ENGINEERING TOMORROW

Enabling Technologies for Integrated Systems

Jonas Loholm Hamann, Business Process Expert

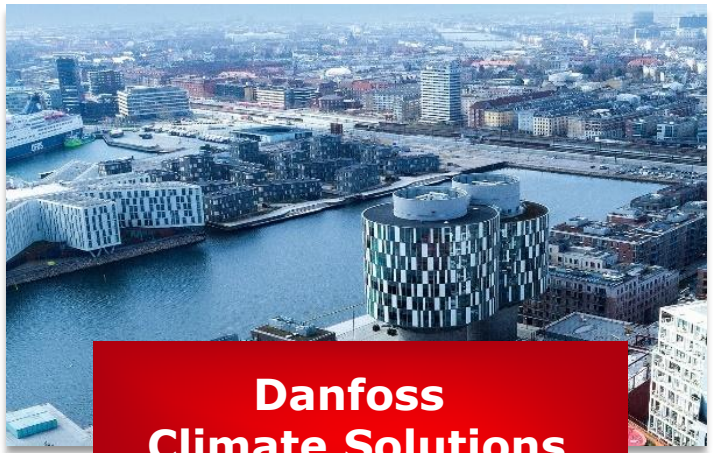
Our **Segments**

Danfoss Power Solutions

#2 Market position

- 17,200 employees
- 53 factories in 19 countries
- 3.4bn EUR annual sales

50%
of Group sales

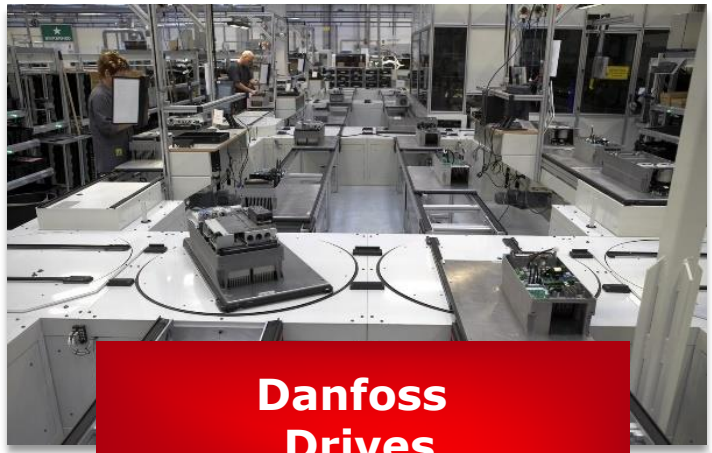


Danfoss Climate Solutions

#2 Market position

- 10,500 employees
- 35 factories in 14 countries
- 2.5bn EUR annual sales

30%
of Group sales



Danfoss Drives

#2 Market position

- 4,400 employees
- 9 factories in 7 countries
- 1.4bn EUR annual sales

20%
of Group sales

Unique technologies and know-how are at the core of the world's heating and cooling applications

Chillers

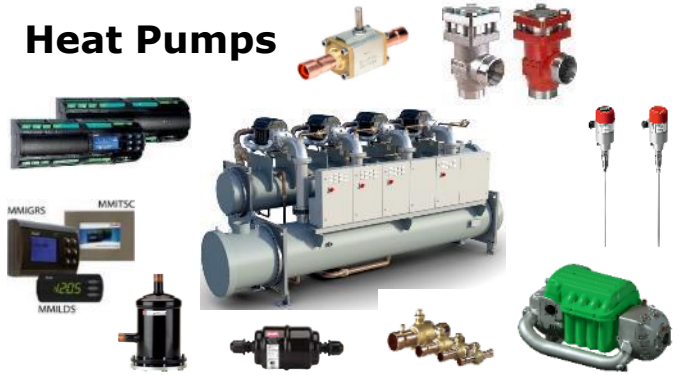
District Heating & Cooling

Danfoss **Climate Solutions**

Roof Top Units

Condensing Units

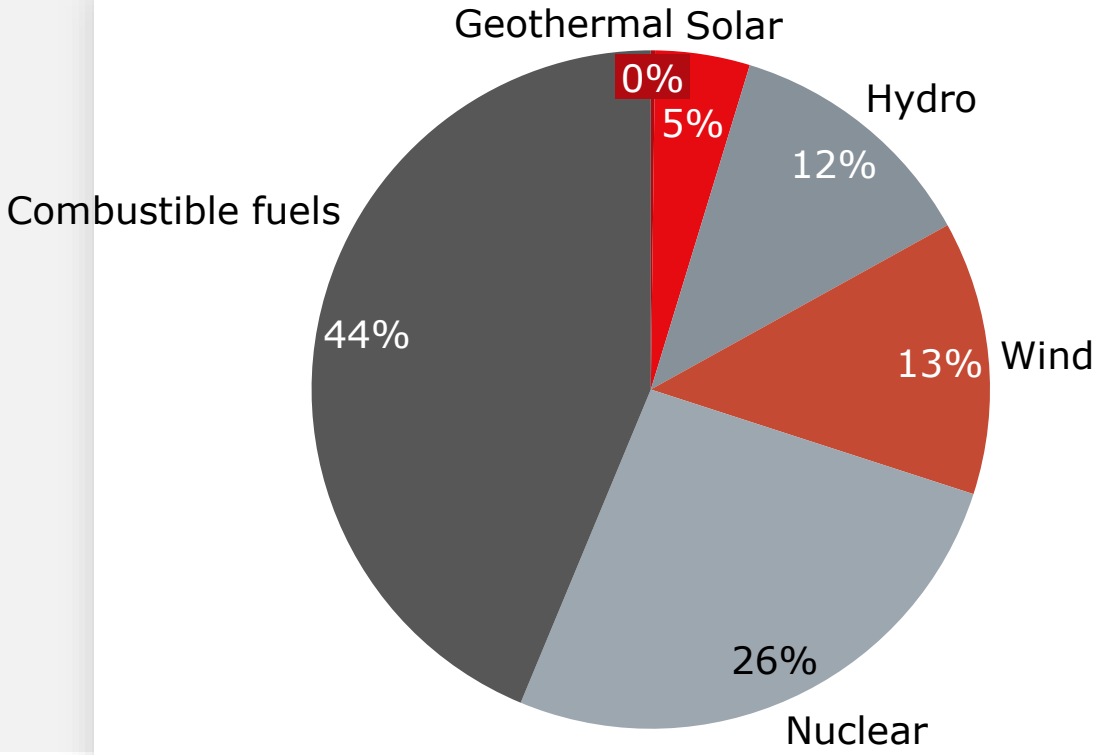
Heat Pumps



Emissions Reduction –

EU electricity generation and share from selected fuels and renewable sources

Net electricity generation in 2019 %(*)



