Hall 4A

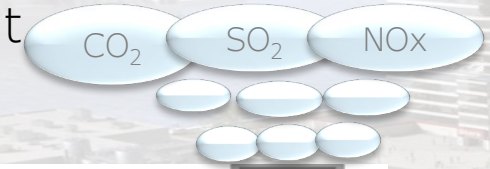
Sector Coupling for Efficient Electrification

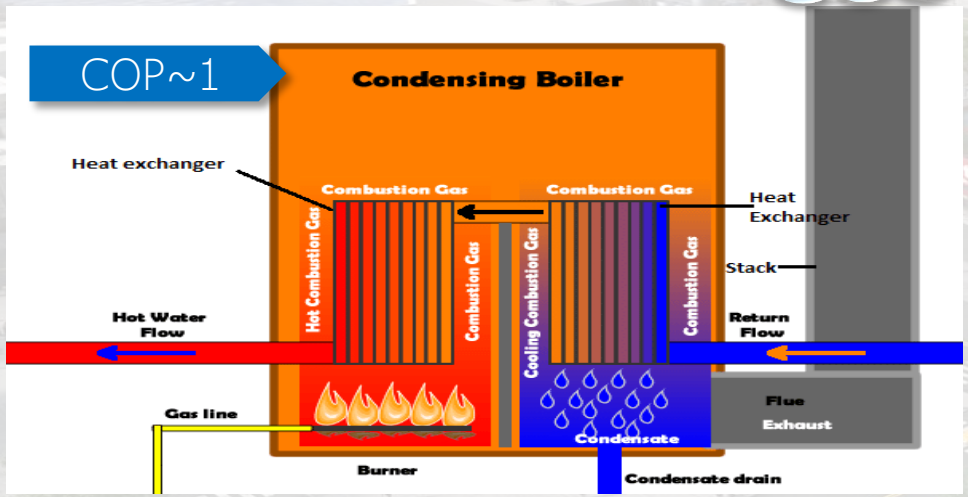
- The opportunity
- How to segment/simplify complex systems
- How source-to-demand differential is critical
- How to take advantage of source and demand differential
- Specific examples/learnings
- Conclusions

Why is the market focused on heat pumps?
Efficiency & Decarbonization

Fossil fuels	Heat pumps

- Inefficient
- Drive CO_2 & other gas emissions impacting environment





Transmission & Distribution

-5%

COP~2.5-3.5

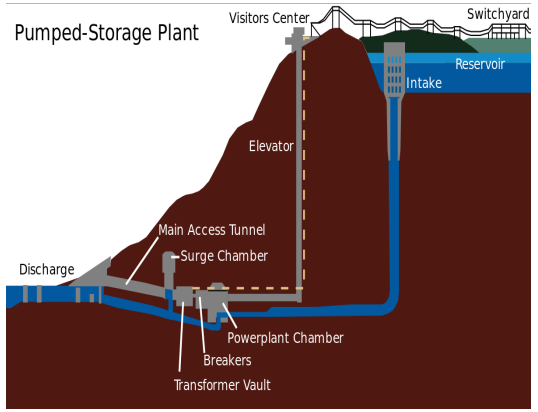
~35% operating cost reduction
~60% emissions reduction

- More efficient
- Efficiency increases at part-load/lift

Heat Pump Part Load Efficiency

Supply/Demand Disconnect – How To Address

Energy storage / Thermal storage



Demand-side scale provides built-in flywheel storage & enables options

The Excess 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:

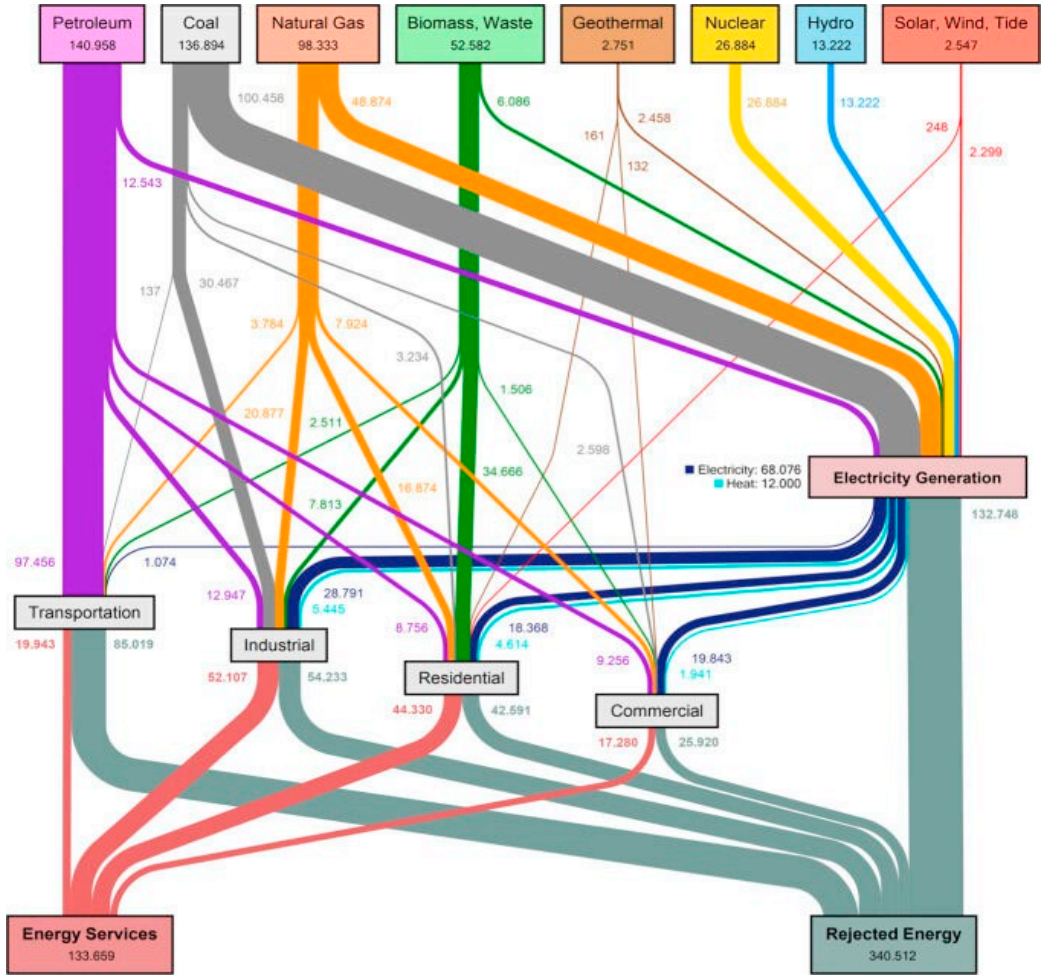
a) electricity-only" renewables (mainly solar and wind)

