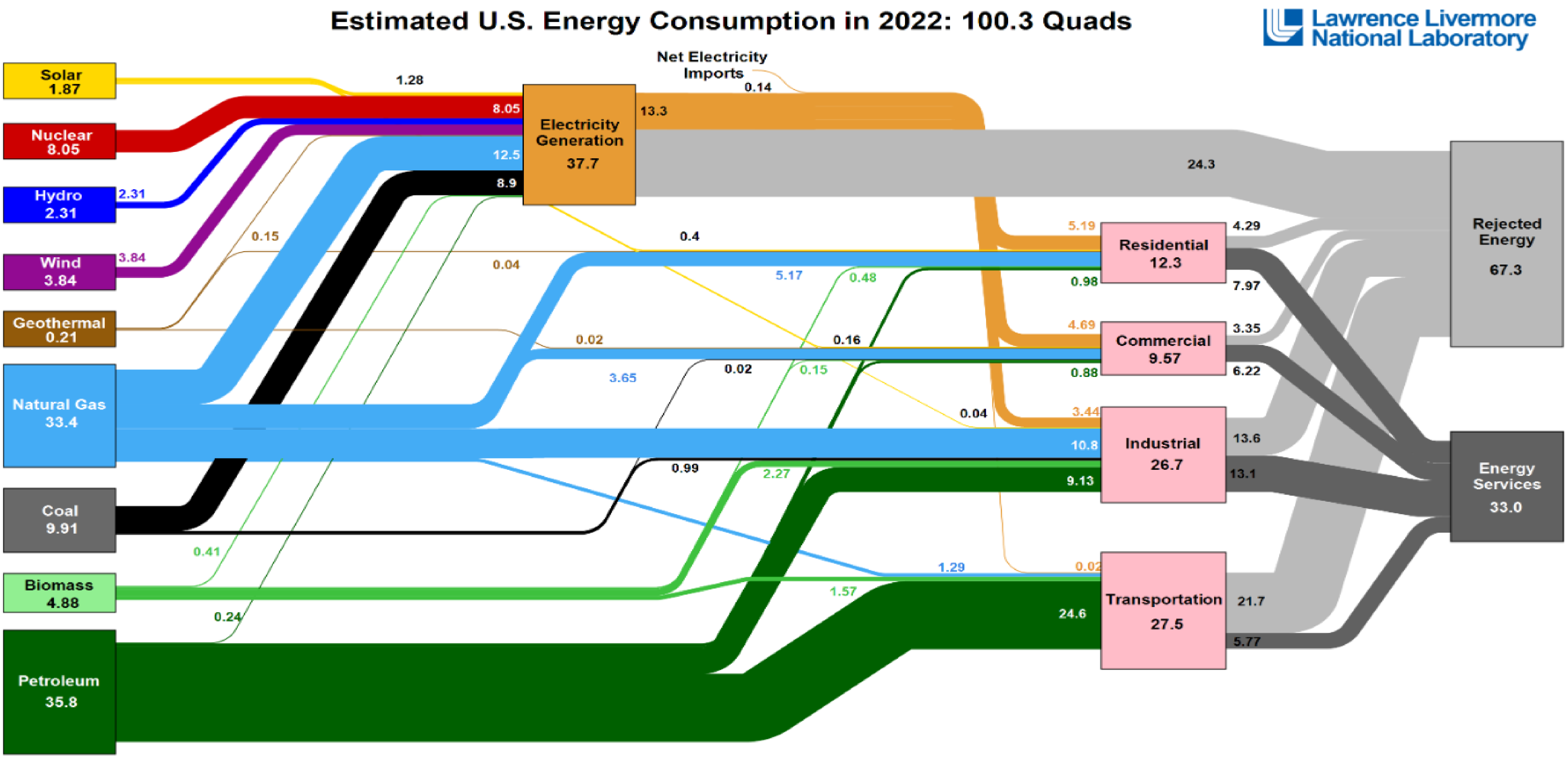
The Risk of Decoupling Efficiency and Decarbonization

ENGINEERING
TOMORROW

Market trends, challenges & opportunities

Sinem Gundogdu Kalkin, Danfoss Climate Solutions, Sector Coupling

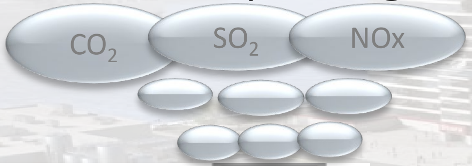
The Waste Heat Opportunity

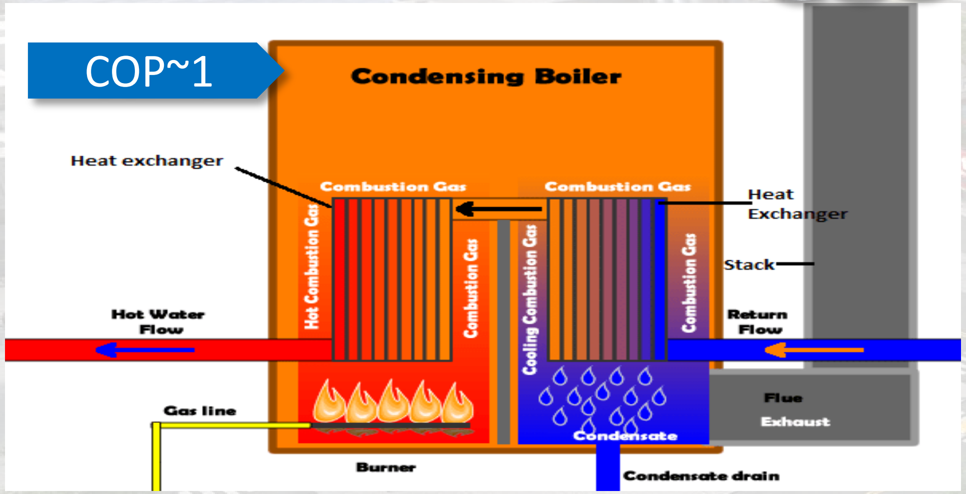


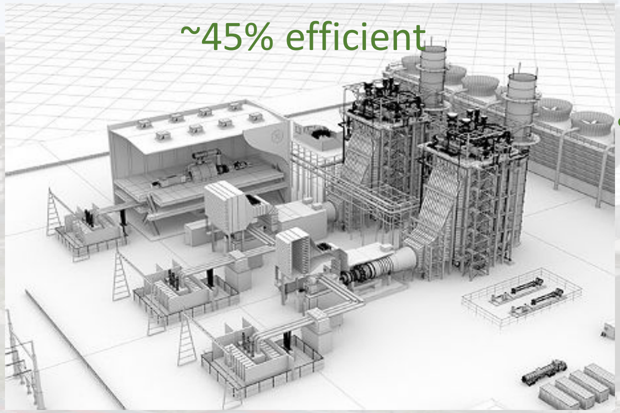
Why is the market focused on Heating Electrification
Efficiency & Decarbonization

Fossil fuels	Heat pumps

- Inefficient
- Drive CO_2 & other gas emissions impacting environment

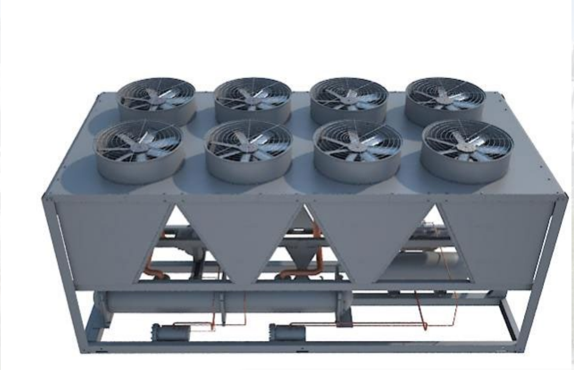






Transmission & Distribution

-5%



COP~2.5-3.5

~35% operating cost reduction
~60% emissions reduction

- More efficient
- Efficiency increases at part-load/lift
- Goal is to exceed "spark spread"