(*) Source: Eurostat

Supply

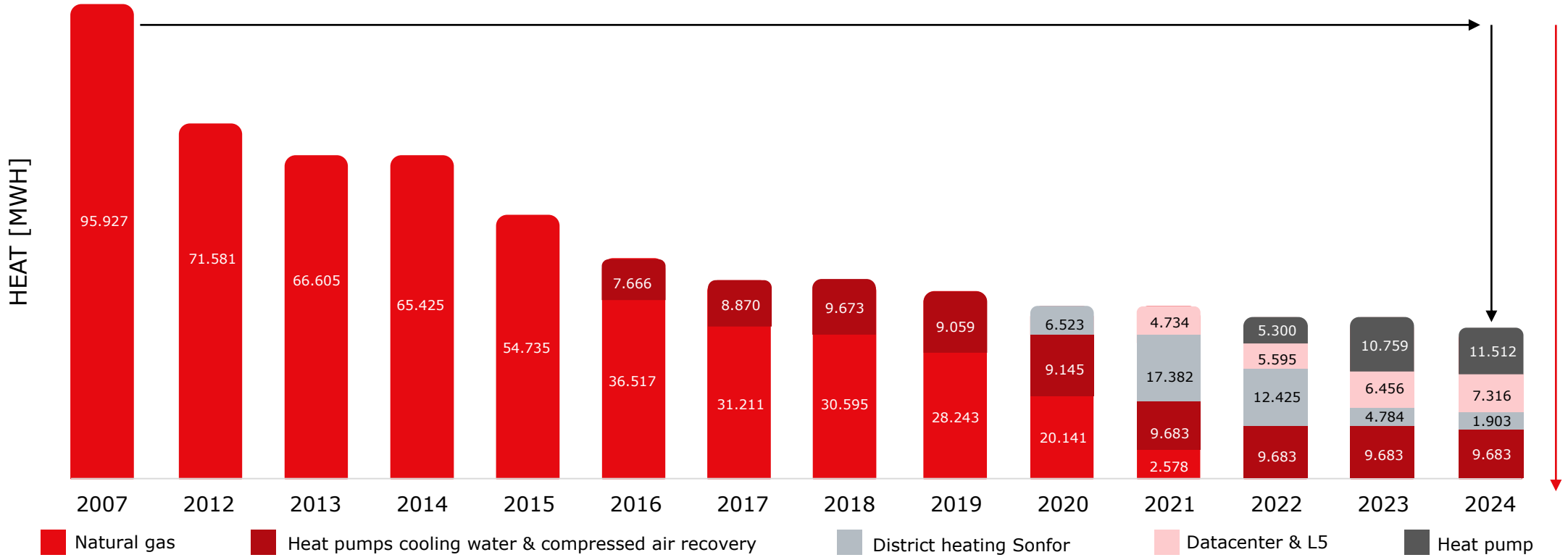
Challenge: Danfoss CO2 Neutrality in 2030
Enable Low Carbon Campus Heat via Heat Recovery

Reduced consumption of natural gas for heating = 95.927 MWh (-100%)

Reduced consumption for heating = 65.512 MWh (-68%)

Turbocor compressor technology to be used to displace natural gas or other fossil fuels

ANNUAL HEAT CONSUPTION DANFOSS NORDBORG DEGREE DAY ADJUSTED



Solution – Performance

TER = (Heating + Cooling Capacity) / Power Input

$$\text{TER} = \frac{\text{500kW Cooling + 618kW Heating}}{\text{118kW power draw}} = \text{9.5 COP}$$

Distributed application benefit:

01 | Chiller cooling

02 | Heat pump heating

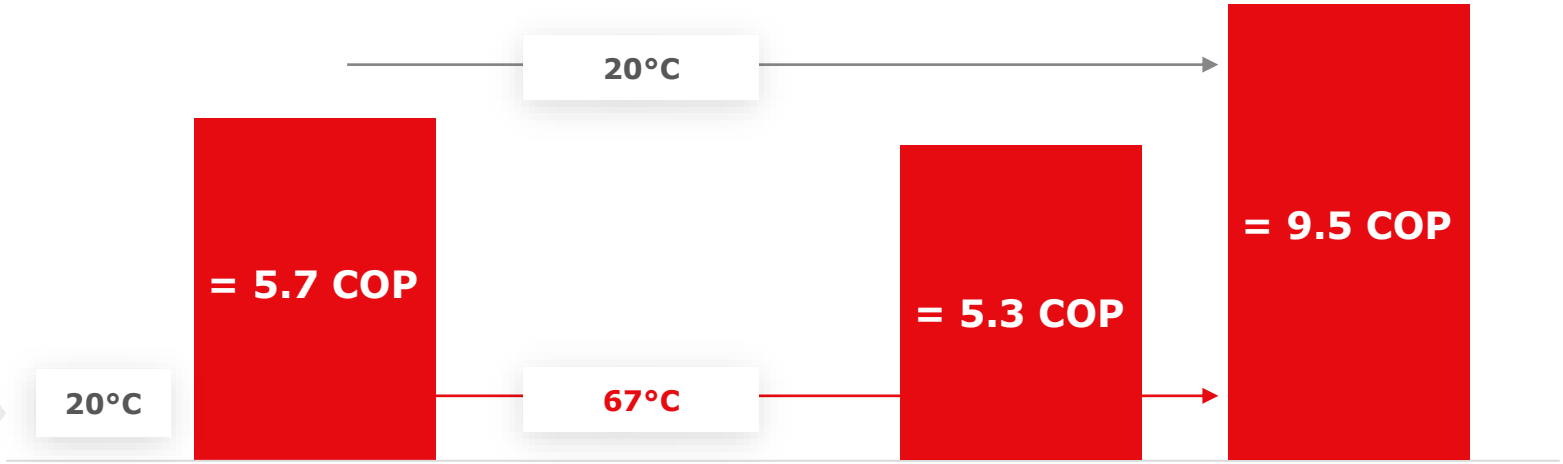
"Symbiosis System" – Total Efficiency Ratio

From cooling or heating to "moving heat"