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

System Design Example – Subway Recovered to District Energy

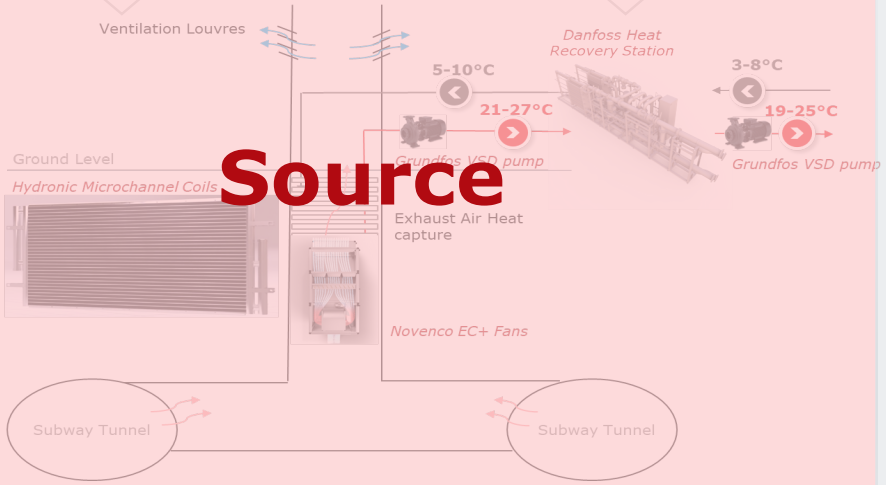
Heat Recovery
Airside Hydronic Microchannel

