

Opportunities by Heat Source (# of projects)

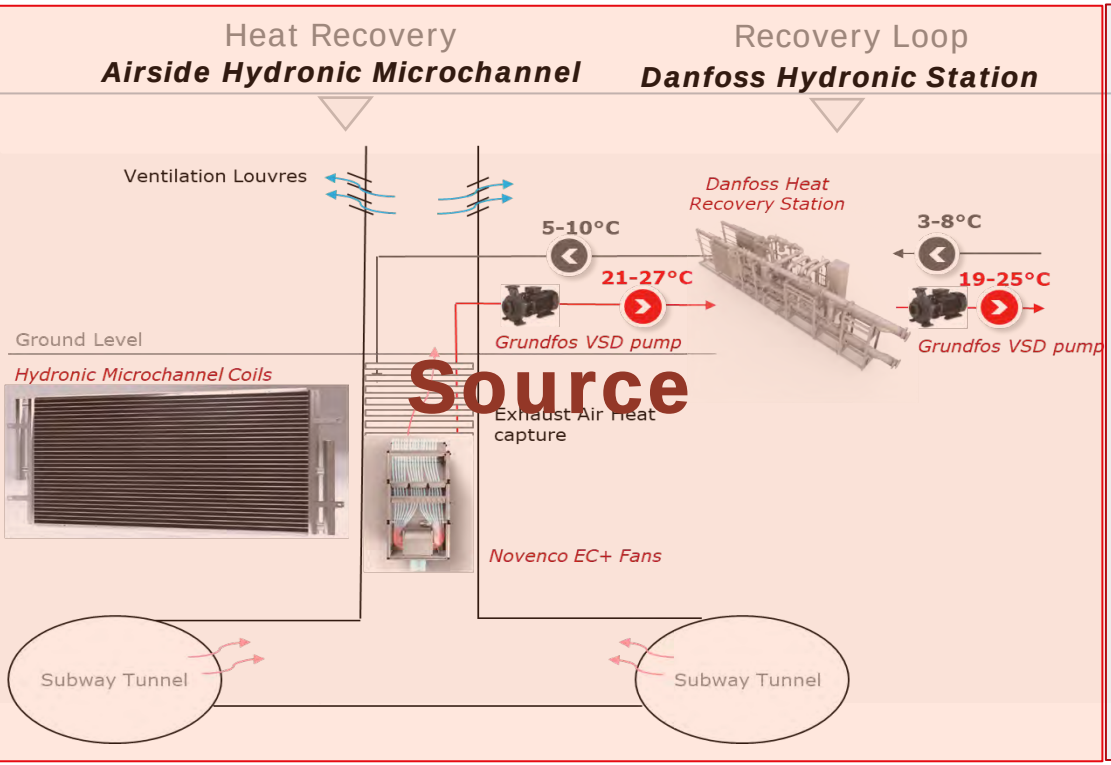


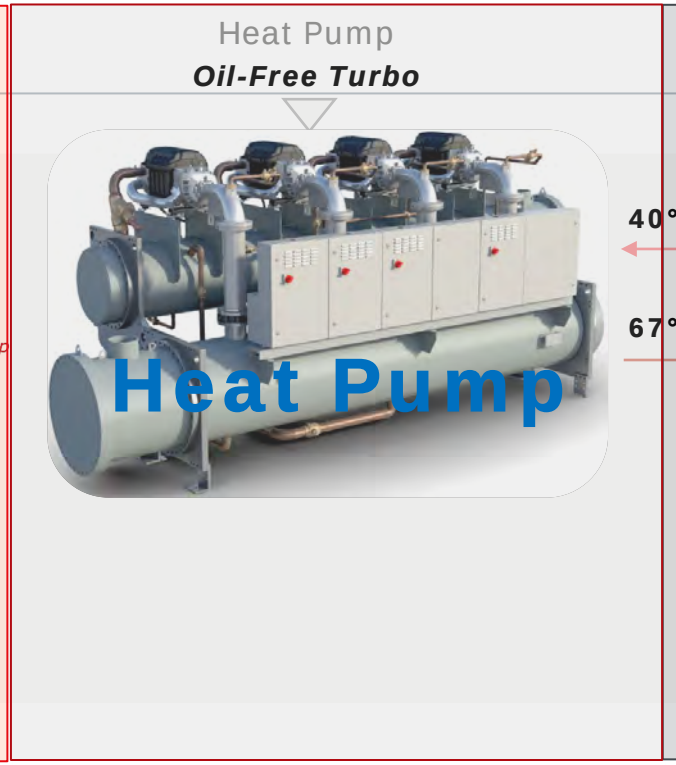
Source Temperature Average/Range

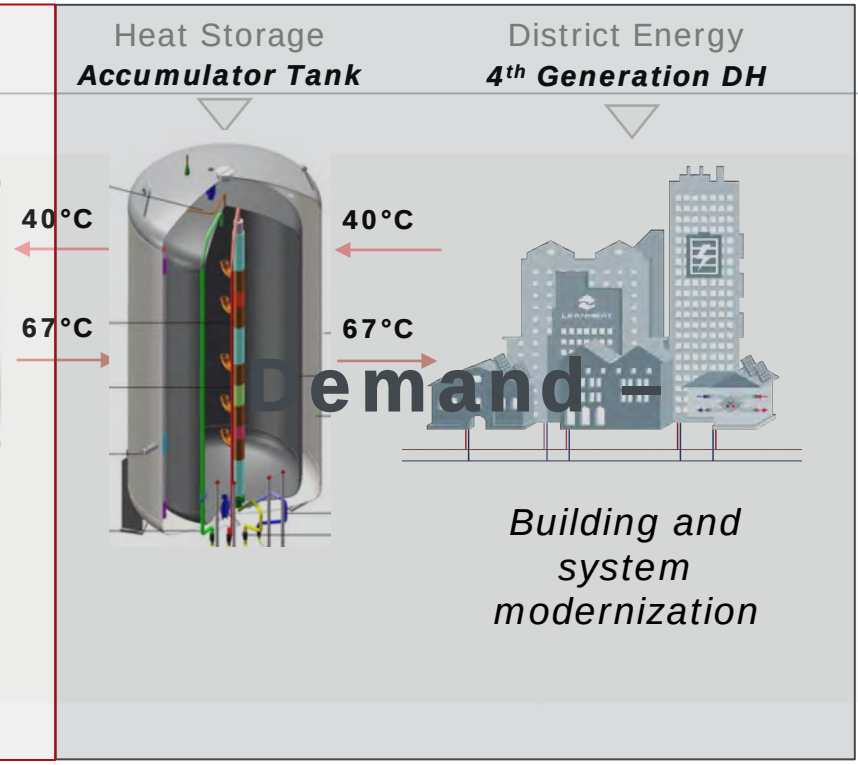


Source, Heat Pump and Demand Analysis

System Design Example – Subway Recovered to District Energy







- (Multiple potential) - Low, medium and high-temp