Recovery capacity limitations eliminated with district heating

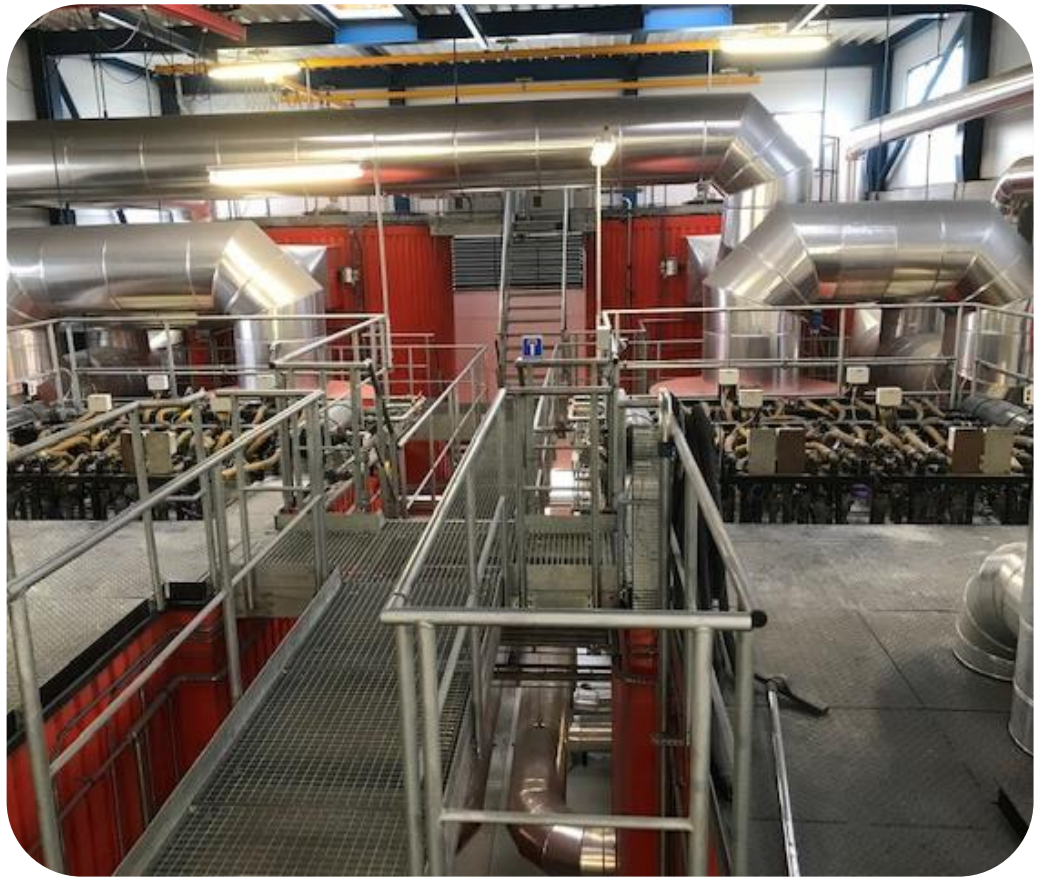
Air-Cooled Chiller

Symbiosis System



Achieving 97% Carbon-Free Heat

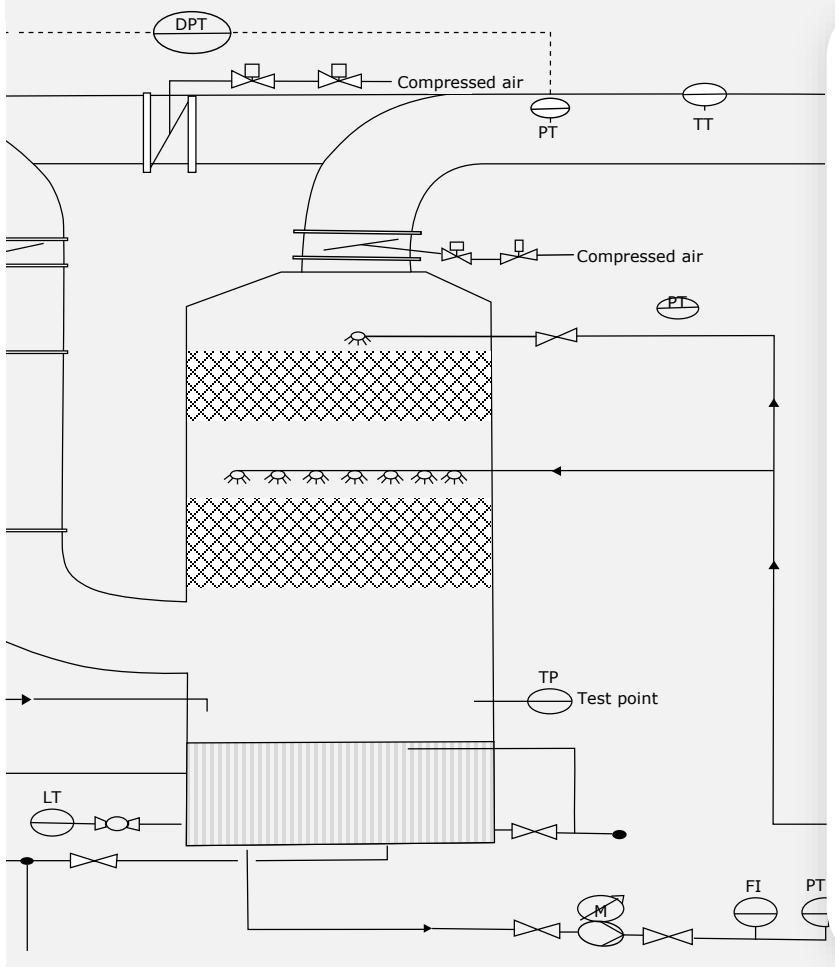
- Ringsted, Denmark District Heating Utility commitment to achieve 97% carbon-free heat supply by 2020
- Heat previously provided by two straw-fired biomass boilers and a gas-powered Combined Heat & Power (CHP) plant – 75% carbon-free



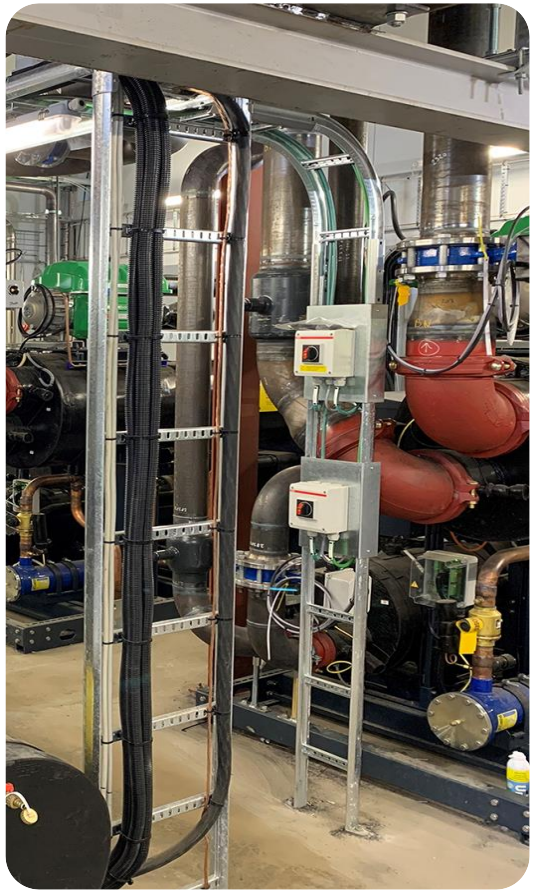
Increase From 75% to 97% Carbon-Free Heat

- Add large capacity air-water heat pump
- Recover all possible heat via cooling –
  - Air-water heat pump drives
  - Flue gas scrubber (remove SO2)
  - CHP engine jacket water
  - Equipment room
- Maximize capacity & efficiency - Minimize heat price