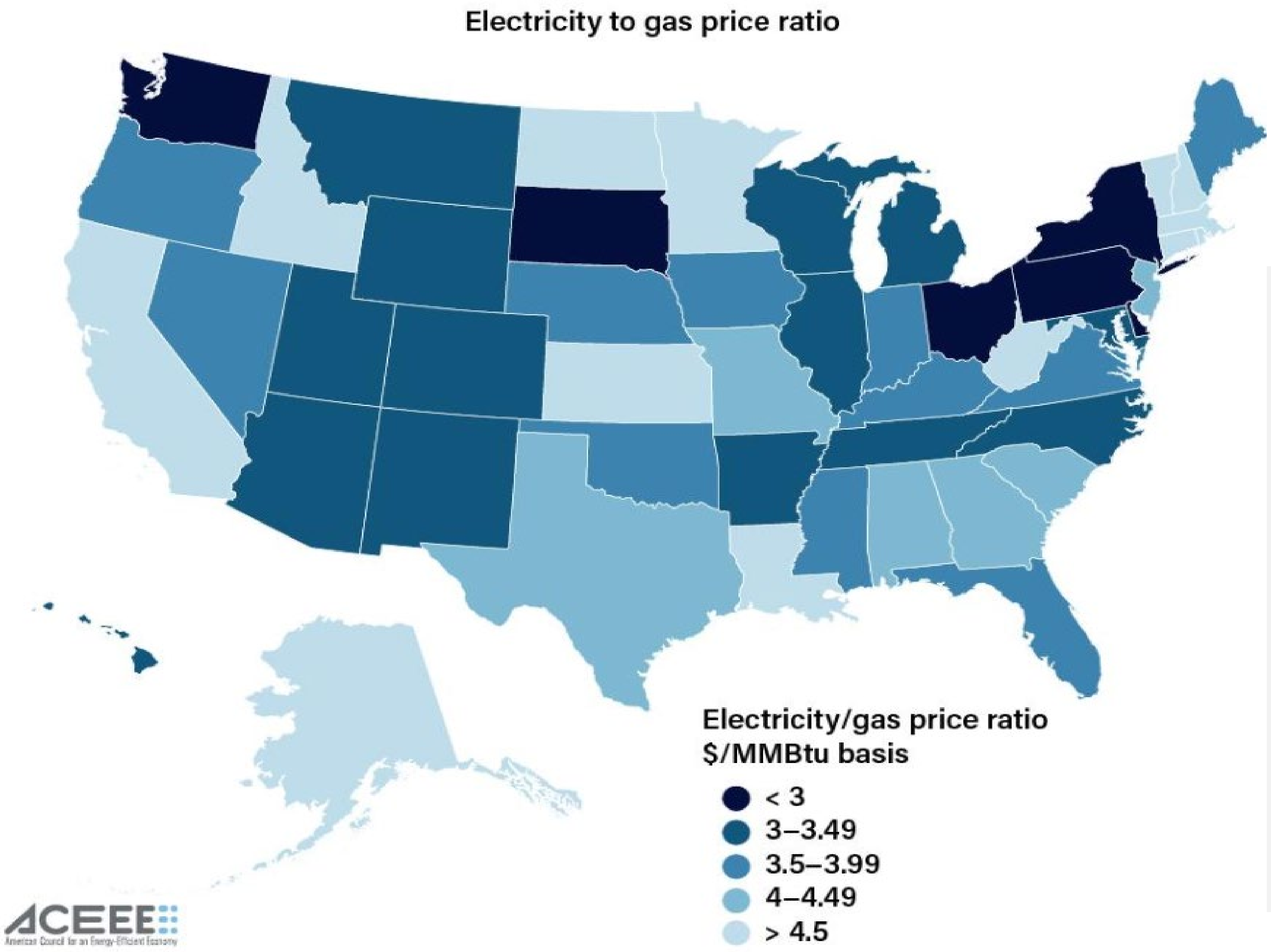
Heat Pump
Part Load
Efficiency

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

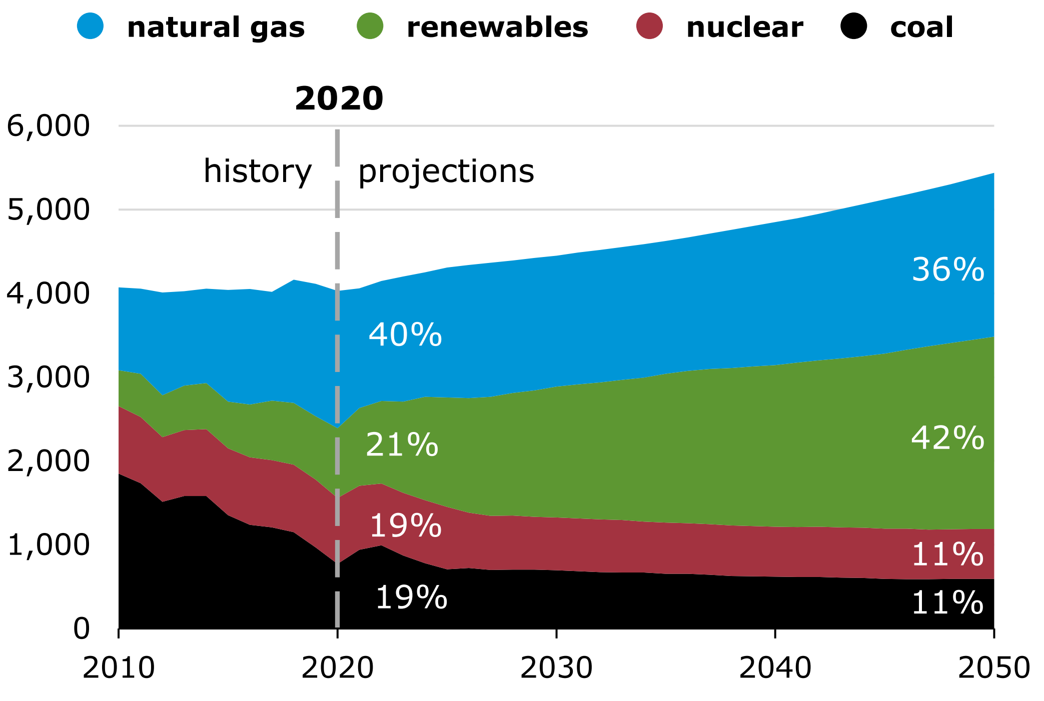
https://www.greenbiz.com/article/its-time-electrify-industrys-process-heat-heat-pumps



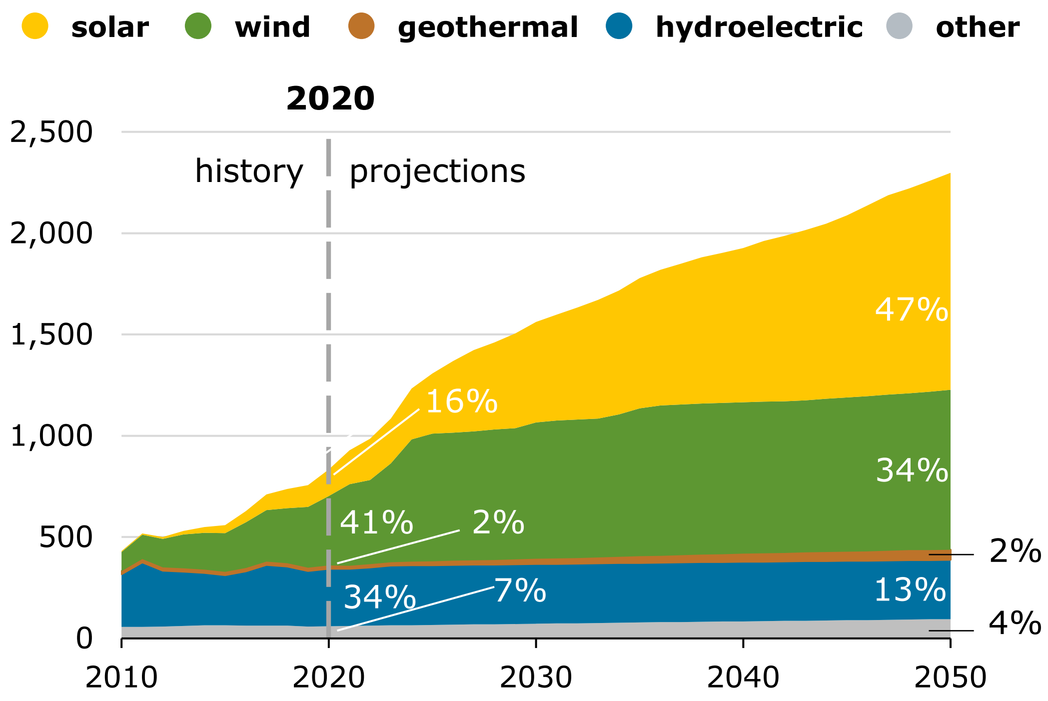
Emissions Reduction –

U.S. electricity generation and share from selected fuels and renewable sources

U.S. electricity generation from selected fuels
AEO2021 Reference case
billion kWh



U.S. renewable electricity generation, including end use
AEO2021 Reference case
billion kWh