- Bock, scroll or Turbocor-based

- (Multiple potential) – Low, medium and high-temp

Sector Integration

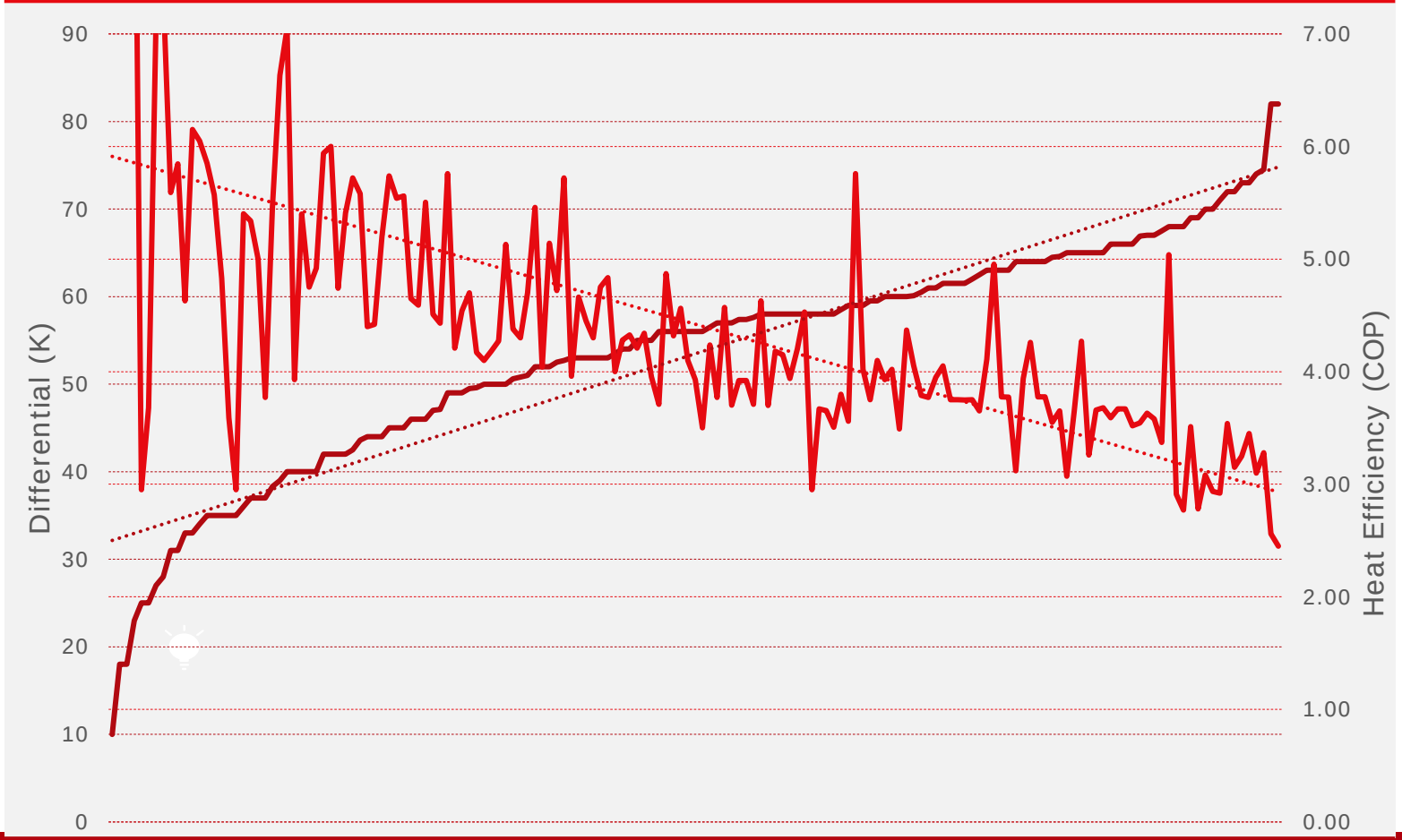
Efficiency & Electrical Load are Critical

- Range of heat source to heat supply differential (K)
- Corresponding heat pump system efficiency (COP)
- 0.3-60MW+ systems