Boiler Flue Gas Scrubber



- Heat Capacity: 962kW
- Added boiler condensing capacity: 850kW
- Efficiency: 6.2 COP
- Total System Applied Cost: $1.88m
- Annual savings – operating cost: $0.55m
- Simple payback: 3.4 years



Why Oil-Free Technology Was Chosen

- Efficiency – Optimized to application & maintained
- Operating temperature flexibility (efficiency-related)
- Footprint – Limited space available
- Install/startup/commission – 1 week vs 2 months
- Maintenance/cost – Downtime & heat price
- Refrigerant – A2L, low-charge & pre-packaged
- Sound levels
- OEM partner (Geoclima) installation, startup & service support

Why Water-Water Heat Pump & High Heat Recovery Temperature are Critical

- **Multiple heat source choices**
- **Large air-water heat pump ~3-3.5 COP**
- **Oil-free water-water recovery heat pumps ~6-7 COP, based mainly on higher source temperature**
- **High electricity price fluctuation**
- **From efficiency & resulting operating cost / heat price**
  - Air-water heat pumps operate when electricity price < 600 DKK/MWh (~300 hours this year)
  - Oil-free heat pumps operate when electricity price < 1200 DKK/MWh (>80% of the year)

Daily electricity price fluctuation – One day (10/21)

Low	~$120/MWh
High	~$360/MWh

For DHU, difference between low-cost baseload heat source with quick payback and peaking plant backup

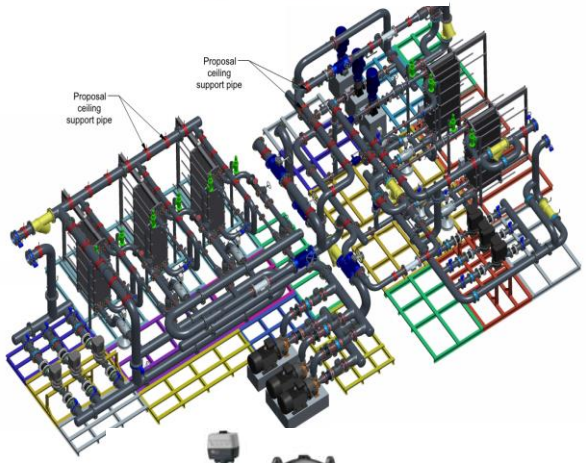
Critical Technologies – Energy Transfer Stations

Energy Meters

JIP™ Ball Valves

Electronic Controllers ECL Comfort

SCADA visualization and monitoring systems



Customer Benefits:

- Substation equipped with high quality components, ensuring comfort, performance and energy saving
- Components optimized and tested for district applications
- Control loop components tuned together for system optimization
- Packaged system with single supplier
- Station solutions for all applications & sizes
- Broad portfolio enabling application knowledge & support

Temperature Controllers

Differential Pressure and Flow Controllers

Motorized Control Valves

Plate Heat Exchangers*

Danfoss Hydronic System Portfolio

Hydronic Heat Exchangers

Heavy duty, efficient heat transfer for energy reuse

Optimization tools for DC networks

Supply temperature optimization in DHC networks

DP optimization in networks / lower pumping costs and dT improvement

Leanheat Production | Leanheat Network + Virtus iNET

Δp relief control

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

AVPA/AFPA

Precise control of cooling network

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

AFQM, AFQMP

Cooling tower control

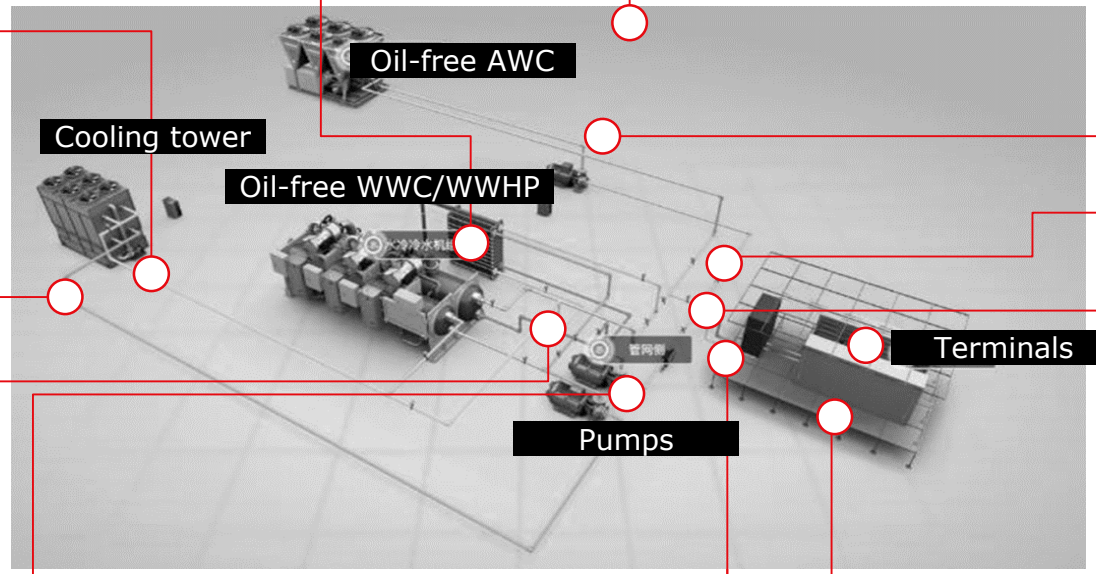
Precise control of cooling water from cooling towers

VF3/ VFY

Active pressure optimization of colling network

Precise control of cooling water from cooling towers

iNet, iSet



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

BRV **Ball valves**
(Brass)
DN15-300; t:-20°C +120°C

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

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

Air-vents
(Brass)
DN10-15; t:0°C +110°C

All products are high-runners in HVAC applications

Rotary mixing valves and actuators

Maintining a chosen minimum temperature through a mixing loop

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

Safety temperature monitor

Controller closes on rising temperature and has a spring that ensure the valve closes if the thermostatic sensor malfunctions

STM

Water flow control Motorised valves or PICV with electical actuators

For precise flow control of water flows in cooling systems

AMV/E 65x, 55, 855, 20/23, ...