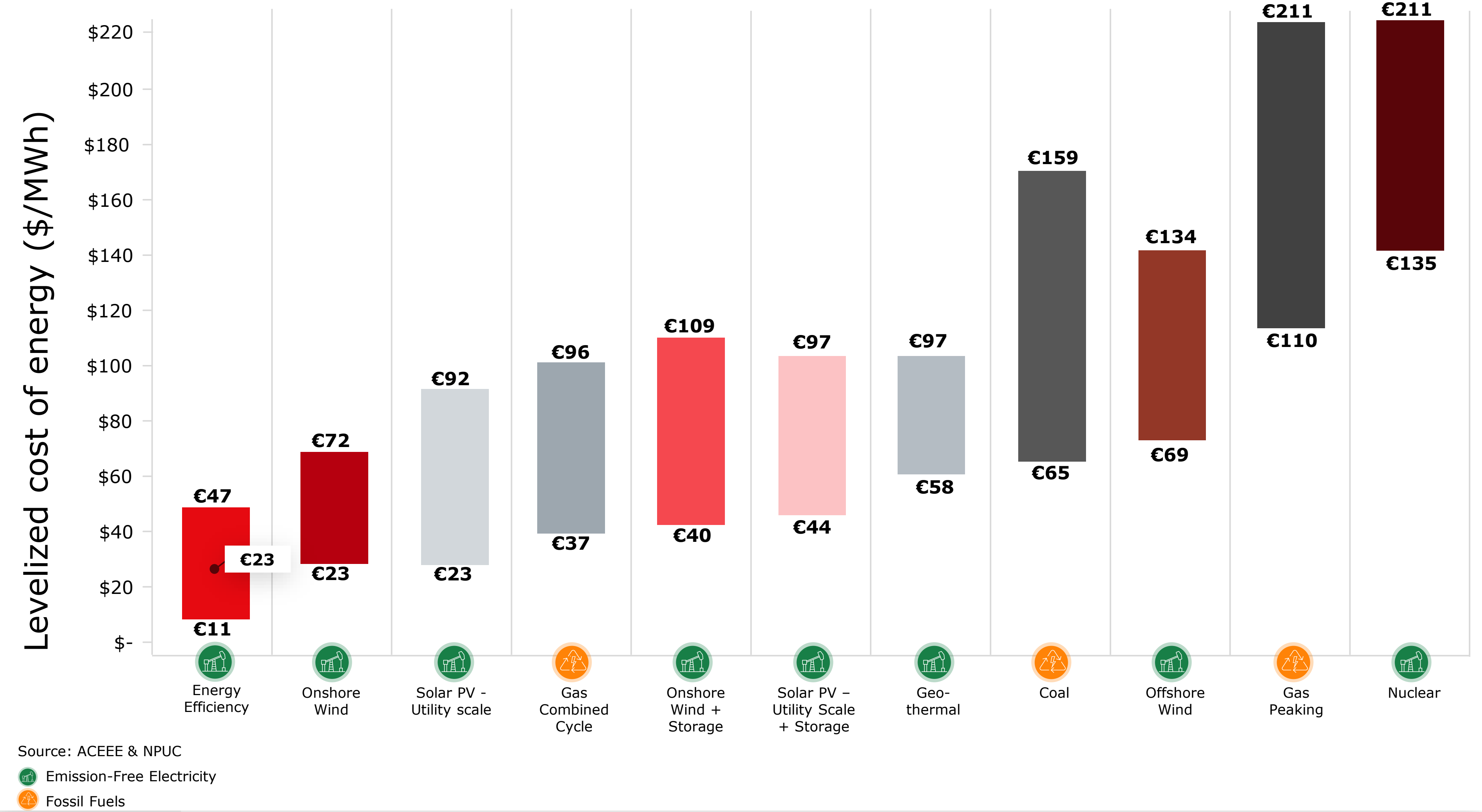


Source: EIA

Energy costs and utility sources

Efficiency still the lowest cost energy source

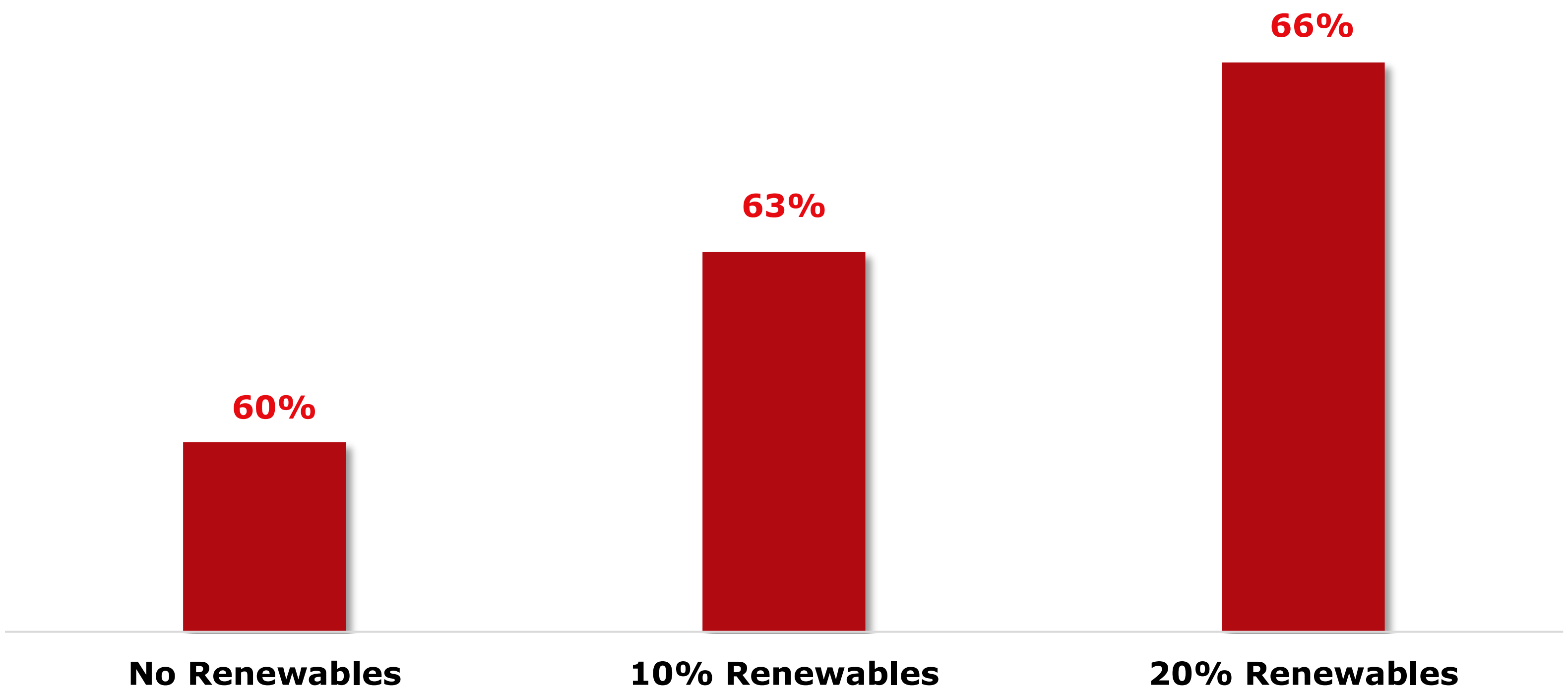
As renewable volumes go up, cost comes down – Lowest cost, next to efficiency



Source: ACEEE & NPUC

Emissions reduction

CO_2 Emissions Reduction: Renewables integration impact



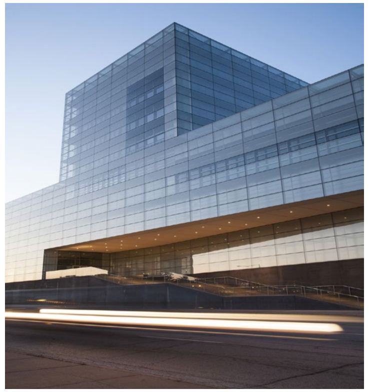
Based on AWHP applied in 'warm' climate

As grid integration of renewable energy grows, so does heat pump resulting **greenhouse gas emissions reductions**