1K differential = 2% heat pump efficiency

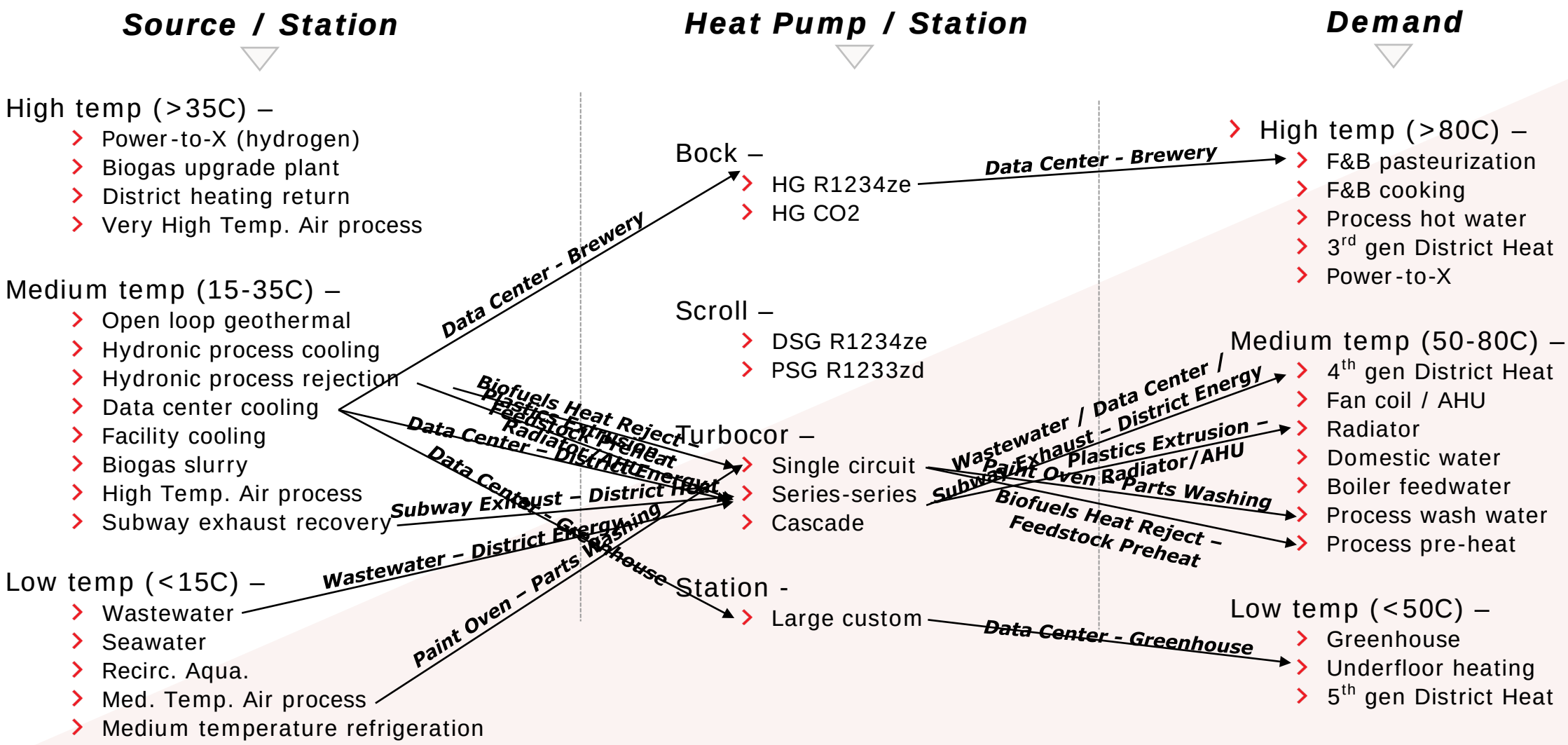
= 2% electrical load

Heat Pump – System Differential and Associated Efficiency



Source, Heat Pump and Demand Analysis

Variations to Include

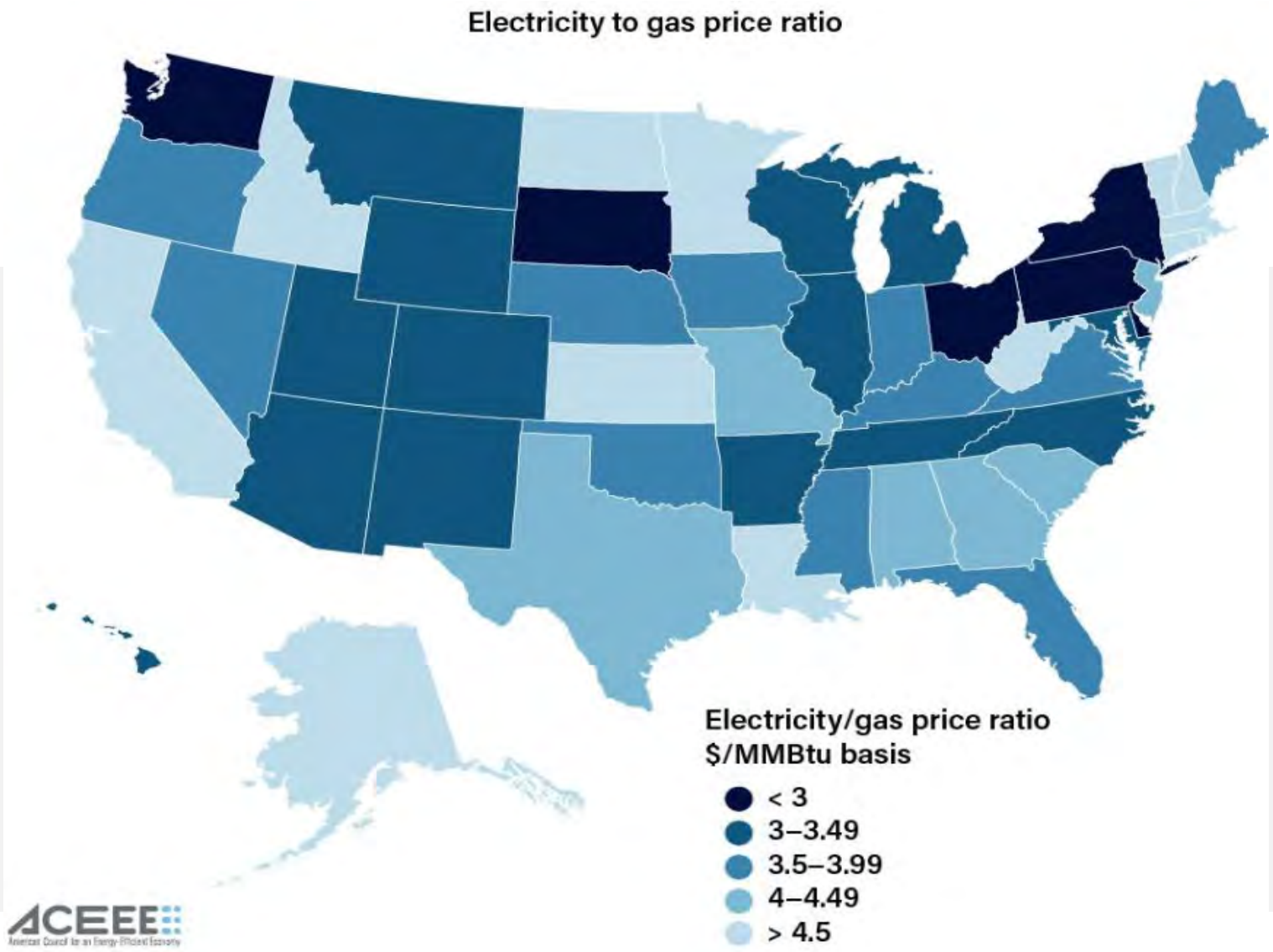


Spark Spread –

2022

- Electrification COP > spark spread = payback
- Ratio driven by both electricity and gas cost
- Wide variation by state and region
- Variation also in real-time vs average

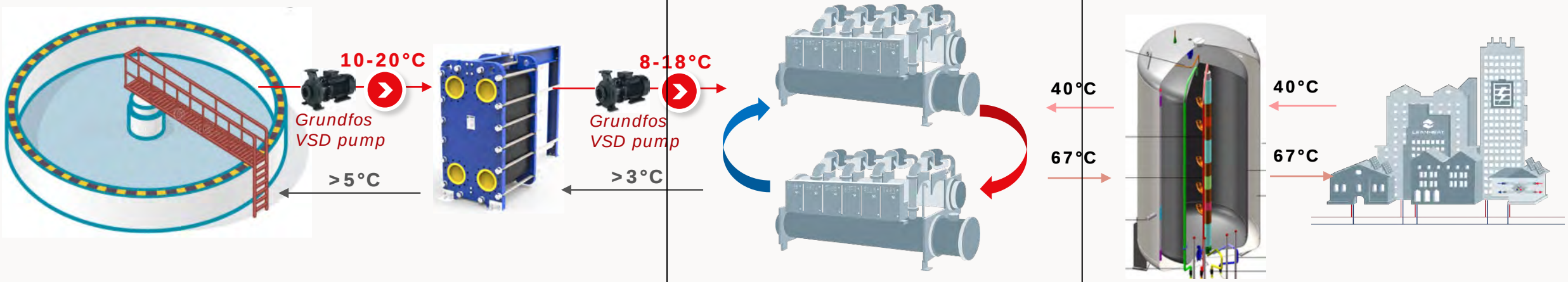
https://www.greenbiz.com/article/its-time-electrify-industrys-process-heat-heat-pumps



Source, Heat Pump and Demand Analysis

Source Variation - Wastewater

Heat Recovery	Recovery Loop	Heat Pump	Heat Storage	District Energy
Treated Wastewater	***Sondex Heat Exchanger***	***Oil-Free Turbo***	***Accumulator Tank***	***4th Generation DH***



- Treated wastewater heat recovered to Sondex heat exchanger then discharged to river, etc.
- Sondex gasketed plate heat exchanger wastewater isolation
- Supplied to evaporator loop of water-water heat pump

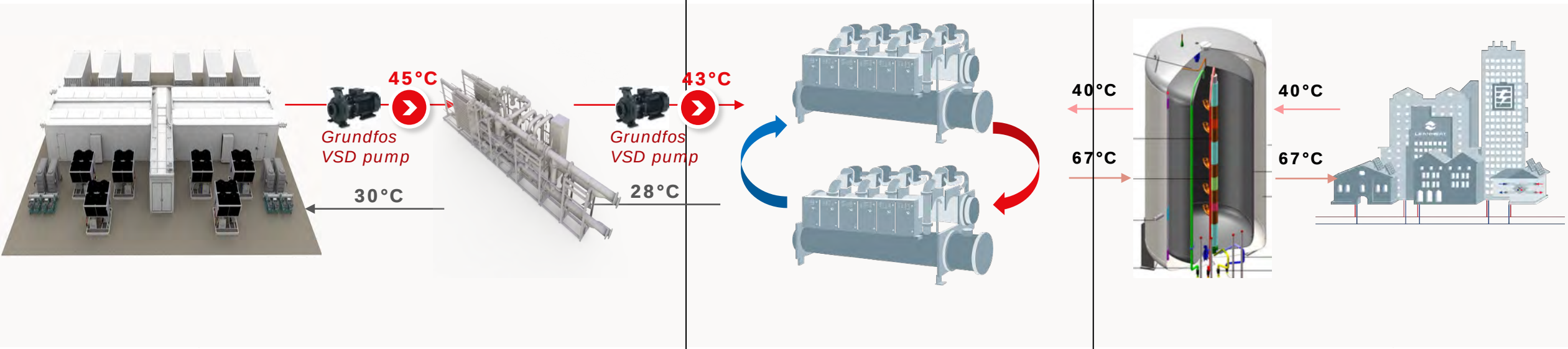
- Oil-Free turbo series-series counterflow heat pump
- Boosting recovered heat directed from Danfoss station
- Boosted to loop for heat accumulator tank

- Heat accumulator tank to store heat at temperature supplied by heat pump
- Storage to district energy per demand / loading
- Supplied to existing district heating network

Source, Heat Pump and Demand Analysis

Source Variation – Data Center

Heat Recovery	Recovery Loop	Heat Pump	Heat Storage	District Energy
Liquid Cooled Data Center	***Danfoss Custom Station***	***Oil-Free Turbo***	***Accumulator Tank***	***4th Generation DH***



- Data Center direct-on-chip liquid cooling
- Recovered heat to Danfoss custom hydronic station
- Danfoss Custom Station data center cooling system isolation
- Supplied to evaporator loop of water-water heat pump

- Oil-Free turbo series-series counterflow heat pump
- Boosting recovered heat directed from Danfoss station
- Boosted to loop for heat accumulator tank

- Heat accumulator tank to store heat at temperature supplied by heat pump
- Storage to district energy per demand / loading
- Supplied to existing district heating network