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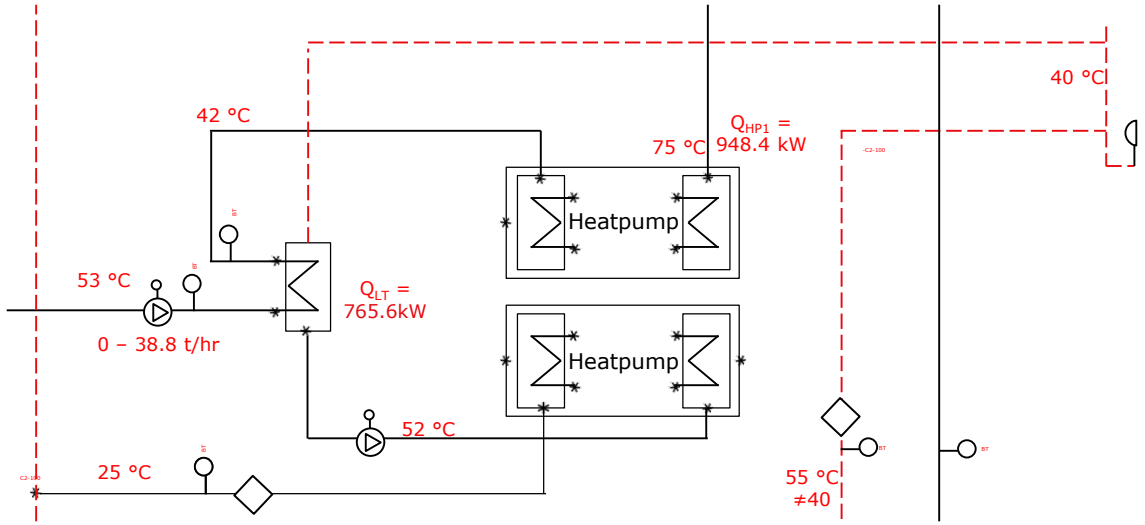
Critical Facility Cooling / Heat Recovery Systems – Best Bet for Baseload Heat Recovery Heat Source

01 Critical facility cooling & heat recovery ~20°C+

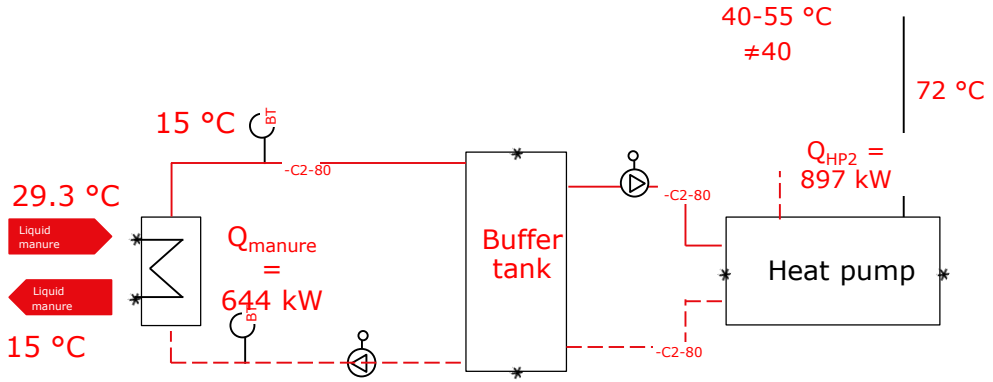
02 Geothermal and comfort cooling ~10-20°C

03 Ambient air/water & refrigeration ~<10°C

Biogas Upgrade Plant



Slurry Cooling



Slurry Cooling / Heat Recovery COP 3.5	Upgrade Plant Heat Recovery HP COP 5.2 System COP 7.9

Related Opportunities – Biogas Plant

Heat recovery from Biogas Upgrade Plant

- DH return water through PHE to preheat up to 49.5 ℃, then WWHP to 75℃
- Solution: 1 WWHP with 2 refrigerant circuits, each circuit with single compressor

Cooling and Heat Recovery from Biogas Slurry

- Source water temperature from Slurry HEX 15/10℃, targeting hot water temperature @72 ℃
- Slurry cooling enables more biogas participation and eliminates neighbor complaints

System Performance

	Heat Pump / Compressor					Source Water			Supply Water		
	Compr. Quantity	Power kW	Cool kW	Heat kW	Heat COP W/W	Inlet ℃	Outlet ℃	Flow m^3/h	Inlet ℃	Outlet ℃	Flow m^3/h
Biogas Upgrade Plant											
WWHP	2	183	766	**948**	**5.2**	42	25	39	52	75	36
HEX	1		493	493		53	42	39	40	52	36
Total system		183	1,259	1,441	7.9	53	25	39	40	75	36
Slurry Cooling/Recovery											
WWHP	3	253	644	**897**	**3.5**	15	10	111	52	**72**	39

Refrigeration/HVAC Warehouse System Integration

Refrigerated Section

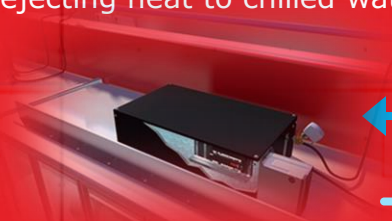
Low- & Medium-Temp

Replace Medium-Temp DX Refrigeration with water-water heat pump glycol loop

-9°C

-3°C

Tie low-temp refrigeration with semi-plug-in cabinets, rejecting heat to chilled water loop



-20°C

-15°C

7°C

12°C

Water-Water Heat Pump

1.3MW Heat

Adiabatic Chillers

1.3MW Cool

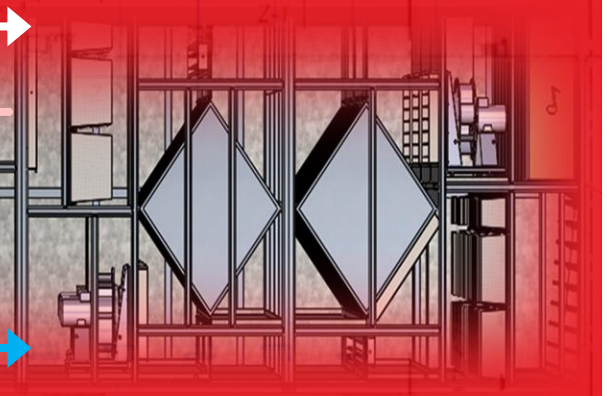
HVAC Section

Comfort Heating & Cooling

Replace RTUs with AHUs, providing heating and cooling

35°C

45°C



7°C

12°C

Benefit Factor	NPV (20-Yr 5% discount)	CO2 Reduction (20-yr Tons)	Energy Savings (20-Yr MWh)
Medium-Temp Refrigeration Heat Recovery	$1,745,729	8,204 tons	124,395
Adiabatic Chiller / AHU Replace RTU Cooling	$646,198	3,187 tons	6,928
Low-temp refrig. reject heat to chilled water	$192,810	951 tons	2,067
Replace HFC refrigerants with HFO		3,631 tons	
Total	**$2,584,737**	**15,972 tons**	**133,389**