Supply

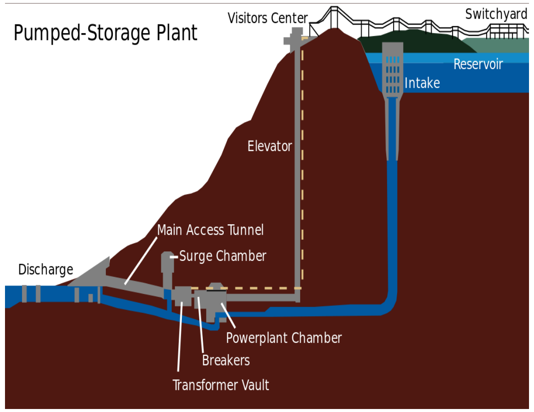
≠

Demand

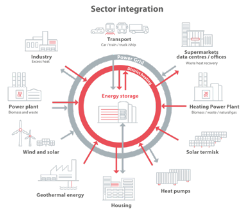


Re-Connecting Supply and Demand

Energy storage / Thermal storage



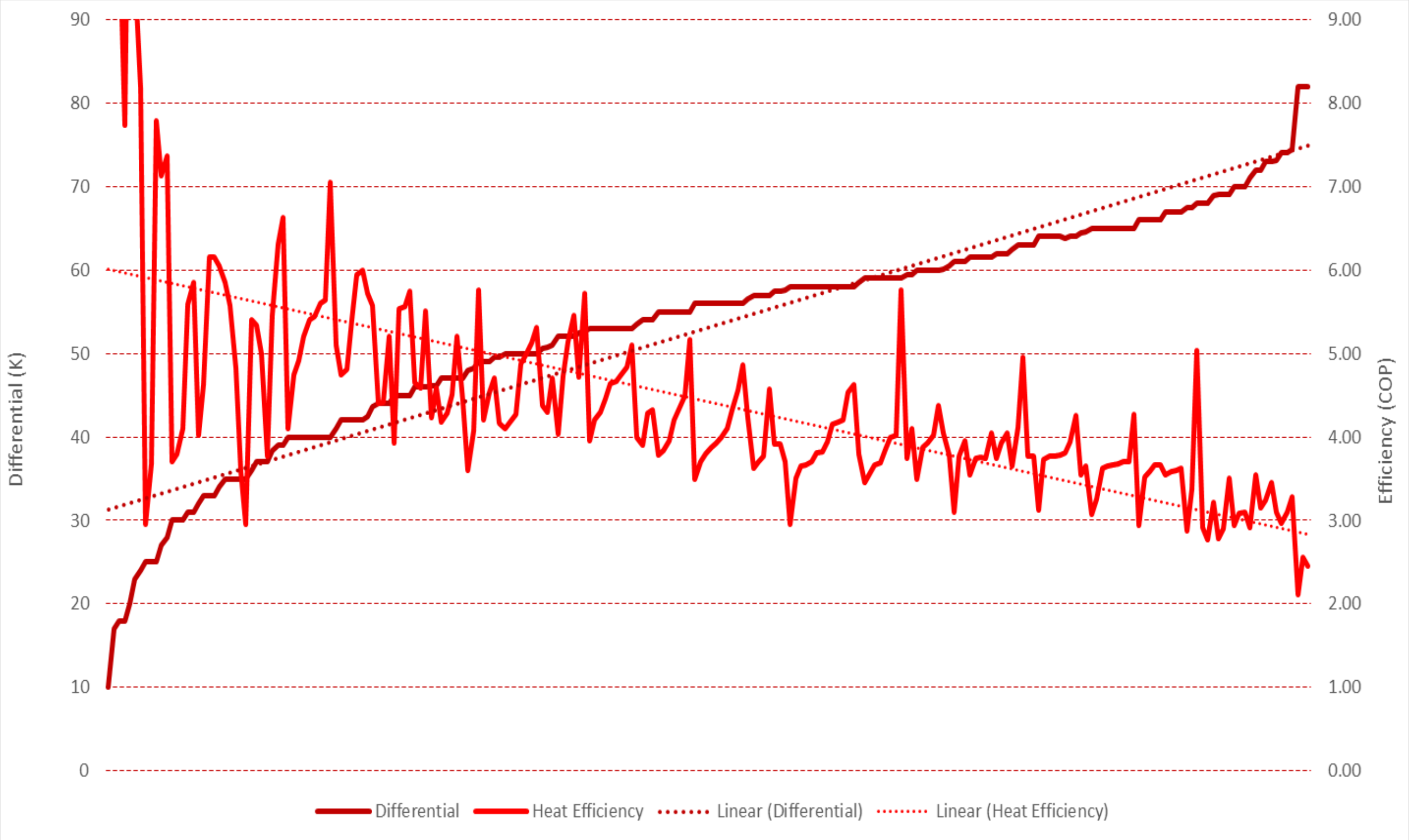
Heat Pump System Modeling Summary
Efficiency & Differential



- Range of heat source to heat supply differential (K)
- Corresponding heat pump system efficiency (COP)
- Large (0.3-50MW+) systems

	Differential (K)	Efficiency (COP)
Minimum	10	2.5
Maximum	82	12.7
Range	72	10.2
Average	53	4.4
Average % efficiency drop per K differential increase		**1.7%**

Heat Pump – System Differential and Associated Efficiency



Sector Integration System Design Summary

Heat Sources

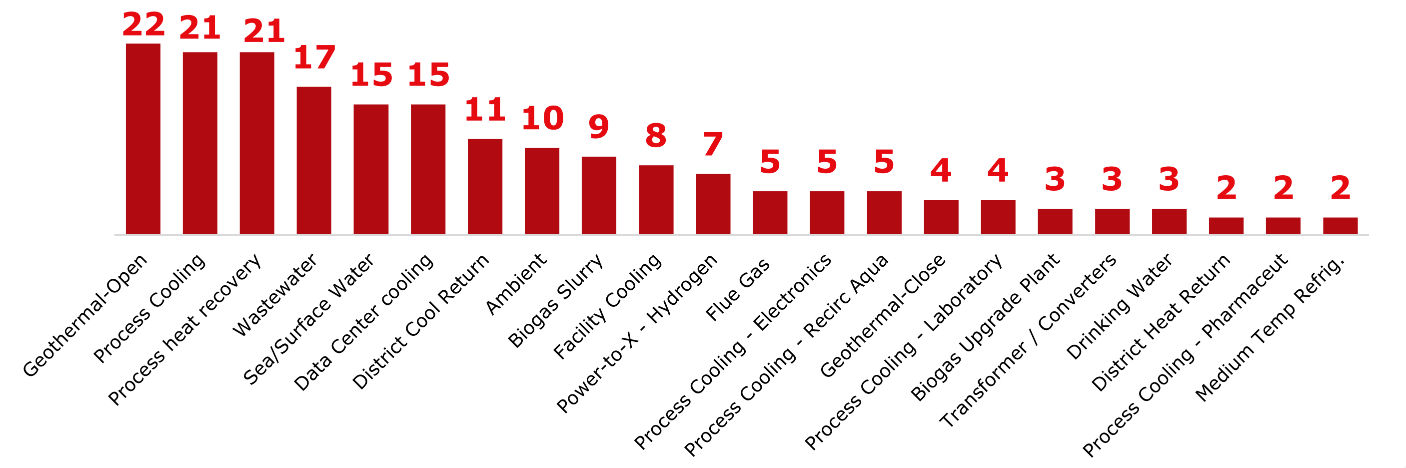
The most prevalent heat recovery heat sources

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

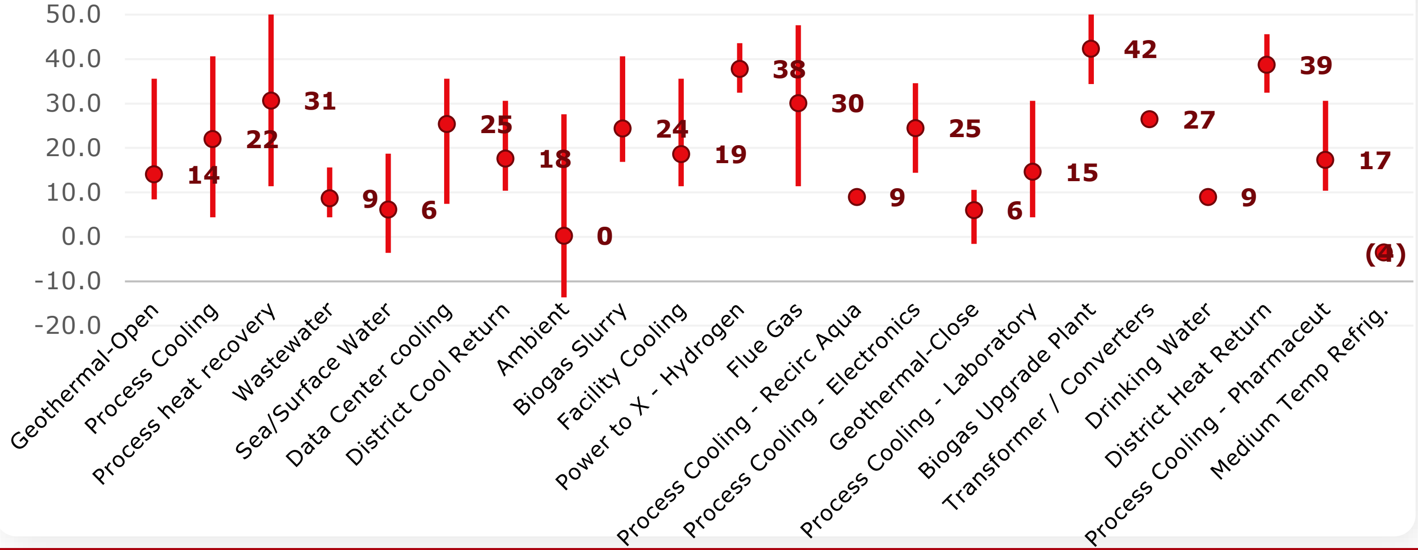
- Target the most consistent availability and highest temperature heat sources

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

Opportunities by Heat Source (# of projects)