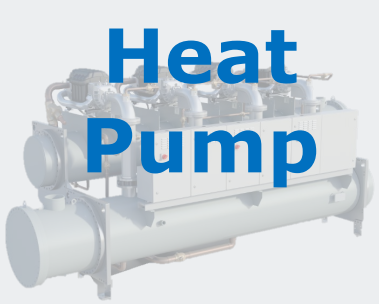
Recovery Loop
Danfoss Hydronic Station

Heat Pump
Oil-Free Turbo

Heat Storage
Accumulator Tank

District Energy
4th Generation DH





40°C

67°C

40°C

Demand

67°C

Building and system modernization

(Multiple potential)
Low, medium and high-temp

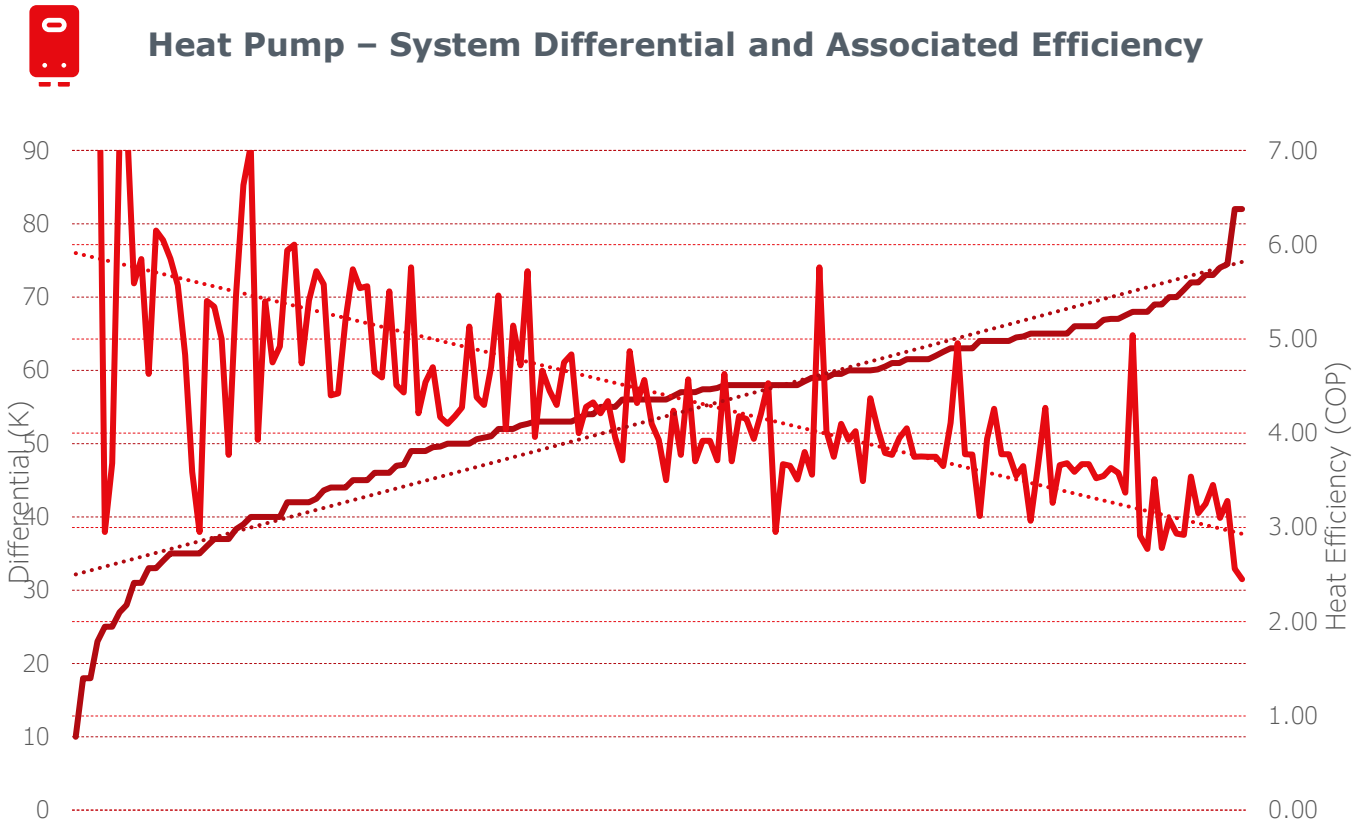
Various compressor technologies

(Multiple potential)
Low, medium and high-temp

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 / Decarbonization** = **2% Payback Period / Electrical load**