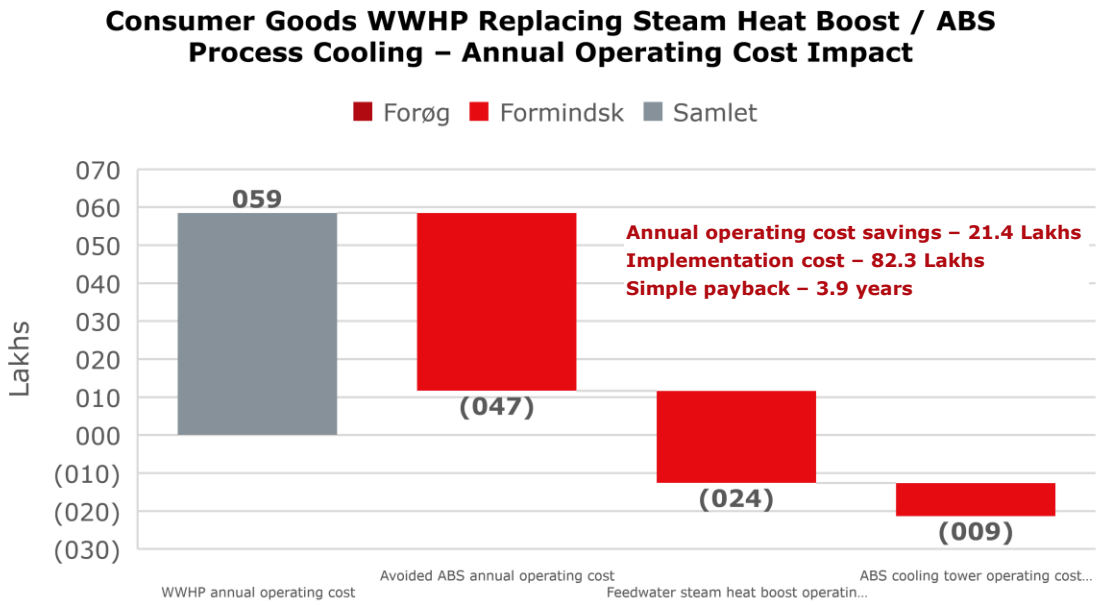
Consumer Goods Process Improvement (Hybrid Systems)

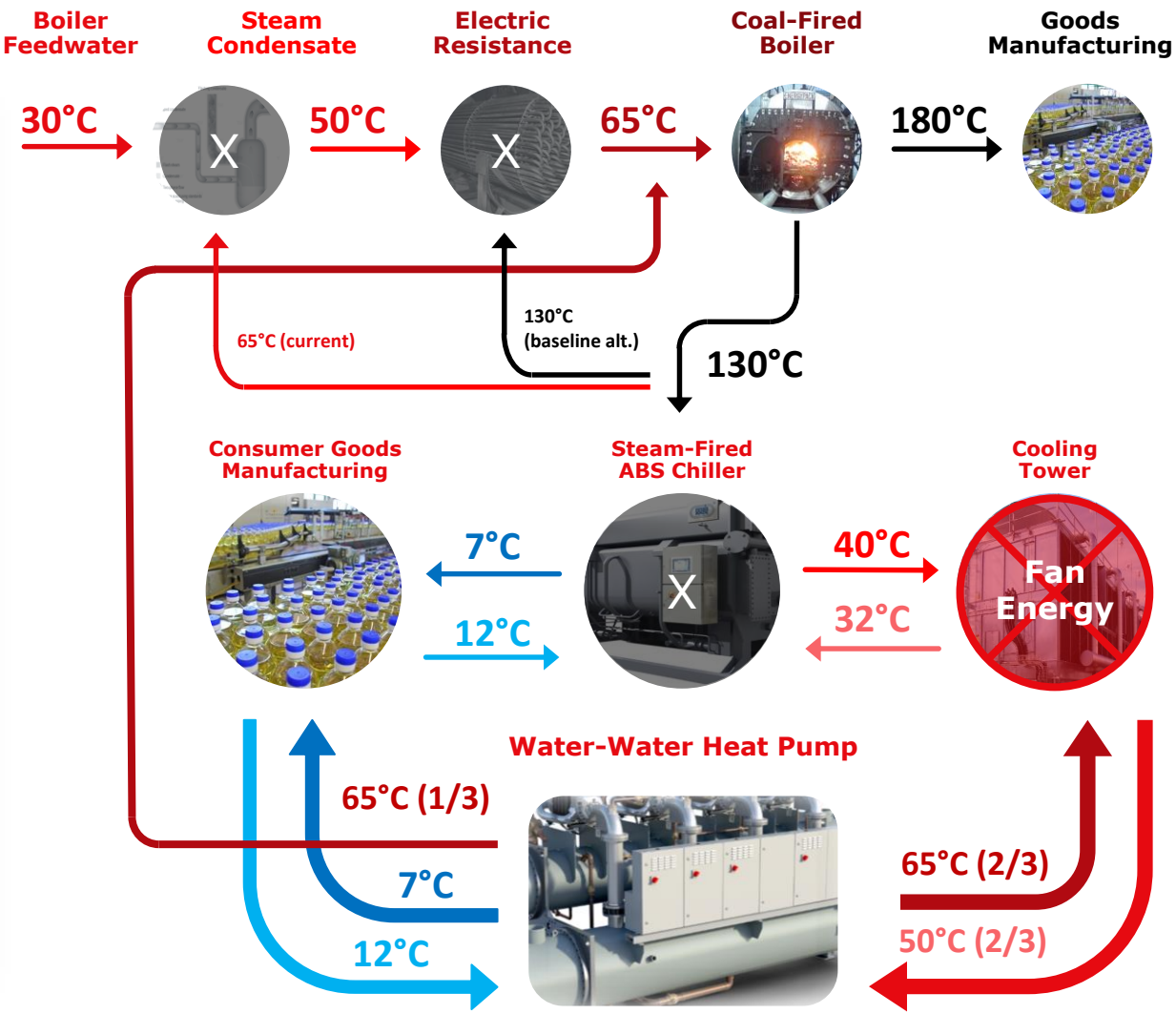
Existing process

- Condensate/electric boiler feedwater pre-heat
- Steam-fired ABS cooling, cooling tower heat reject

Proposed symbiosis solution

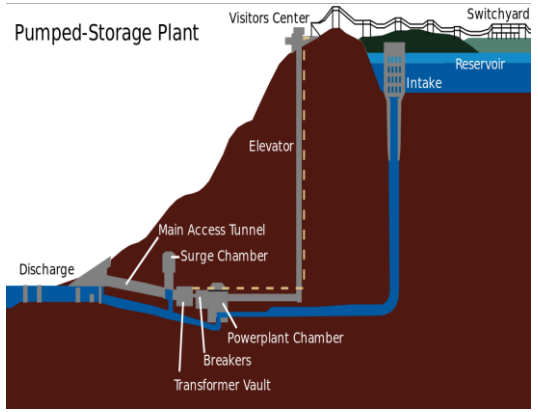
- Replace ABS with water-water heat pump
- Cooling process & recovering 1/3 heat to feedwater