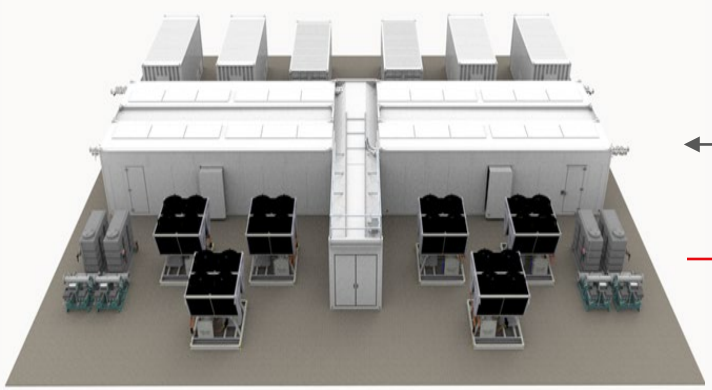
Source Temperature Average/Range



Sector Integration Retrofit Options

Baseline - Data Center Cooling / Heat Recovery

Data Center	Heat Pump	District Energy
Chilled Water / Air Cooling	***Oil-Free Water-Water***	***4^{th} Generation Heating***

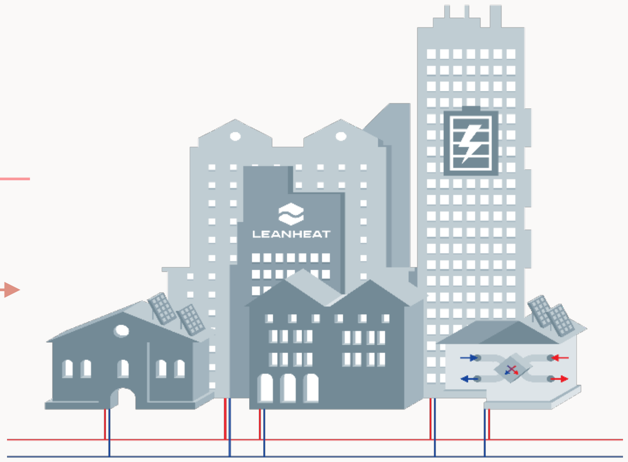


20°C

28°C

50°C

65°C

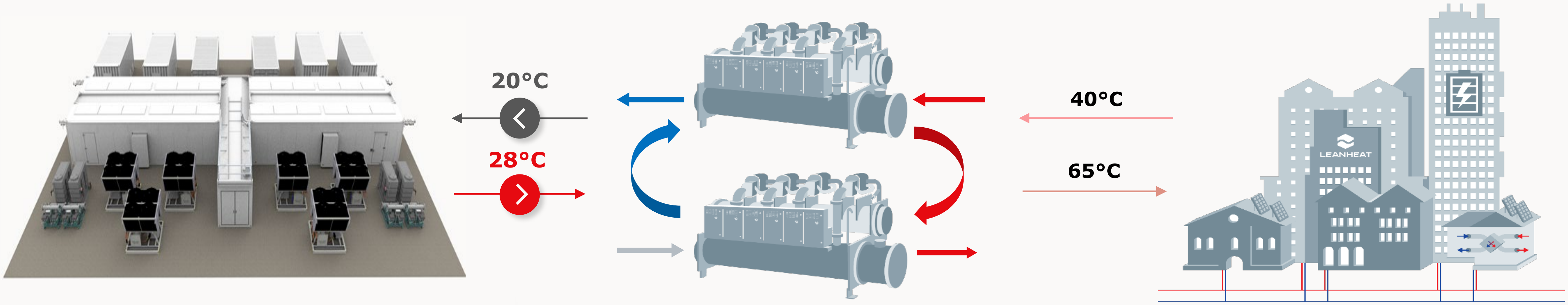


4.0 COP Cooling	**250k€/MW** Heat	**5.0 COP** Heating

Sector Integration Retrofit Options

Lower Temps Enable Higher Heat Pump Efficiency

Data Center	Heat Pump	District Energy
Chilled Water / Air Cooling	***Series-Series Counterflow***	***4th Generation Heating Lower Return Temp***



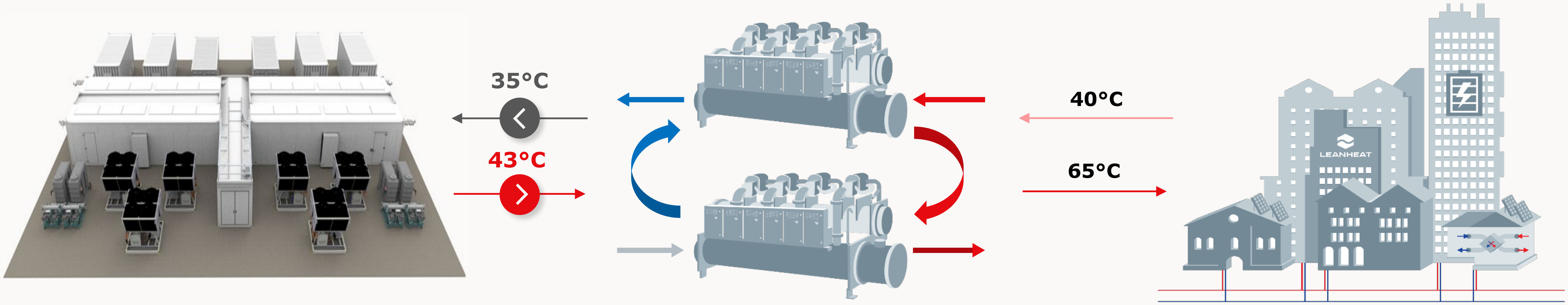
4.8 COP
Cooling

- Lower return temp from variable flow, 2-way PICV and Leanheat optimization
- In-turn allows series-series counterflow heat pump - 20% efficiency increase

5.8 COP
Heating

Sector Integration Retrofit Options
Liquid Cooling / Higher Temps Allows Max Efficiency

Data Center	Heat Pump	District Energy
Liquid / On-Chip Cooling	***Oil-Free Water-Water***	***4th Generation Heating***



6.2 COP
Cooling

15K
differential decrease

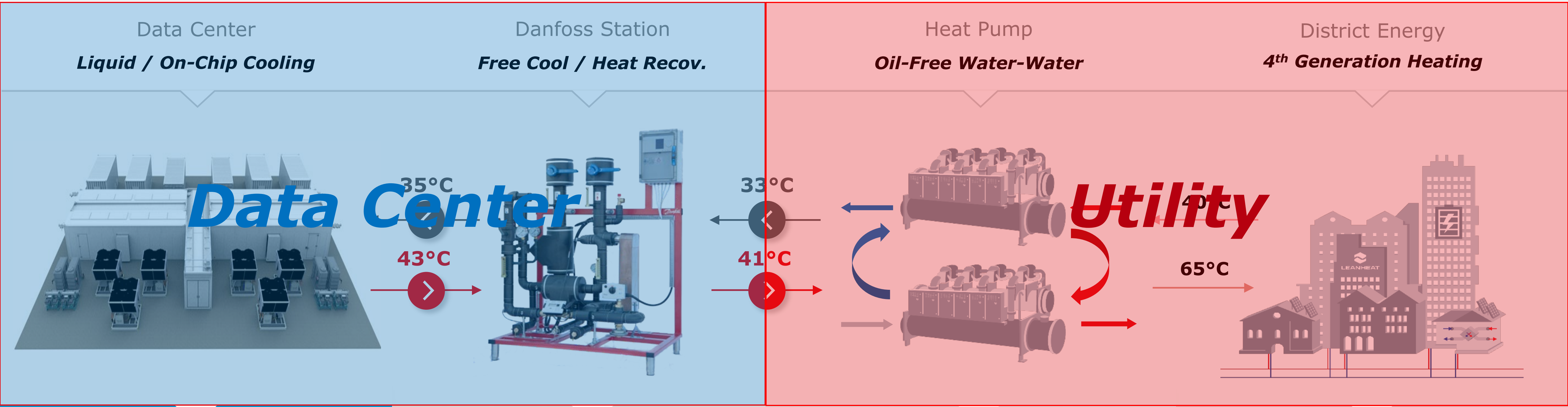
=

30%
efficiency increase

7.2 COP
Heating

Sector Integration Retrofit Options

Data Center Free Cooling / Heat Reuse



Free Cooling

~20 COP

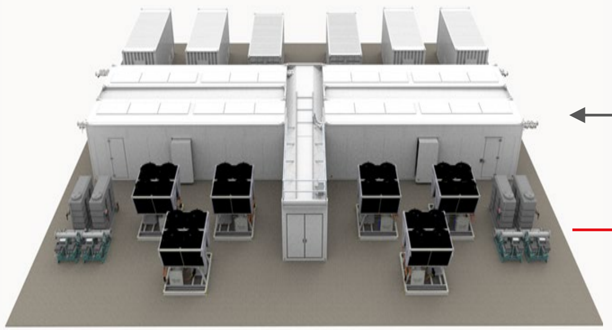
- Data center heat station enables free cooling / heat recovery at 25% heat pump applied cost with minor heat efficiency impact
- Cooling power limited to supply pumps, driven by recovered heat
- Scenario suited for different data center cooling and heating ownership model