Source, Heat Pump and Demand Analysis

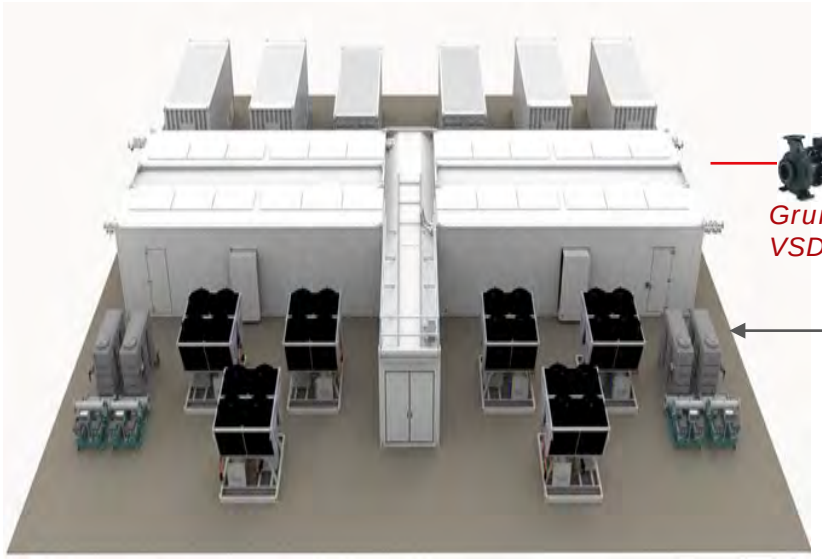
Demand Variation – Greenhouse

Heat Recovery
Liquid Cooled Data Center

Recovery Loop
Danfoss Custom Station

Air-Handlers
Novenco EC+ Fans

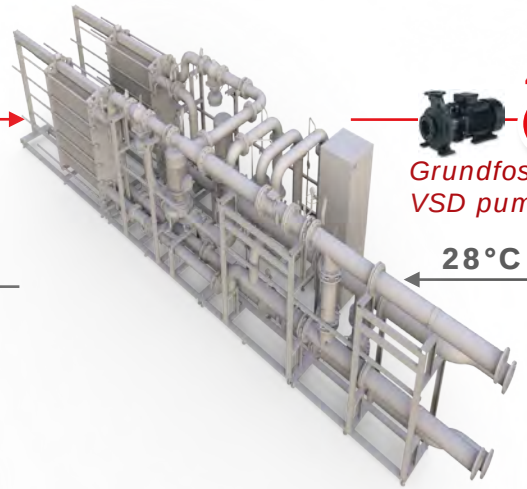
Greenhouse Farming
Supply Air Heat



45°C

Grundfos
VSD pump

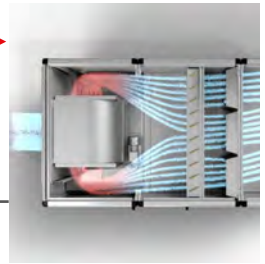
30°C



43°C

Grundfos
VSD pump

28°C



~25°C

- Data Center direct-on-chip liquid cooling
- Supplied direct to custom station with no heat pump boost – True symbiosis system
- Data center cooling backup air-cooled chillers or dry cooler heat rejection (when not recovered)

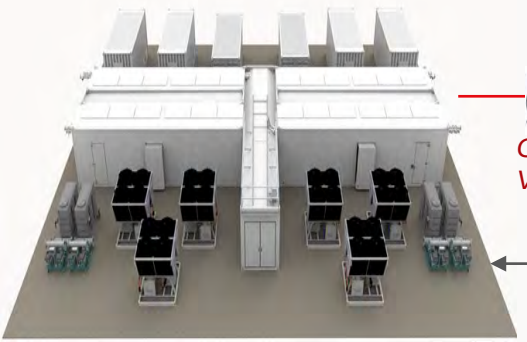
- Recovered heat to Danfoss custom hydronic station
- Danfoss Custom Station data center cooling system isolation

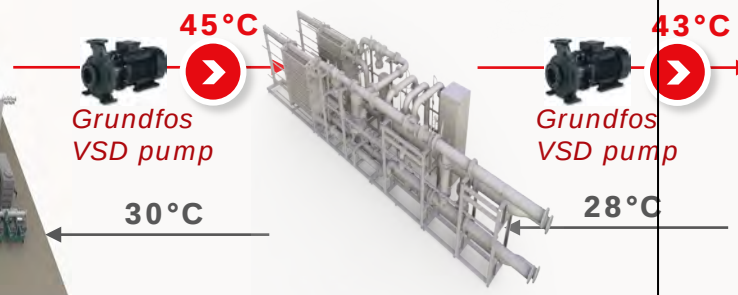
- Recovered heat supplied to air-handler for heating of outdoor air
- Heated outdoor air supplied to greenhouse to maintain year-around optimal growing temperature

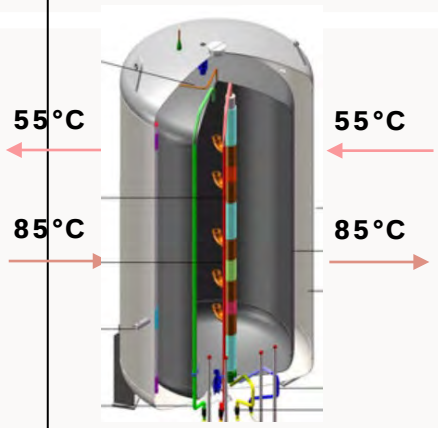
Source, Heat Pump and Demand Analysis

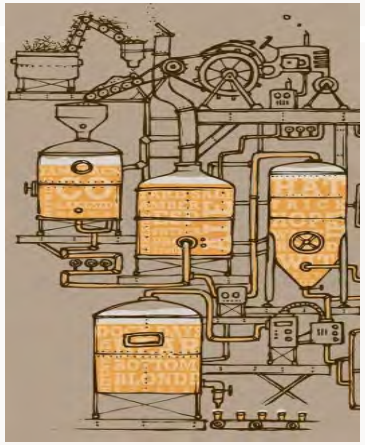
Heat Pump and Demand Variation – Brewery