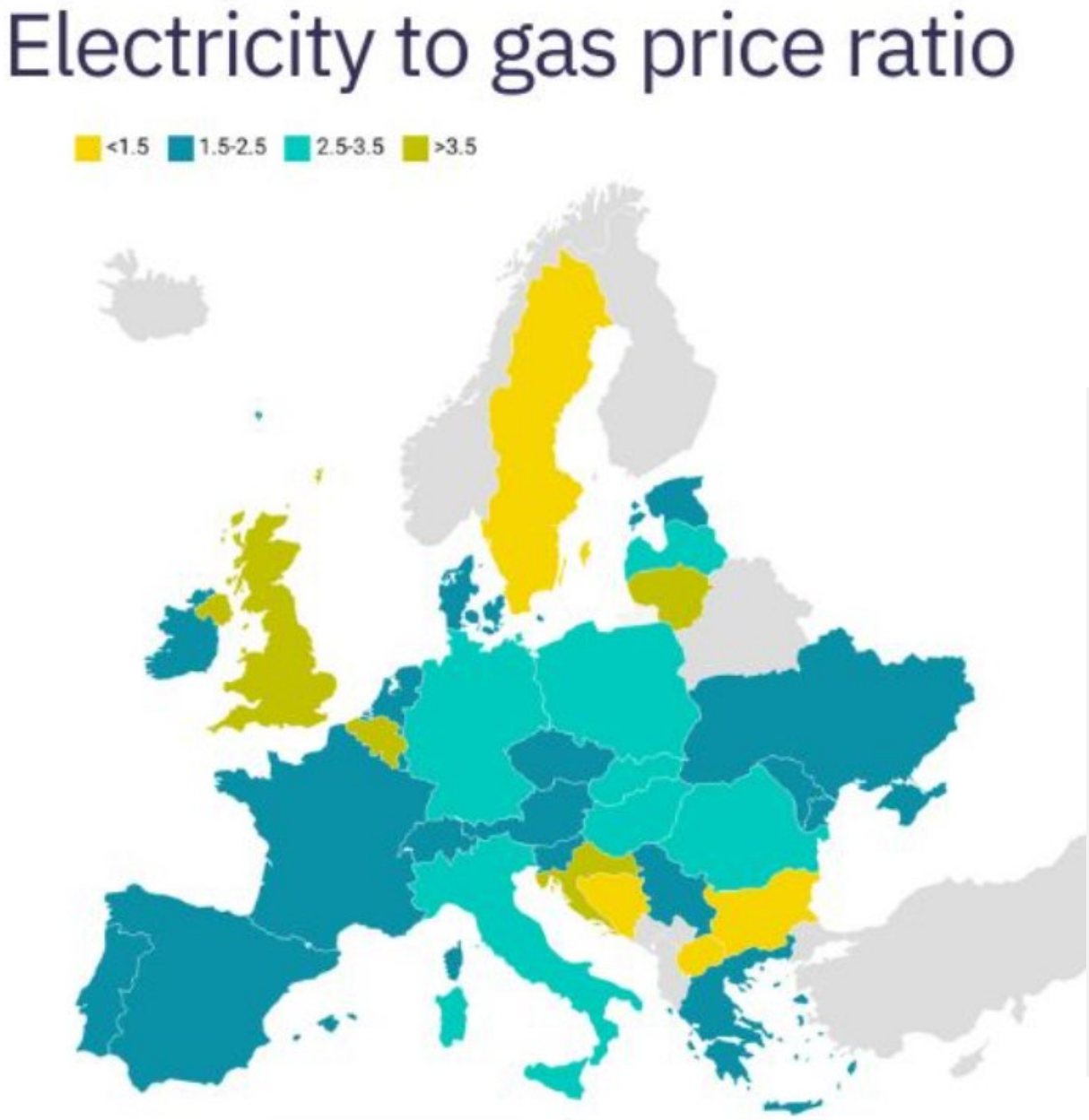


Spark Spread –

EUR 1st Half 2023

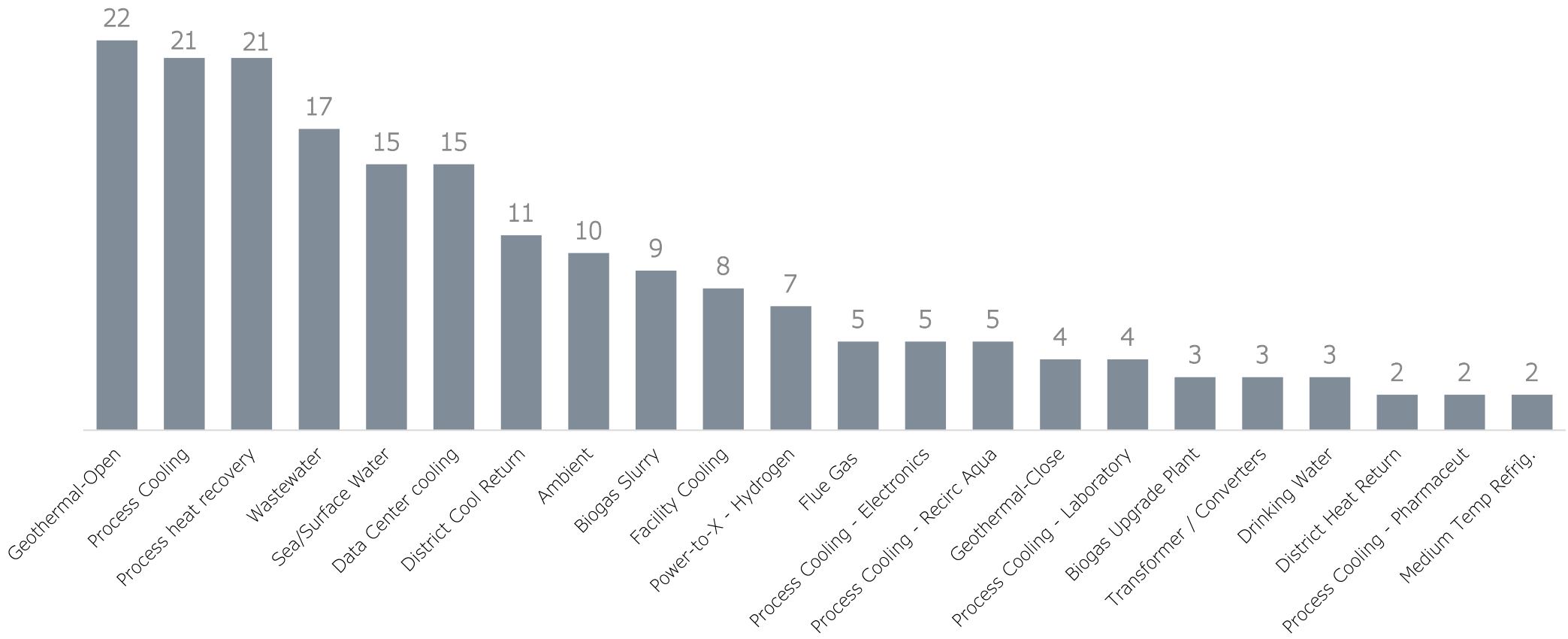
- **Electrification COP > spark spread = payback**
- **Ratio driven by both electricity and gas cost**
- **Wide variation by country**
- **Variation also in real-time vs average**

(3) European Heat Pump Association: Overview | LinkedIn



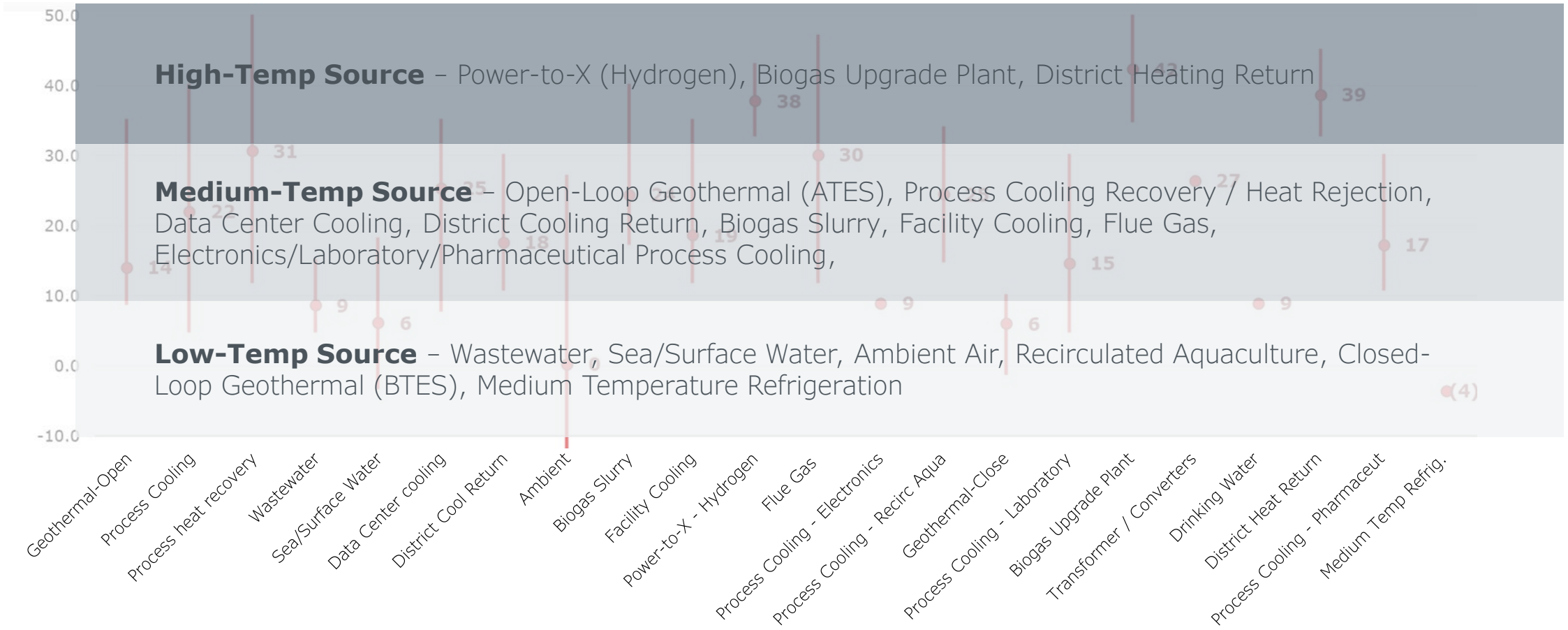
Heat Sources - Projects

Opportunities by Heat Source (# of projects)

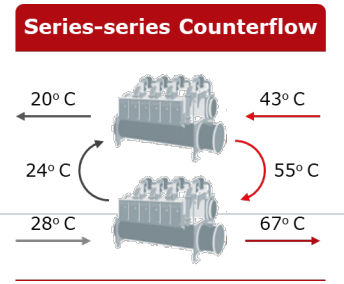


Heat Sources - Quality Grouping

Source Temperature Average/Range



Performance
Why Is Series-Series Counterflow More Efficient?