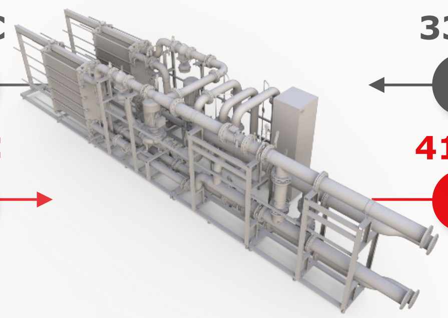
7.0 COP
Heating

Sector Integration Retrofit Options

Data Center Free Cooling / Food Production Heat Reuse

Data Center	Danfoss Station	Greenhouse Farming	Indoor Fish Farms
Liquid / On-Chip Cooling	***Free Cool / Heat Recov.***	***Supply Air Heat***	***Supply Water Heat***





Free Cooling

~20 COP

- Vertical farms and indoor horticulture as potential heat recovery customers, collocated with data center
- Symbiotic efficiency relationship with data center - Directly use available heat without heat pump boost

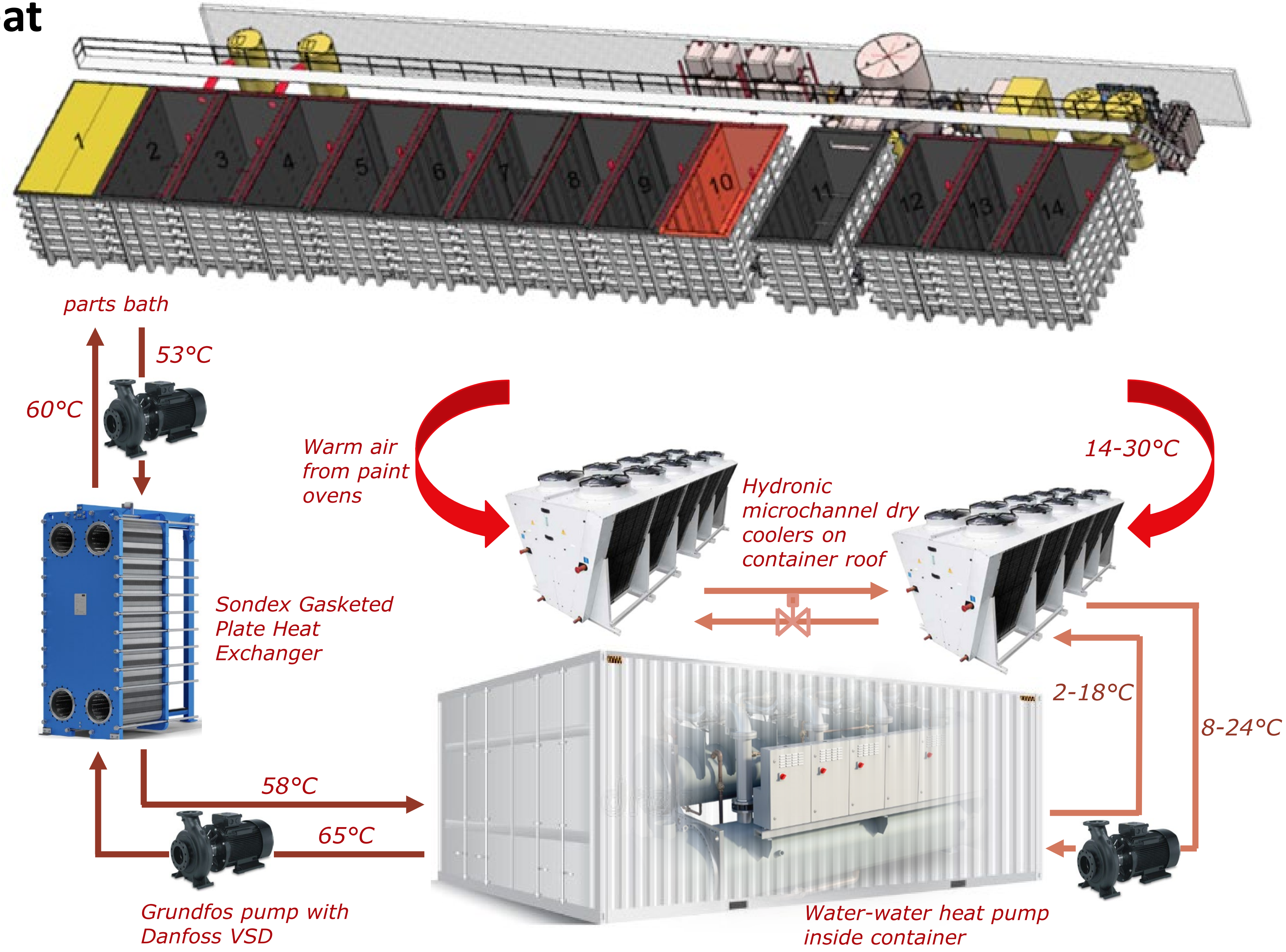
Free Heating

~20 COP

Electrification of Parts Bath Heat

- Paint ovens generate significant heat radiated to parts manufacturing room
- Utilize excess heat to replace gas boiler heat for parts bath
- Dry coolers installed on top of container to absorb ambient heat
- Recovered to evaporator loop of oil-free turbo compressor water-water heat pump installed in container
- Boosts heat to required temperature to supply to parts bath via Sondex gasketed plate heat exchanger

Equipment	Ambient	Heat Efficiency COP
Boiler	All	~0.87
Heat Pump	14	3.5
Heat Pump	27	4.6