Heat Recovery	Recovery Loop	Heat Pump	Heat Storage	Brewery
Liquid Cooled Data Center	***Danfoss Custom Station***	***Bock Piston-Based***	***Accumulator Tank***	***Ferment./Pasteur.***









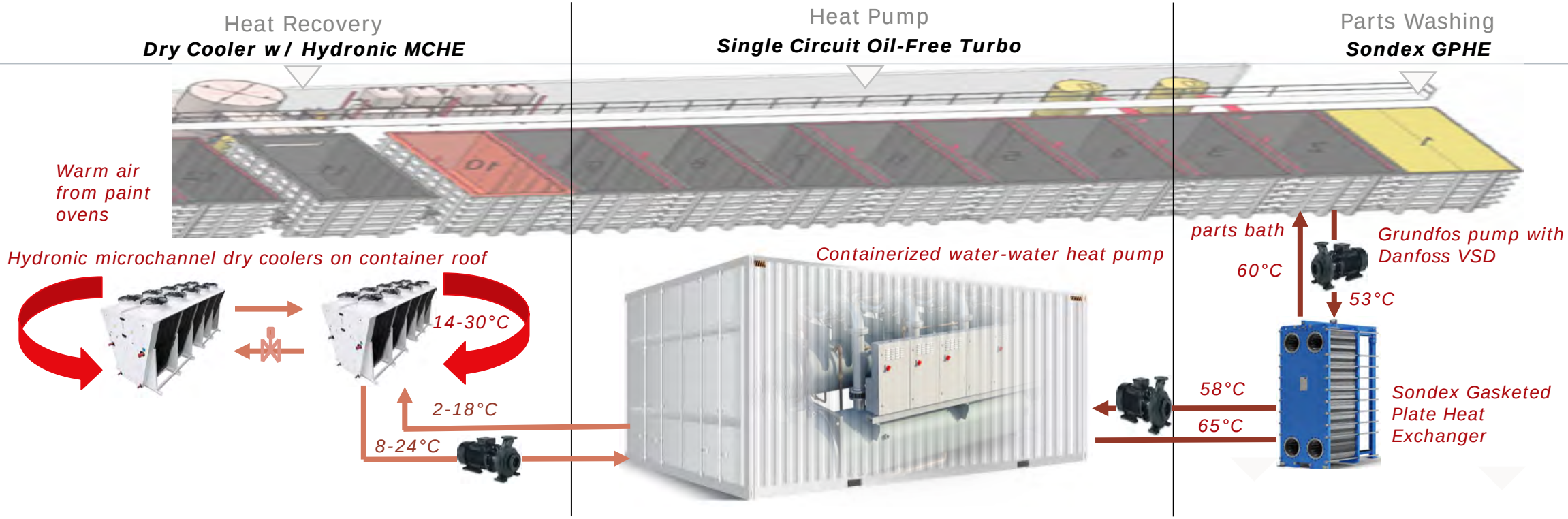
- Data Center direct-on-chip liquid cooling
- Recovered heat to Danfoss custom hydronic station
- Danfoss Custom Station data center cooling system isolation
- Supplied to evaporator loop of water-water heat pump

- Bock piston-based water-water heat pump
- Boosting recovered heat directed from Danfoss station
- Boosted to loop for heat accumulator tank

- Heat accumulator tank to store heat at temperature supplied by heat pump
- Storage to brewery fermentation and pasteurization per demand

Source, Heat Pump and Demand Analysis

Source and Demand Variation – Paint Oven Recovery / Parts Wash Process



- Parts paint baking oven heating surrounding air
- Heat recovered to dry coolers with Danfoss hydronic MCHE, installed on top of container
- Recovered to hydronic loop with Grundfos pumps with Danfoss VSDs

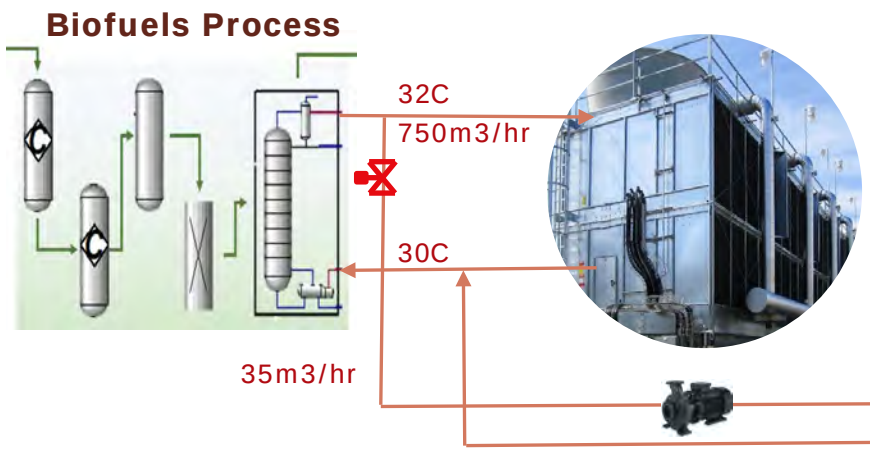
- Supplied to evaporator loop of water-water heat pump
- Oil-Free turbo single circuit heat pump
- Boosting recovered heat directed from dry cooler loop

- Boosted to heat exchanger loop
- Heat exchanger hydronic break to parts washing loop