67°C Heating Supply

55°C Circuit 1 Supply

43°C Heating Return

28°C Cooling Return

24°C Circuit 2 Supply

20°C Cooling Supply

Temperature °C

Heating

Series-Series Circuit 1 Compressor Work

Single Circuit Compressor Work

Series-Series Circuit 2 Compressor Work

Cooling

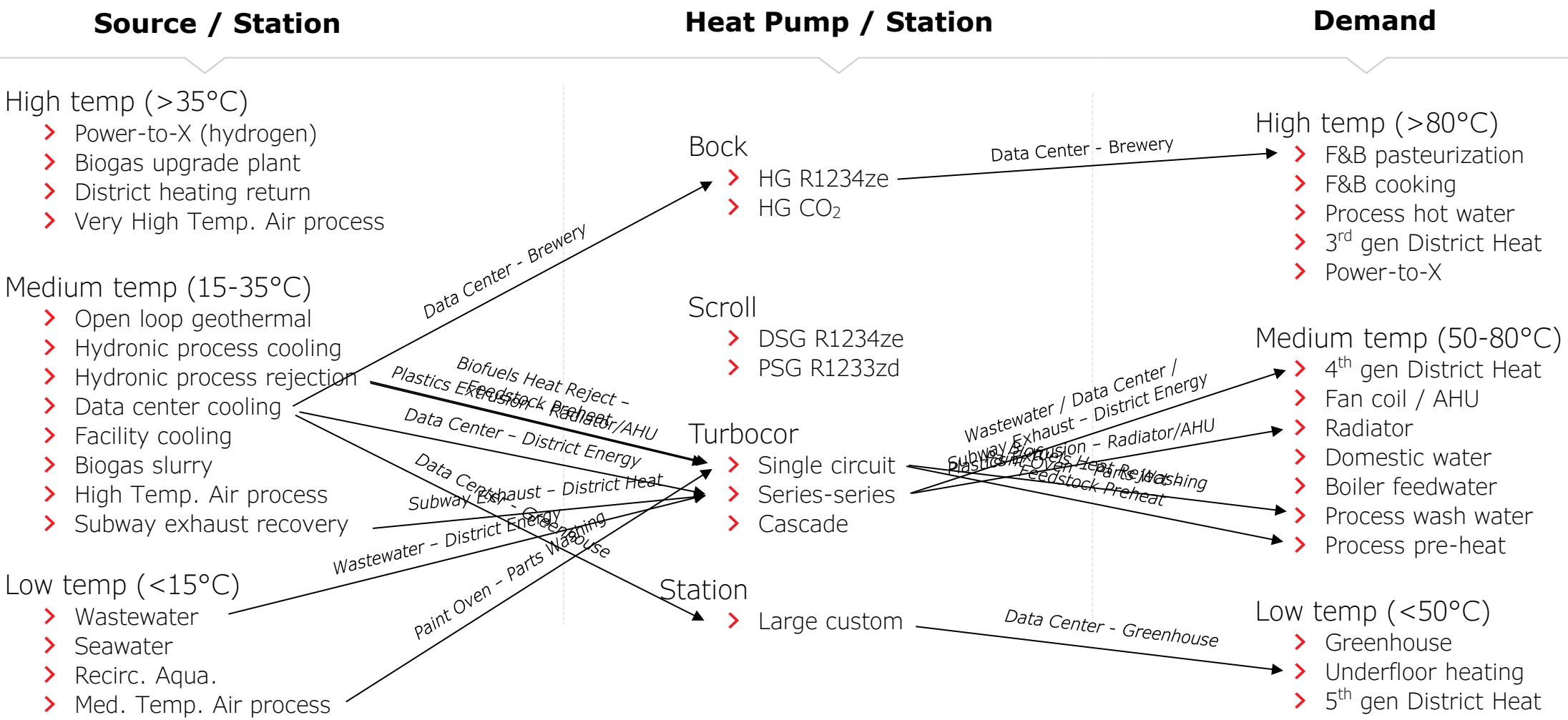
43K Series-Series Circuit 2 Differential

47K Single Circuit Differential

35K Series-Series Circuit 1 Differential

Dividing system into two circuits lowers work and increases efficiency (18% in this case)

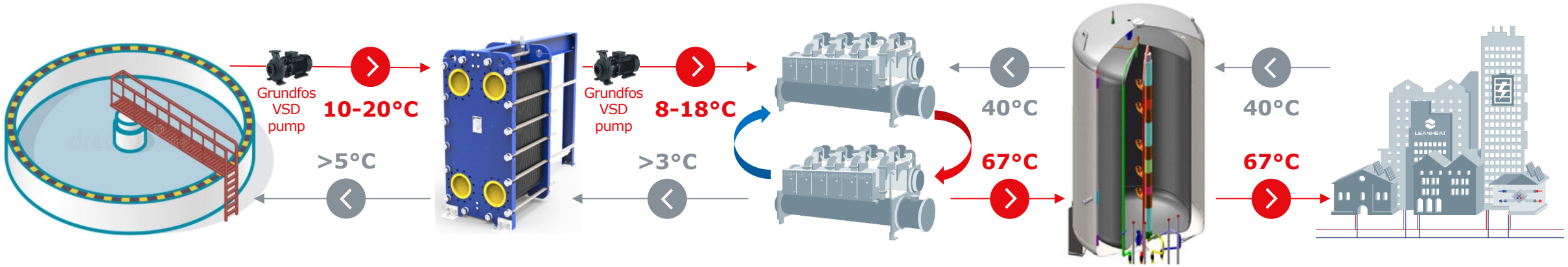
Source, Heat Pump and Demand Analysis
Variations to Include