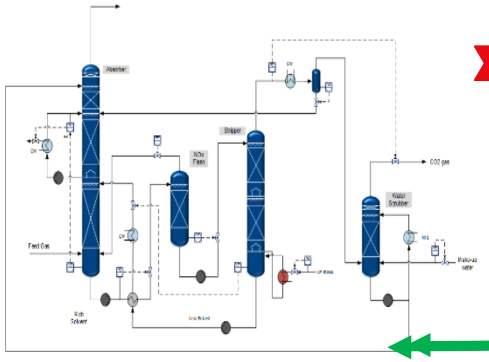


Cement Plant Kiln Recovery

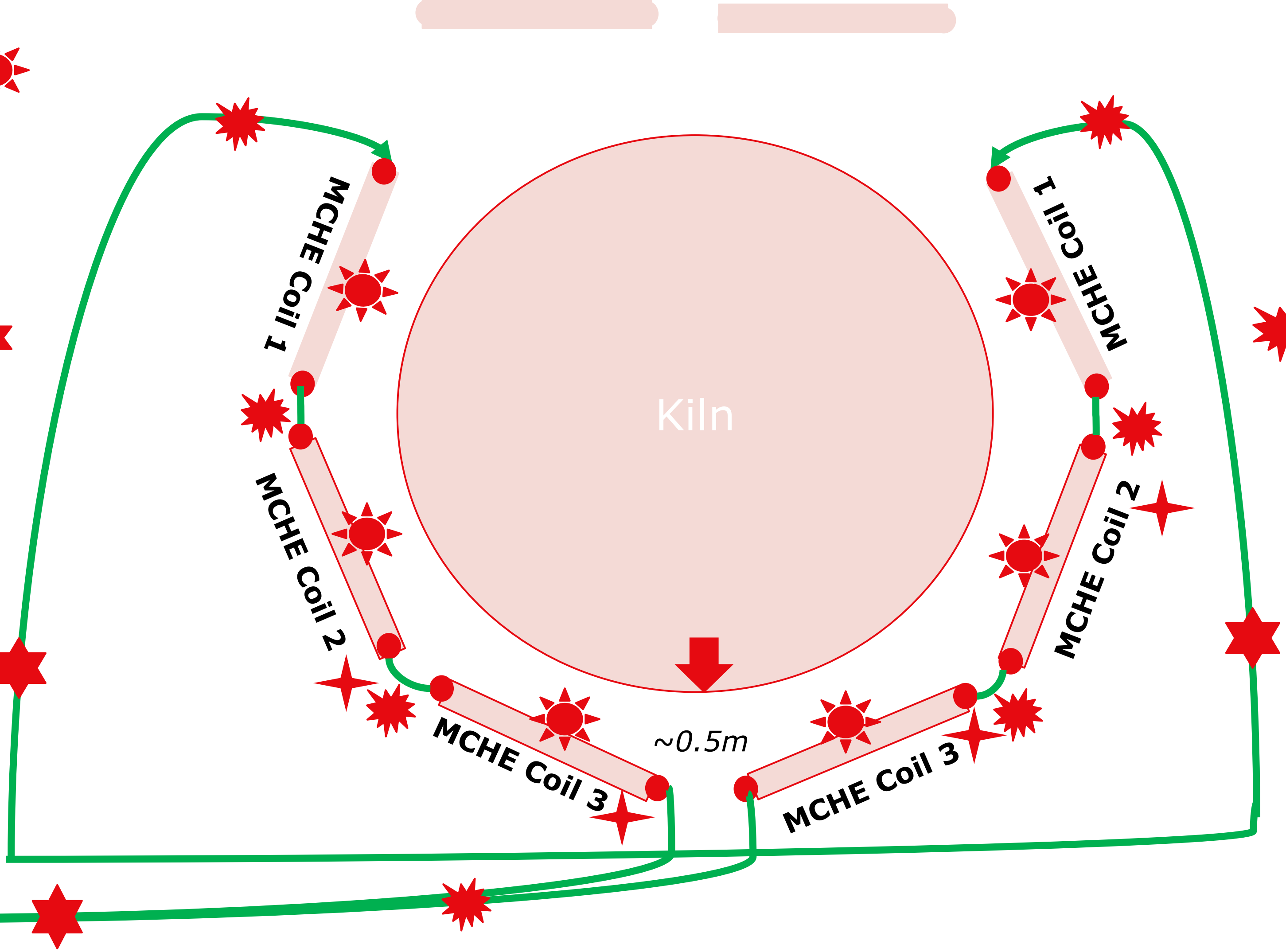
Feeding CCUS Offset Process

PT Temperature Sensors

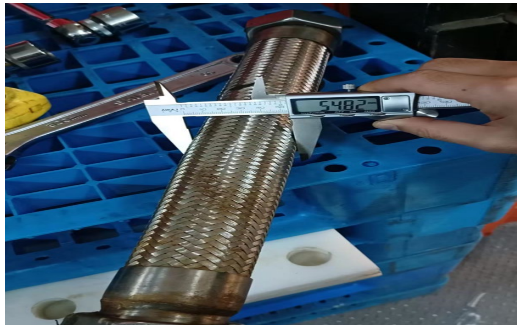
SonoSelect Energy Meters



CCUS



Hydronic Microchannel

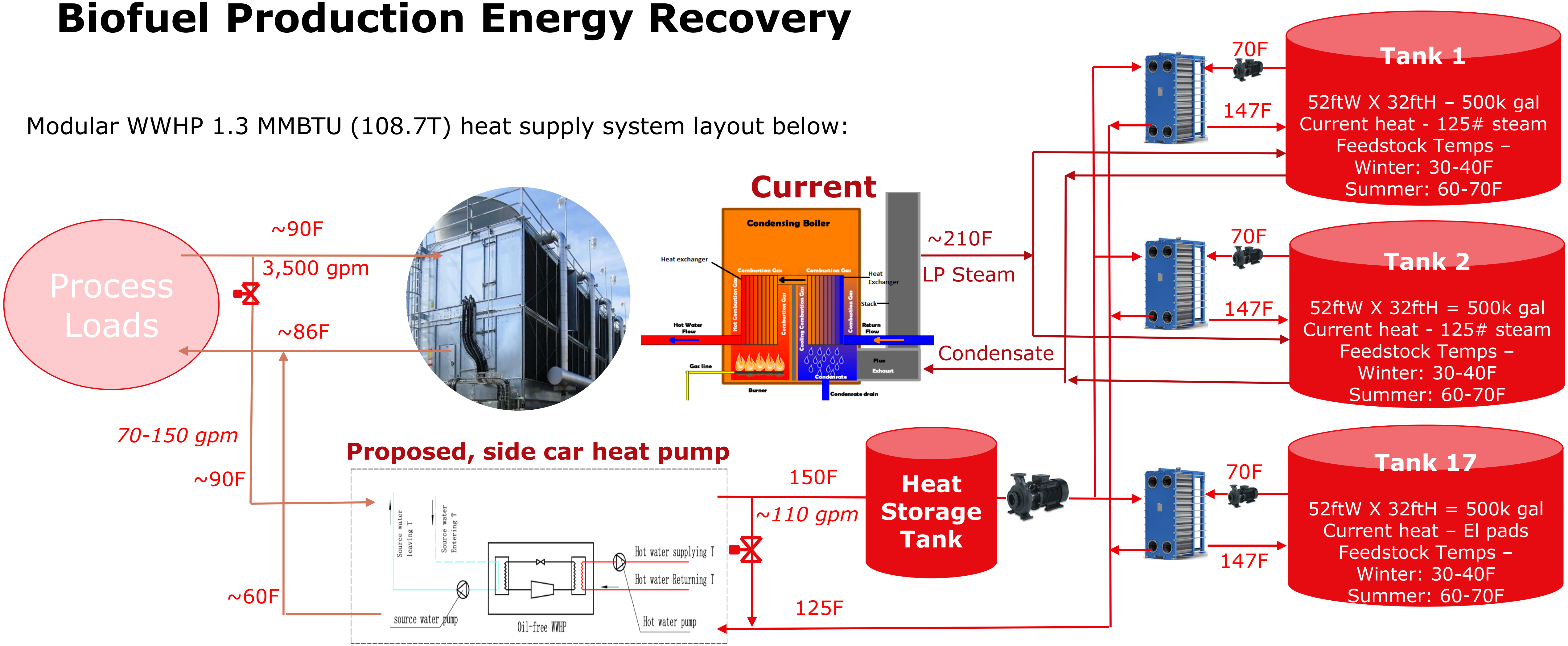


Hoses &

Couplings

Biofuel Production Energy Recovery

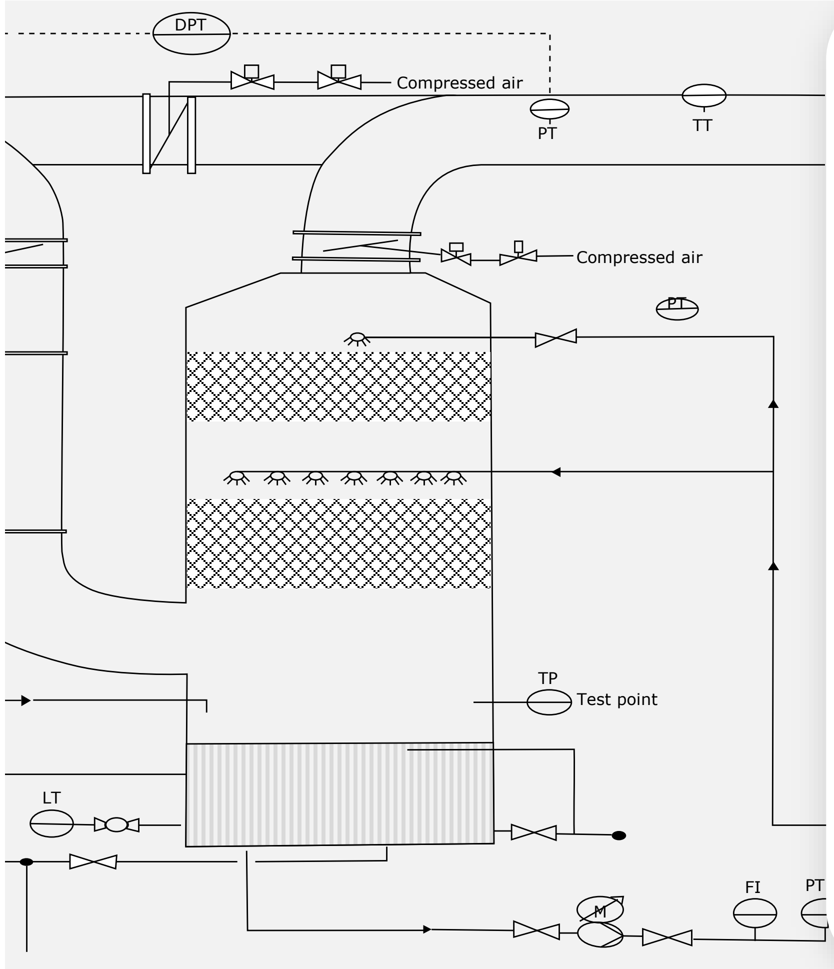
Modular WWHP 1.3 MMBTU (108.7T) heat supply system layout below:



- Control on leaving condenser water temperature
- VSD condenser pump running – Load when supply temperature drops below 150F from flowing feedstock
- Open evaporator valve to start heat pump