Source, Heat Pump and Demand Analysis

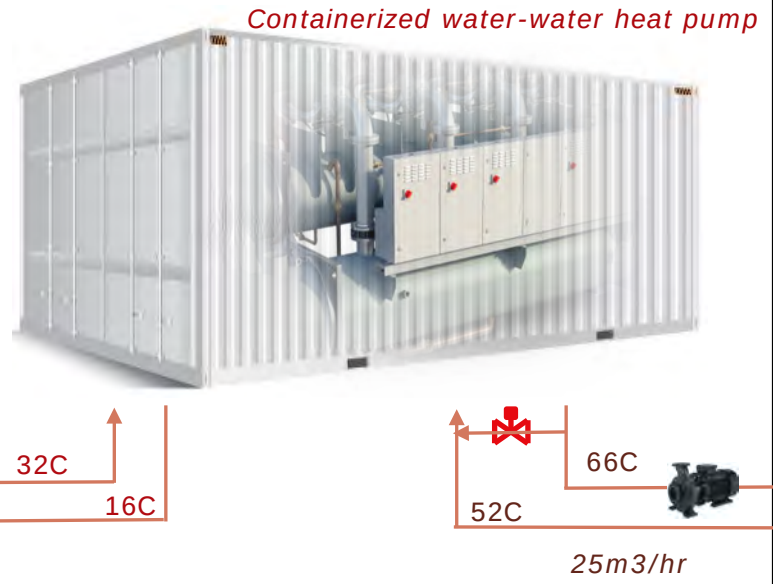
Source and Demand Variation – Process Rejection to Process Pre-Heat

Heat Recovery
Diversion from Cooling Tower



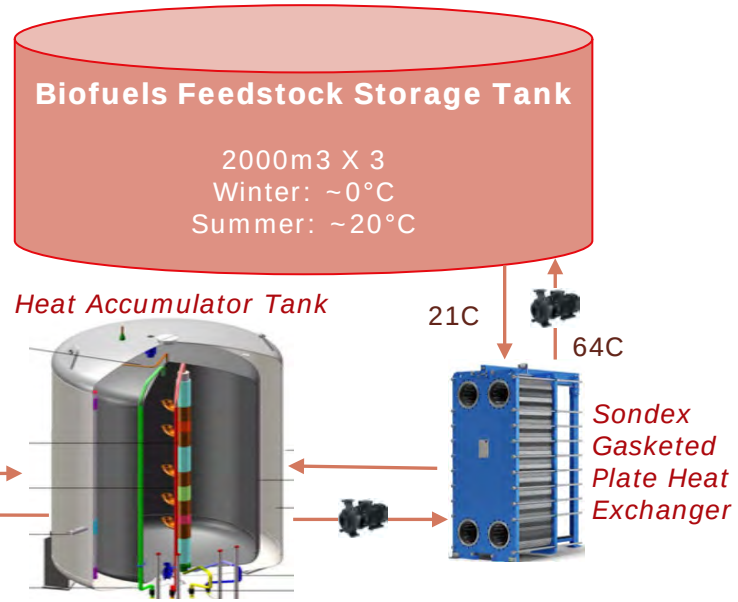
- Biofuels production process rejection heat through cooling tower
- Portion of heat diverted to recovery loop with Danfoss VSD Grundfos pumps
- Cooling towers remain for rejection of heat not recovered

Heat Pump
Single Circuit Oil-Free Turbo



- Supplied to evaporator loop of water-water heat pump
- Oil-Free turbo single circuit heat pump
- Boosting recovered heat directed from cooling tower loop
- Recirculation loop for low-temp startup

Parts Washing
Sondex GPHE

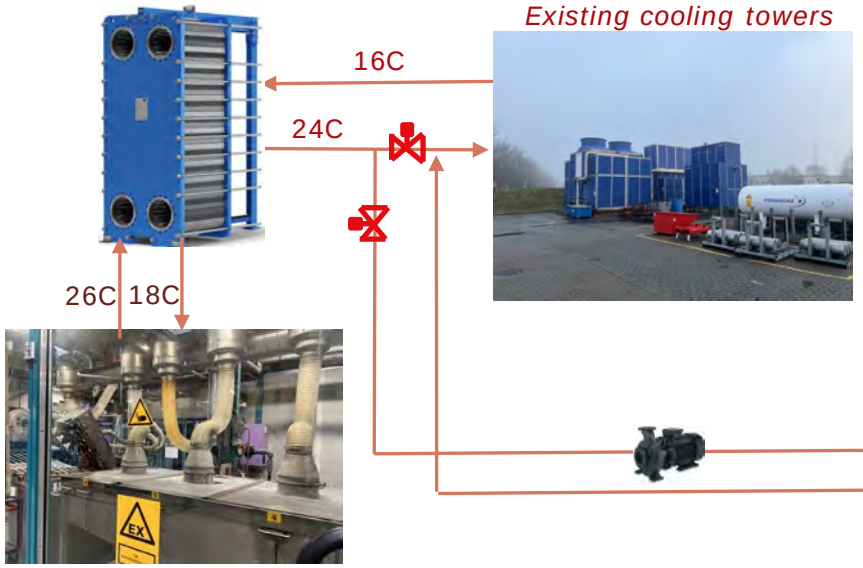


- Heat storage tank for demand disconnect when feedstock not arriving
- Heat supplied to biofuel feedstock via Sondex Gasketed Plate Heat Exchanger
- Small continuous recirculation feedstock pump to three parallel tanks / three heat exchangers

Source, Heat Pump and Demand Analysis

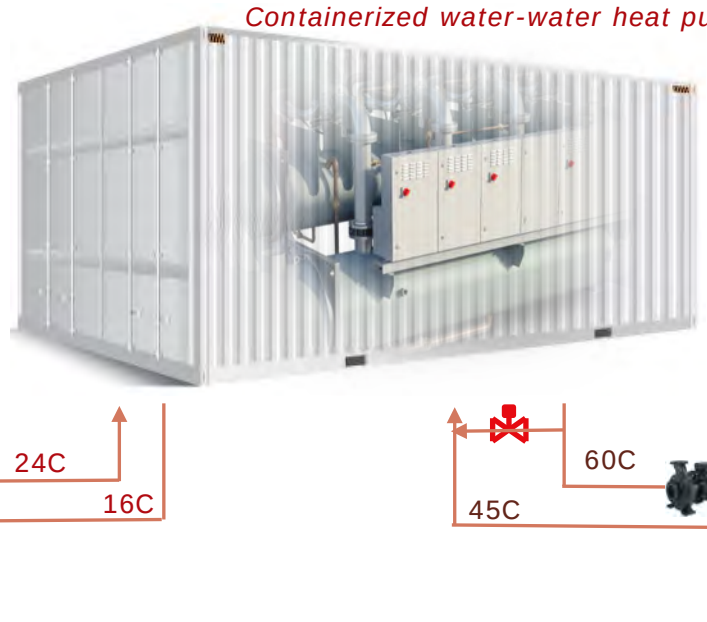
Source and Demand Variation – Process Rejection to Facility Heat