Source, Heat Pump and Demand Analysis
Source Variation – Wastewater

64K Differential = 4.1 COP

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

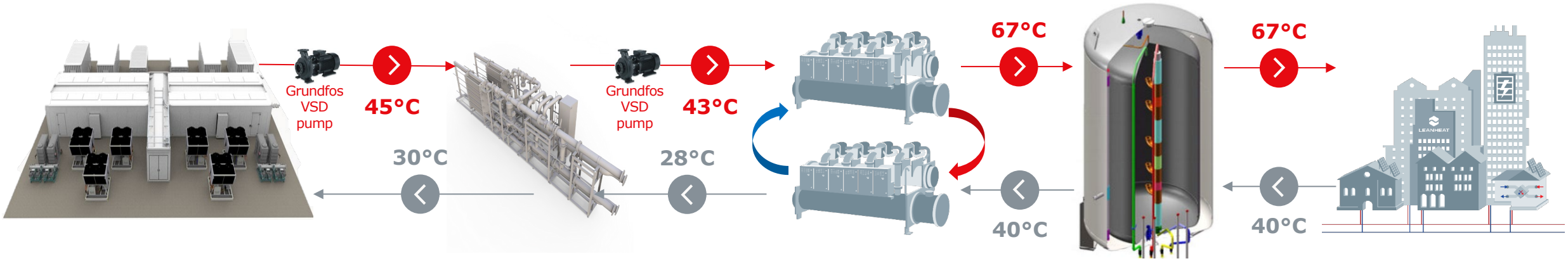
- Series-series counterflow heat pump
- Boosting recovered heat directed from Danfoss station
- Boosted to loop for heat accumulator tank

- 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

39K Differential = 6.8 COP

Heat Recovery	Recovery Loop	Heat Pump	Heat Storage	District Energy
Treated Wastewater	**Danfoss 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

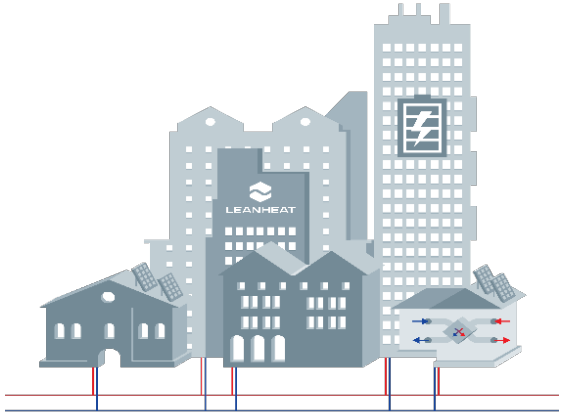
- Series-series counterflow heat pump
- Boosting recovered heat directed from Danfoss station
- Boosted to loop for heat accumulator tank

- 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

Retrofit Danfoss Data Center with Water-Water Heat Pumps

Danfoss data center cooling & heat recovery system digital twin

Retrofit to heat recovery heat pump system, tied to district heating with existing cooling backup