Hybrid Opportunities –

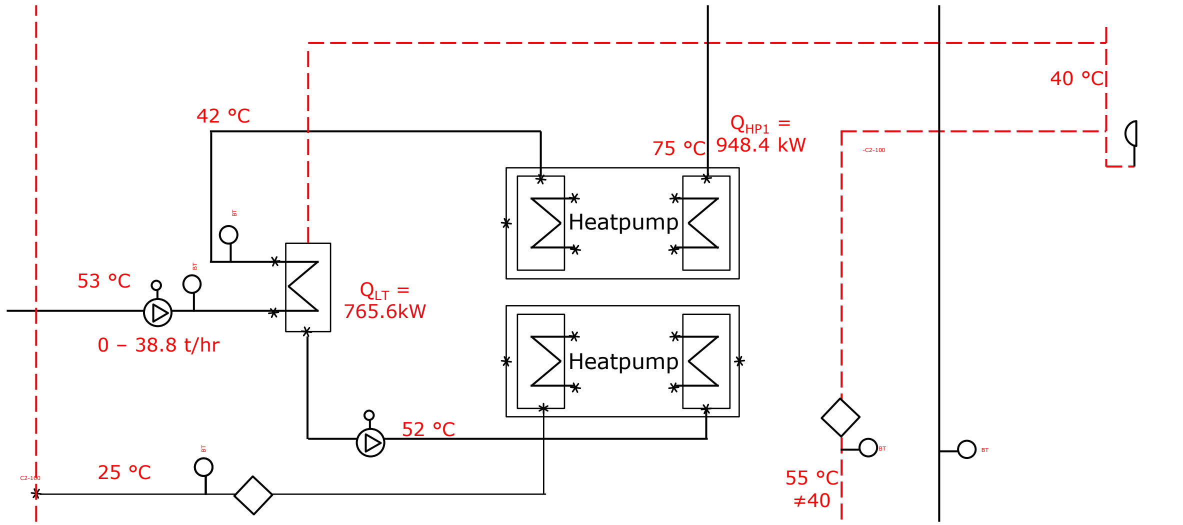
Boiler Flue Gas Scrubber



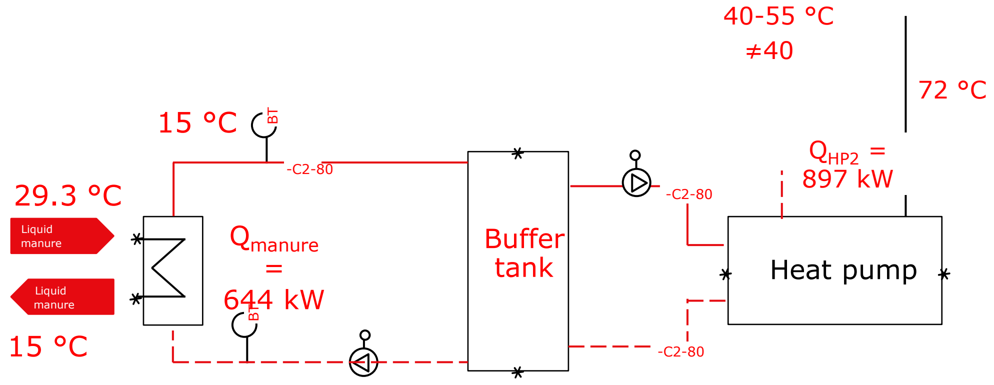
- Heat Capacity: 962kW
- Added boiler condensing capacity: 850kW
- Efficiency: 6.2 COP

- Total System Applied Cost: 1.72m€
- Annual savings – operating cost: 0.5m€
- Simple payback: 3.4 years

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

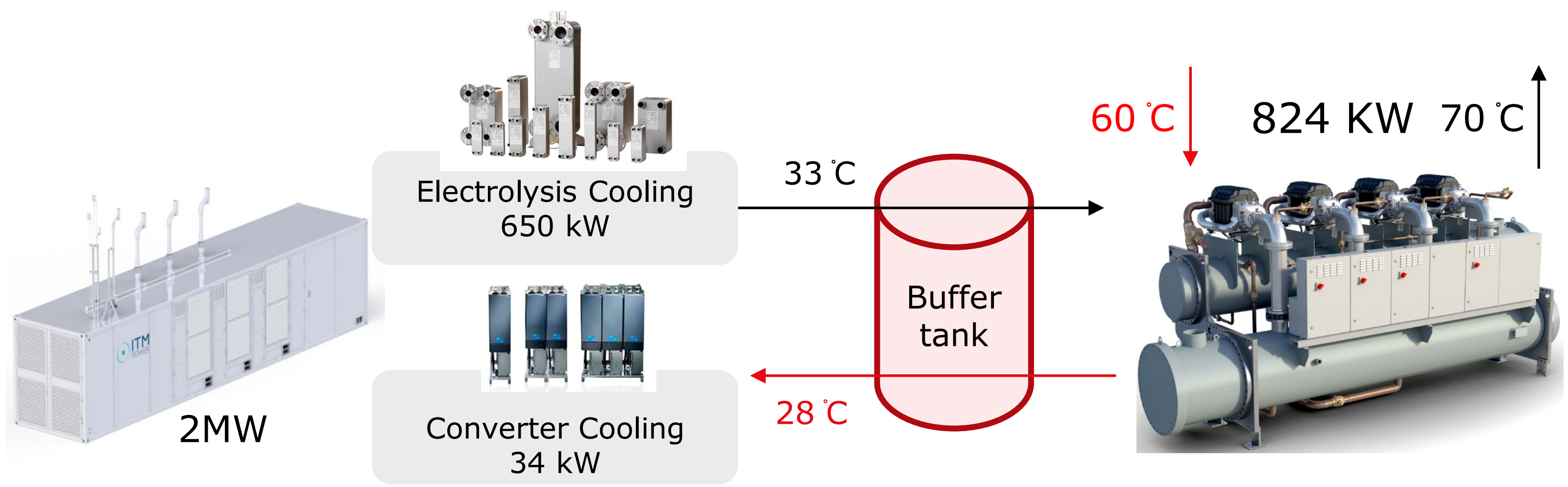
- Source water temperature from Slurry HEX 15/10℃, targeting hot water temperature @72 ℃
- Slurry cooling enables more biogas participation and eliminates neighbor complaints

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

Energy Transition

Hydrogen Production

Water-Water Heat Pump	Cooling capacity	Heating capacity	Power input	COP Cooling	COP Heating	Chilled water leaving Temp	Chilled water enteri Temp	Hot water return Temp	Hot water supply Temp	Minimum load
	kW	kW	kW	W/W	W/W	℃	℃	℃	℃	
Full load, 33-28C	650	824	174	3.74	4.74	33	28	60	70	18.8%



2MW PEM electrolyzer

70% electrolysis efficiency / 30% waste heat recovered

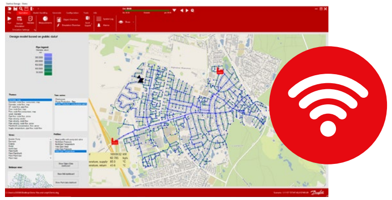
Electrolysis degrades / recovered waste heat increases over time

Recovered waste heat increases further when paired with hydrogen fuel cell for onsite power

Hydronic System Solutions

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

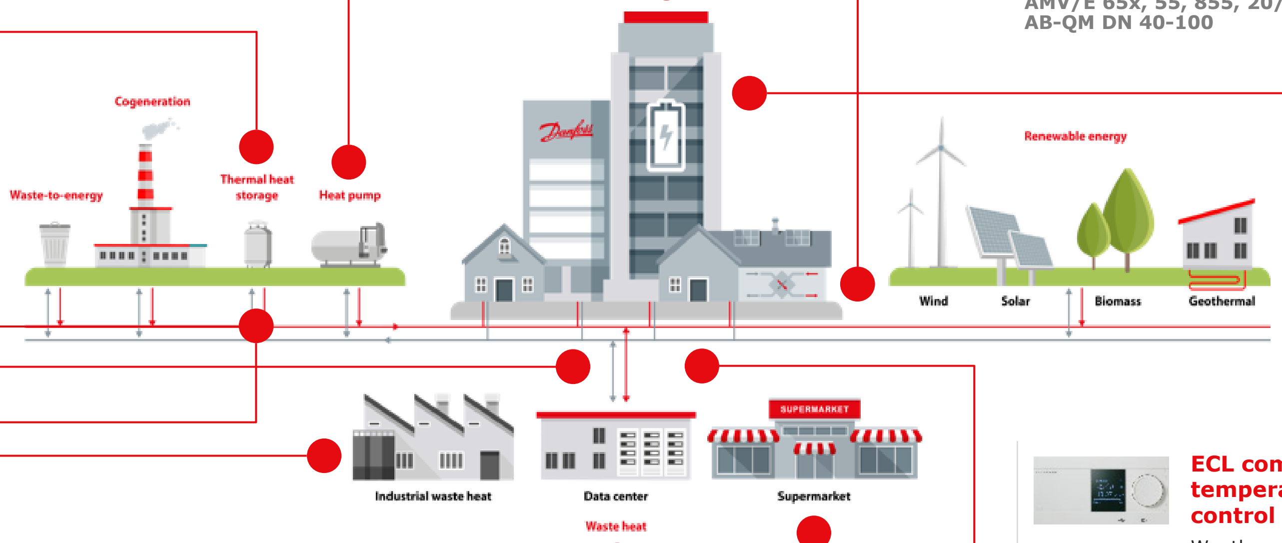
For precise flow control of water flows

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



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

Hydronic Stations

Building, radiator, fan coil and domestic water substations

EvoFlat MSS **Building Substation**

ECL comfort temperature control

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

ECL 210/310/296

SonoSelect Energy Meters

Hydronic heat meters to ensure measuring heat transfer and equipment performance

Rotary mixing valves and actuators

Maintining a chosen minimum temperature through a mixing loop

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

Accessories

- Temp. sensors (PT1000)
- Room units

Reach Us

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