Heat Recovery
Diversion from Cooling Tower



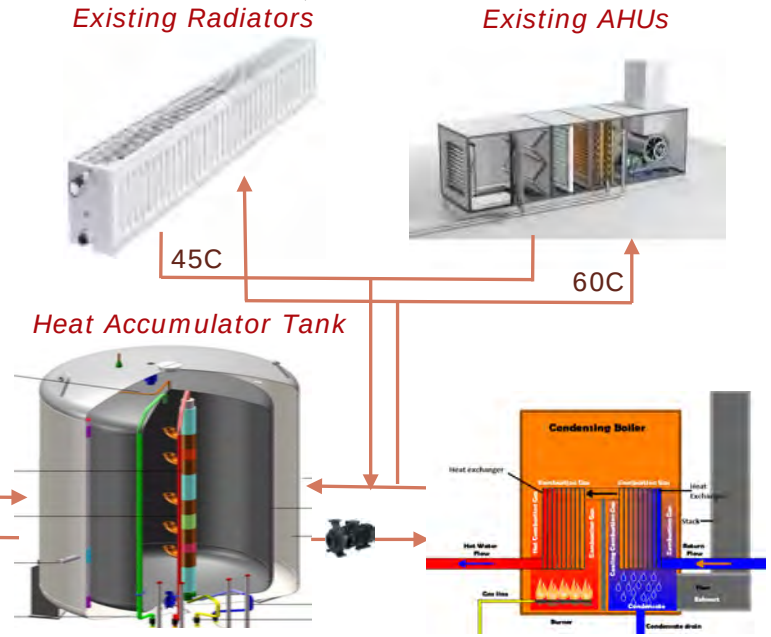
- Extruded aluminum parts production process rejection heat through cooling tower
- Heat diverted to recovery loop with Danfoss VSD Grundfos pumps
- Cooling towers remain for rejection of heat not recovered

Heat Pump
Series-Series Oil-Free Turbo



- Supplied to evaporator loop of water-water heat pump
- Oil-Free turbo series-series counterflow heat pump
- Boosting recovered heat directed from cooling tower loop
- Recirculation loop for low-temp startup

Parts Washing
Sondex GPHE



- Heat storage tank for demand disconnect when comfort heat not needed
- Heat supplied to existing factory AHUs and office radiators
- Condensing boiler remains as backup when recovered heat not sufficient

Danfoss Hydronic System Portfolio

Optimization tools for DC networks
Supply temperature optimization in DHC networks
DP optimization in networks / lower pumping costs and dT improvement

Leanheat Production
Leanheat Monitor/ Network + Virtus iNET
Leanheat Building

Precise control of cooling network

Precise control of chilled water with PICV enabling perfect control and effcient operation

AFQM, AFQMP

Hydronic Heat Exchangers

Heavy duty, efficient heat transfer for energy reuse

GPHE

Spiral HE

Hydronic Microchannel Heat Exchangers

For airside energy recovery and free cooling applications

Water flow control Motorised valves or PICV with electrical actuators

For precise flow control of water flows

AMV/E 65x, 55, 855, 20/23
AB-QM DN 40-100

Cooling tower control

Precise control of cooling water from cooling towers

VF3/ VFY

Hydronic Stations

Building, radiator, fan coil and domestic water substations

EvoFlat MSS

Building Substation

Rotary mixing valves and actuators

Maintining a chosen minimum temperature through a mixing loop

SonoSelect Energy Meters

Hydronic heat meters to ensure measuring heat transfer and equipment performance

Active pressure optimization of cooling network

Precise control of water from cooling towers

iNet, iSet

Safety temperature monitor

Controller closes on rising temperature with spring to ensure valve closes if sensor malfunctions

STM

ECL comfort temperature control

Weather compensation & heat/cold transfer control on a heating/cooling substation.

ECL 210/310/296

Accessories

- Temp. sensors (PT1000)
- Room units

Δp relief control

Placed in a bypass of pumps to achieve protection through limiting of max differential pressure

AVPA/AFPA

Strainers

(cast iron & brass)
DN15-300; t:-10°C +300°C
FVF & FVR

Ball valves

(Brass)
DN15-300; t:-20°C +120°C
BRV

Butterfly valves

(with Manual gearbox and Electric actuator)
DN25-600; t:-10°C +120°C
VFY

Non-return valves

(brass, cast iron or SS)
DN15-600; t:-10°C +100°C
NVD

Air-vents

(Brass)
DN10-15; t:0°C +110°C

Case Studies / Success Stories

1. **Ringsted, Denmark, installed and operating (installed)** - https://www.danfoss.com/en/service-and-support/case-stories/dhs/ringsted-district-heating-company-s-heat-recovery-kickstarts-a-new-era-of-greener-district-heating/
2. **Danfoss data center cooling and heat recovery (installed) -** https://www.danfoss.com/en/service-and-support/case-stories/cf/green-data-centers-at-danfoss-headquarters/
3. **Sonderborg Hospital cooling and heat recovery (installed) -** https://www.danfoss.com/en/about-danfoss/news/dcs/hospital-sets-a-lighthouse-example-in-energy-efficiency/
4. **Danfoss Smartstore and heat recovery -** New 'Smart Store' paves the way for 21st century supermarkets | Danfoss
5. **DSV Headquarters ATES (installed)**
6. **Eurowind Headquarters ATES (installed) – ATES Thesis**
7. **Fredrikshavn district heating flue gas condensing (installed) – Case story draft**
8. **Hyperscale data center heat recovery to district energy – Case story draft**
9. **Aabenraa Wastewater (to be installed 3Q24) – Aabenraa Wastewater General Presentation**
10. **Graasten Brickworks heat recovery (to be installed 4Q24) – Graasten Tegl**
11. **BHJ Petfood (to be installed 1Q25) – BHJ Petfood Energy**

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