Re-Connecting Supply and Demand

Energy storage / Thermal storage



Solution: Retrofit Data Center with Water-Water Heat Pumps

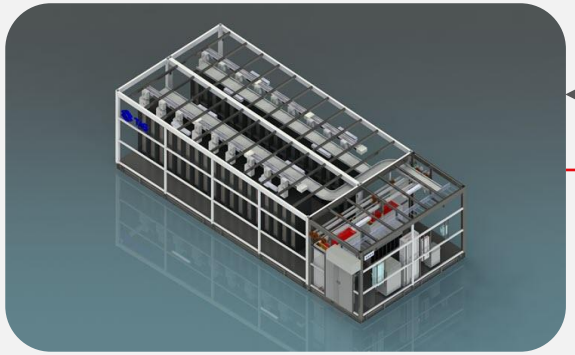
Retrofit to heat recovery heat pump system, tied to district heating with existing cooling backup

28°C

43°C

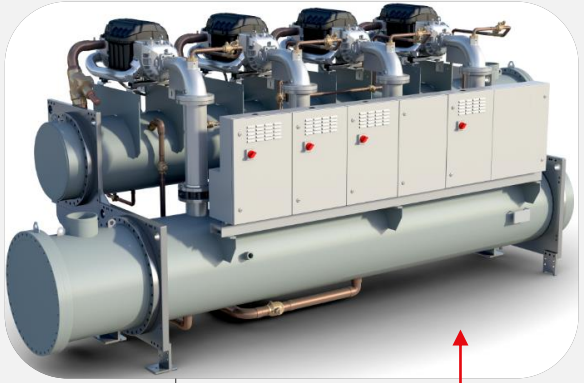
67°C

Original data center cooling system

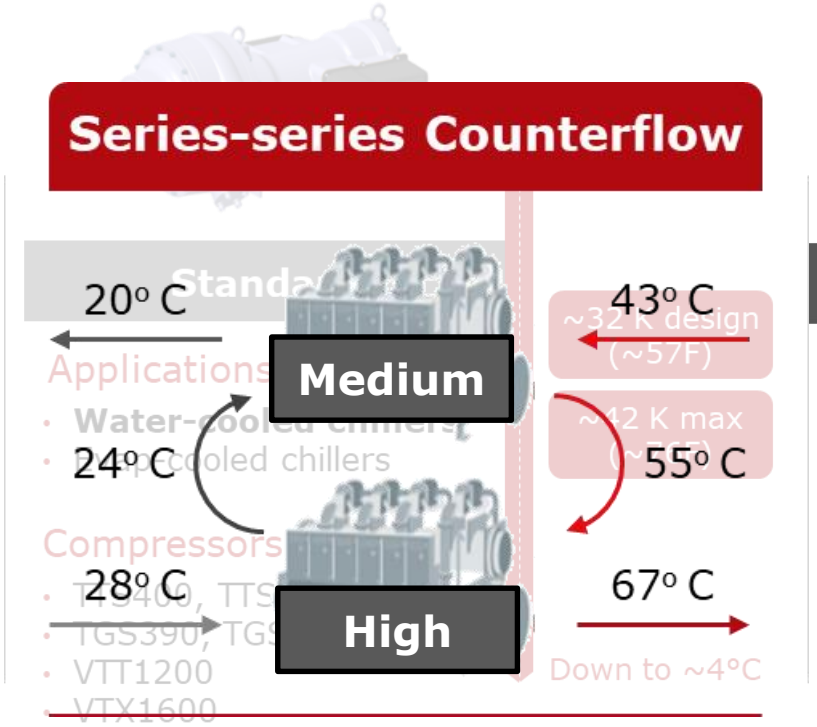


20°C

Buffer tank



Series-Series Counterflow & Compressor Optimization



Medium

Applications:
- Air-cooled chillers
- Water-cooled chillers
- Evap-cooled chillers
- **W-W heat pumps**
- High-temp process

Compressors:
- TTS300, TTS350
- TGS230, TGS310, TGS490

Up to 63°C

~42 K design (~76F)

~57 K max (~103F)

Down to -10°C

High

Applications:
- **W-W heat pumps**
- Air-cooled chillers
- A-W heat pumps
- Med-temp process
- Thermal storage

Compressors:
- TTH375
- TGH285

Up to 69°C

~55 K design (~99F)

~65 K max (~117F)

Down to -18°C

Compressor optimizations increase system performance

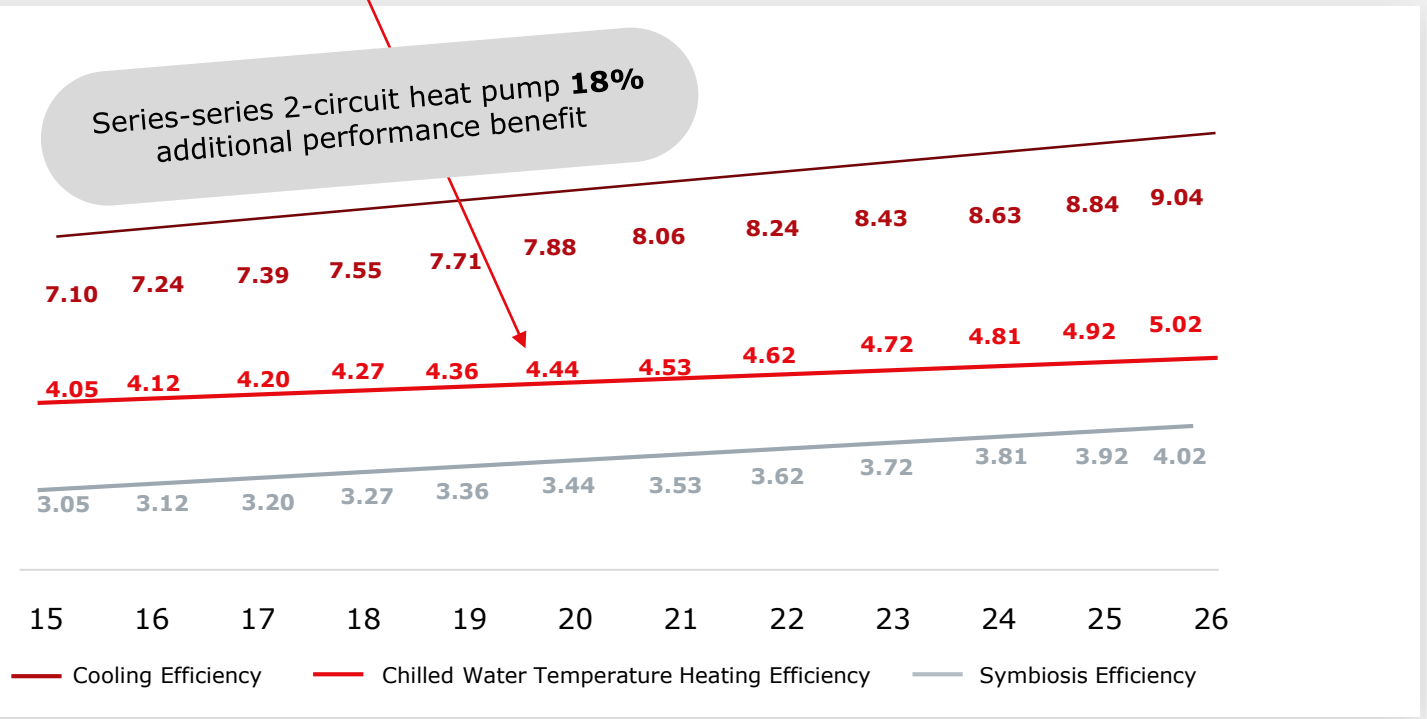
Performance

DANFOSS DATA CENTER PERFORMANCE:

Water-Water Heat Pump	Cooling capacity	Heating capacity	Power input	COP Cooling	COP Heating	Chilled water leaving Temp	Chilled water entering Temp	Hot water returning Temp	Hot water supplying Temp	Min. capability ratio
Compressors	**kW**	**kW**	**kW**	**W/W**	**W/W**	**℃**	**℃**	**℃**	**℃**	
Full load, 28-20C	500	617.8	117.8	4.246	5.25	20	28	43	67	49.2%

Impact of Increased Data Center Cooling Water Temp on Water-Water Heat Pump Efficiency, supplying 67°C hot water

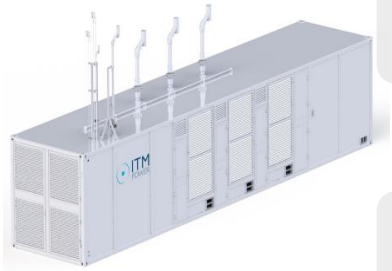
Data center symbiosis (combined heating and cooling) efficiency increases **27%** from the corresponding chilled water cooling temperature increase of 15°C to 26°C, derived from resulting heat pump compressor work.



Additional Campus Heat Recovery Project

Hydrogen Production

Water-Water Heat Pump	Cooling capacity	Heating capacity	Power input	COP Cooling	COP Heating	Chilled water leaving Temp	Chilled water entering Temp	Hot water returning Temp	Hot water supplying Temp	Min. capability ratio
Compressors	**kW**	**kW**	**kW**	**W/W**	**W/W**	**℃**	**℃**	**℃**	**℃**	
Full load, 28-20C	650.0	824.0	174.0	3.74	4.74	33.0	28.0	60.0	70.0	18.8%



Electrolysis Cooling
650 kW

Converter Cooling

33 ℃

28 ℃

Buffer tank

60 ℃

824 KW

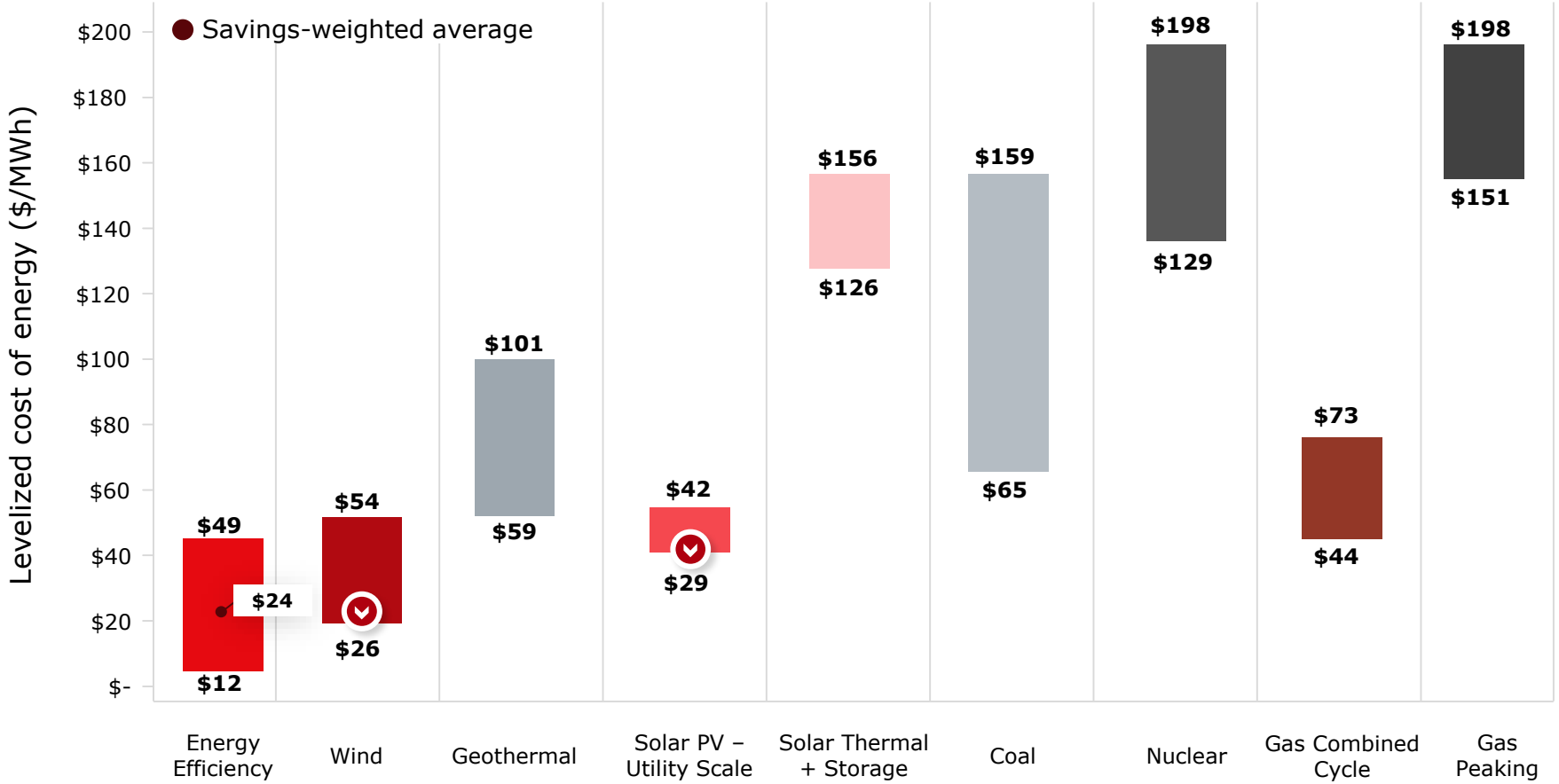
70 ℃

- PEM electrolyzer including: water treatment unit, pressurization, control, ventilation, security
- 10-foot container with transformers and AC/DC converters
- Inlet: Water, electricity, IP and nitrogen
- Outlet: Hydrogen @30 bar

Energy costs and utility sources

Efficiency still the lowest cost energy source

As renewable volumes go up, cost comes down – Lowest cost, next to efficiency



Source: ACEEE