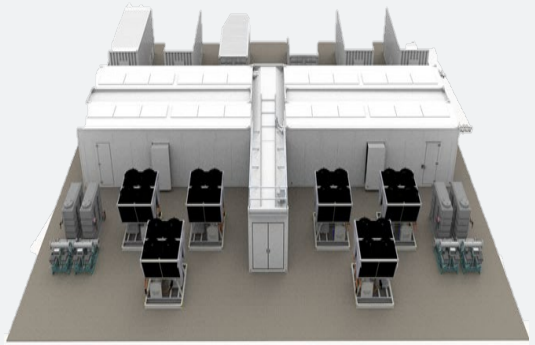


28°C

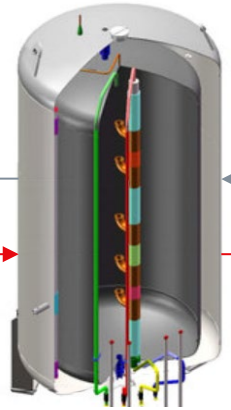
43°C

67°C

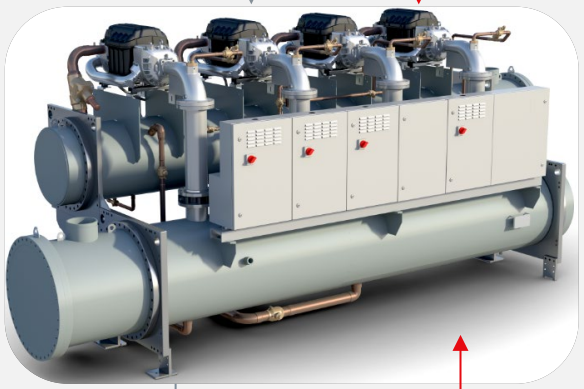
Original data center cooling system



Buffer Tank



20°C



Source, Heat Pump and Demand Analysis
Source Variation - Greenhouse

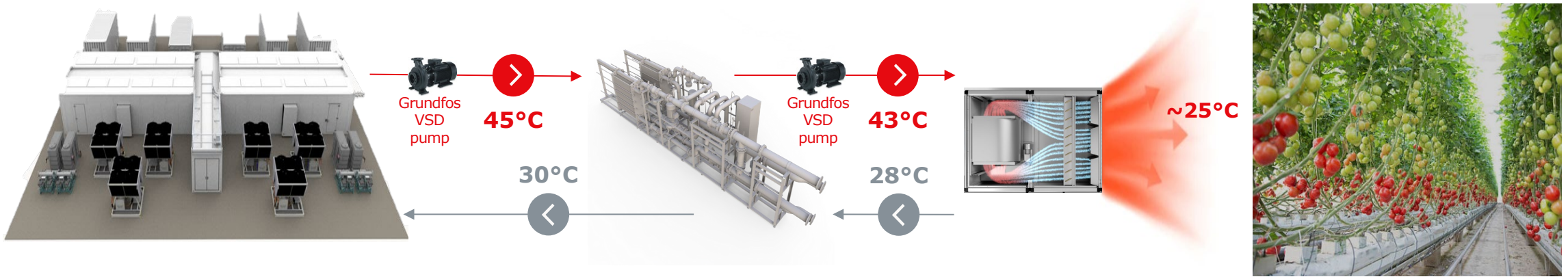
Negative Differential = 20+ COP

Heat Recovery
Liquid Cooled Data Center

Recovery Loop
Danfoss Custom Station

Air-Handlers
Novenco EC+ Fans

Greenhouse Farming
Supply Air Heat



- 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

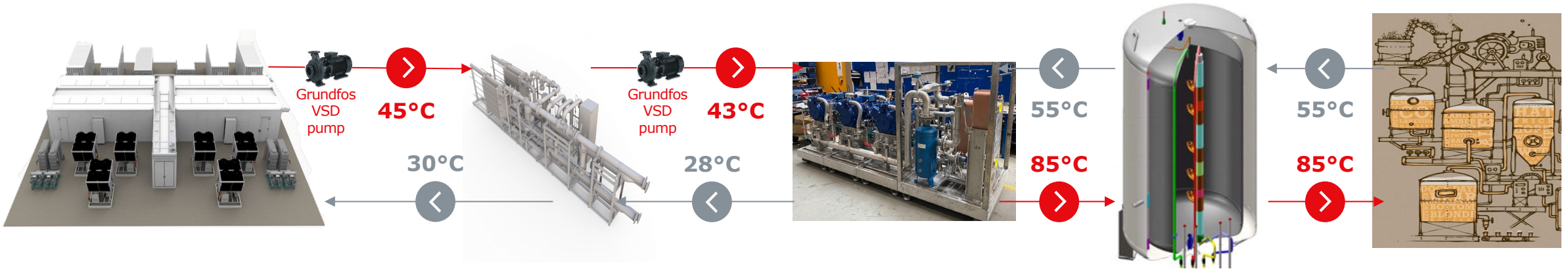
- Recovered heat supplied to air-handler for heating of outdoor air
- Heated outdoor air supplied to greenhouse to maintain year-around optimal growing temperature

Source, Heat Pump and Demand Analysis

Heat Pump and Demand Variation – Brewery

57K Differential = 4.7 COP

Heat Recovery	Recovery Loop	Heat Pump	Heat Storage	Brewery
Treated Wastewater	**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

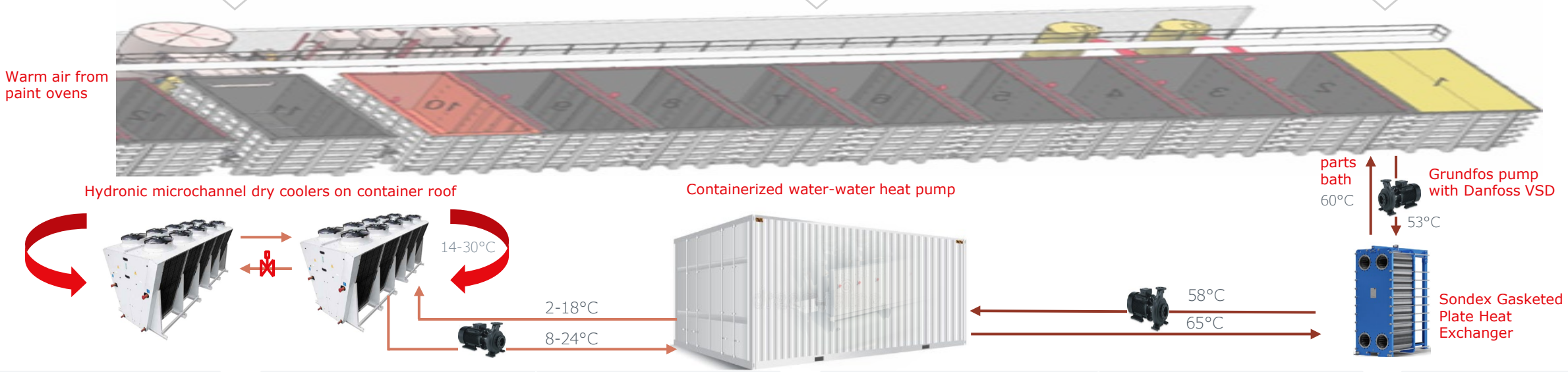
Source, Heat Pump and Demand Analysis
Paint Oven Recovery/Parts Wash Process

63K Differential = 4.2 COP

Heat Recovery
Dry Cooler w/Hydronic MCHE

Heat Pump
Single Circuit Oil-Free Turbo

Parts Washing
Sondex GPHE



- 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

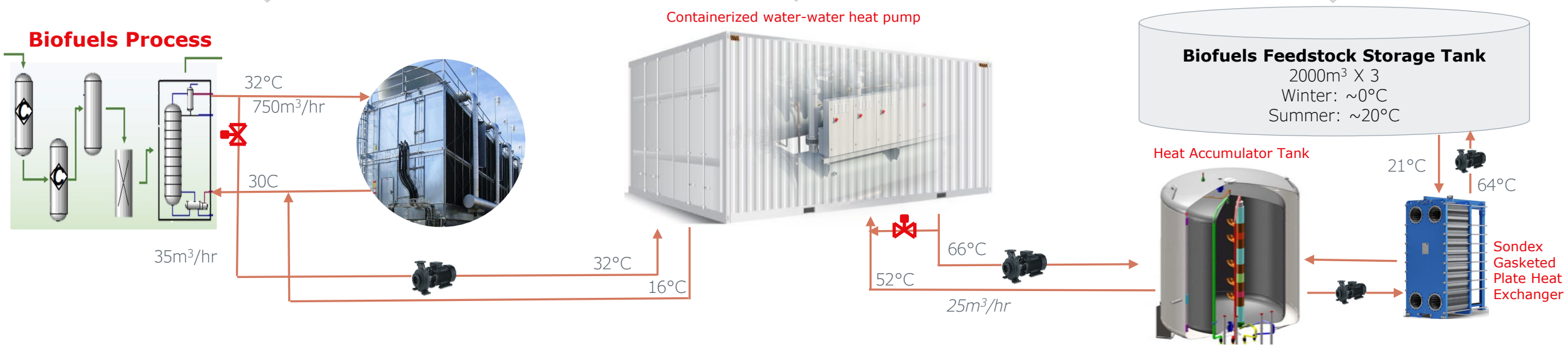
Process Rejection to Process Pre-Heat

49K Differential = 5.6 COP

Heat Recovery
Dry Cooler w/Hydronic MCHE

Heat Pump
Single Circuit Oil-Free Turbo

Parts Washing
Sondex GPHE

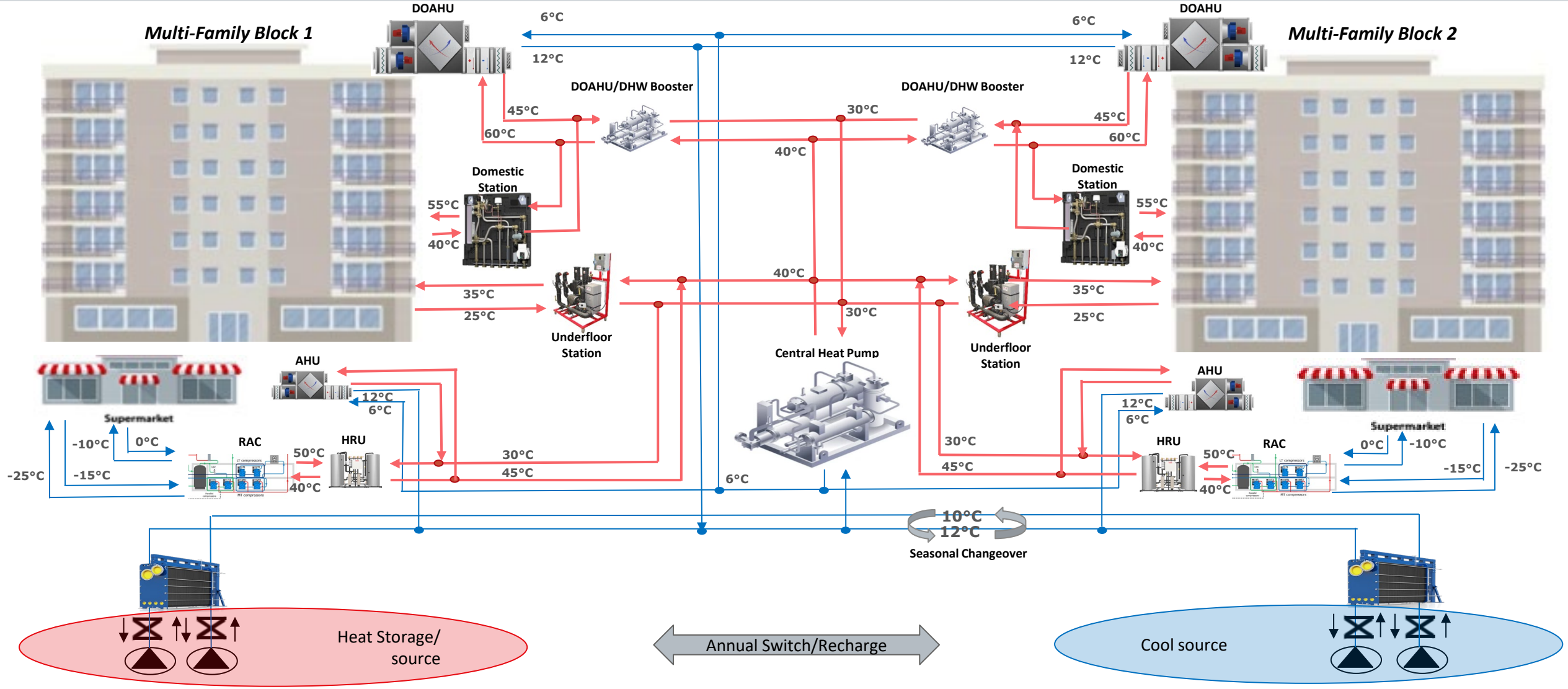


- Biofuels production process rejection heat through cooling tower
- Portion of heat diverted to recovery loop with Danfoss VSD Grundfos pumps
- Cooling towers remain for rejection of heat not recovered

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

- 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

New Build Multi-Family



Conclusion

- Efficiency, integration of renewables and decarbonization via electrification drive heat pump use growth
- Growth of renewables also creates an increasing energy supply/demand disconnect and resulting resiliency and operating cost risk
- Energy system scale with interconnection enables optimal efficiency and resiliency
- Sector coupling is about connecting two or more supply and demand energy systems, including processes and buildings
- We can learn a lot from recent integrated system design experience, in terms of energy sources and interchangeable solutions
- Demand-side efficiency and operating temperature optimization efforts are critical prior to or as a part of integrated system design efforts
- Critical facility retrofits present the ultimate efficiency and decarbonization opportunity also maximizing energy availability and resiliency
- Smart system design is critical to address the different business interests of varying large-scale system stakeholders

Hall 4A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CONNECTING EXPERTS.