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Future in the making

Industrial Heat Pumps for Decarbonization

General Presentation

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August 2021

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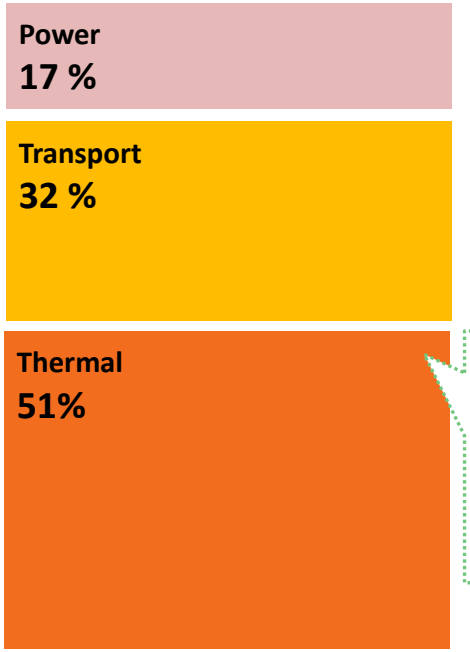
This data serves informational purposes only and is especially not guaranteed in any way.
Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Decarbonization of heat – energy storage and heat pumps playing increasingly important role

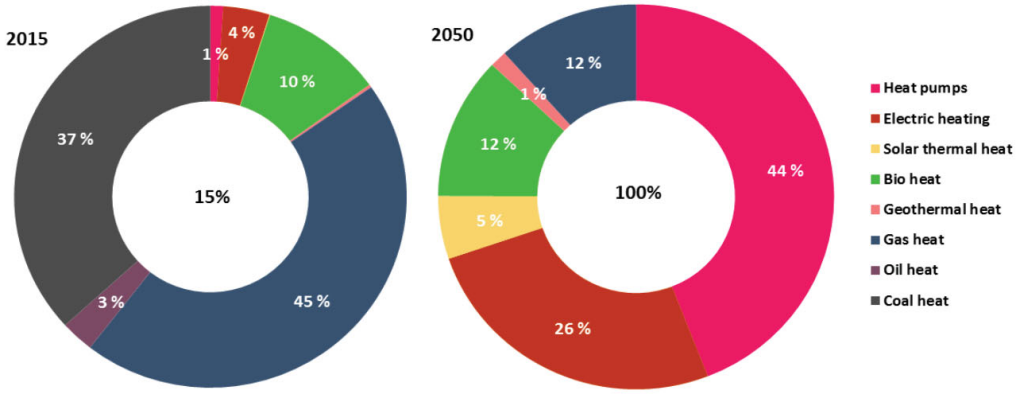
Total Final Energy Consumption, by Final Energy Use, 2017[1]



… of which only ~10% comes today from renewable sources

Decarbonization of thermal segment is critical to reduce global CO2 emissions

Scenario for a 100% renewable heat supply:[2]



- Heat supply shifts from 85% fossil fuels domination towards 100% renewable energy supply in 2050
- Electrification, esp. with heat pumps, plays a significant role in this transition
- Renewable and synthetic gases as alternative, especially for high temperatures

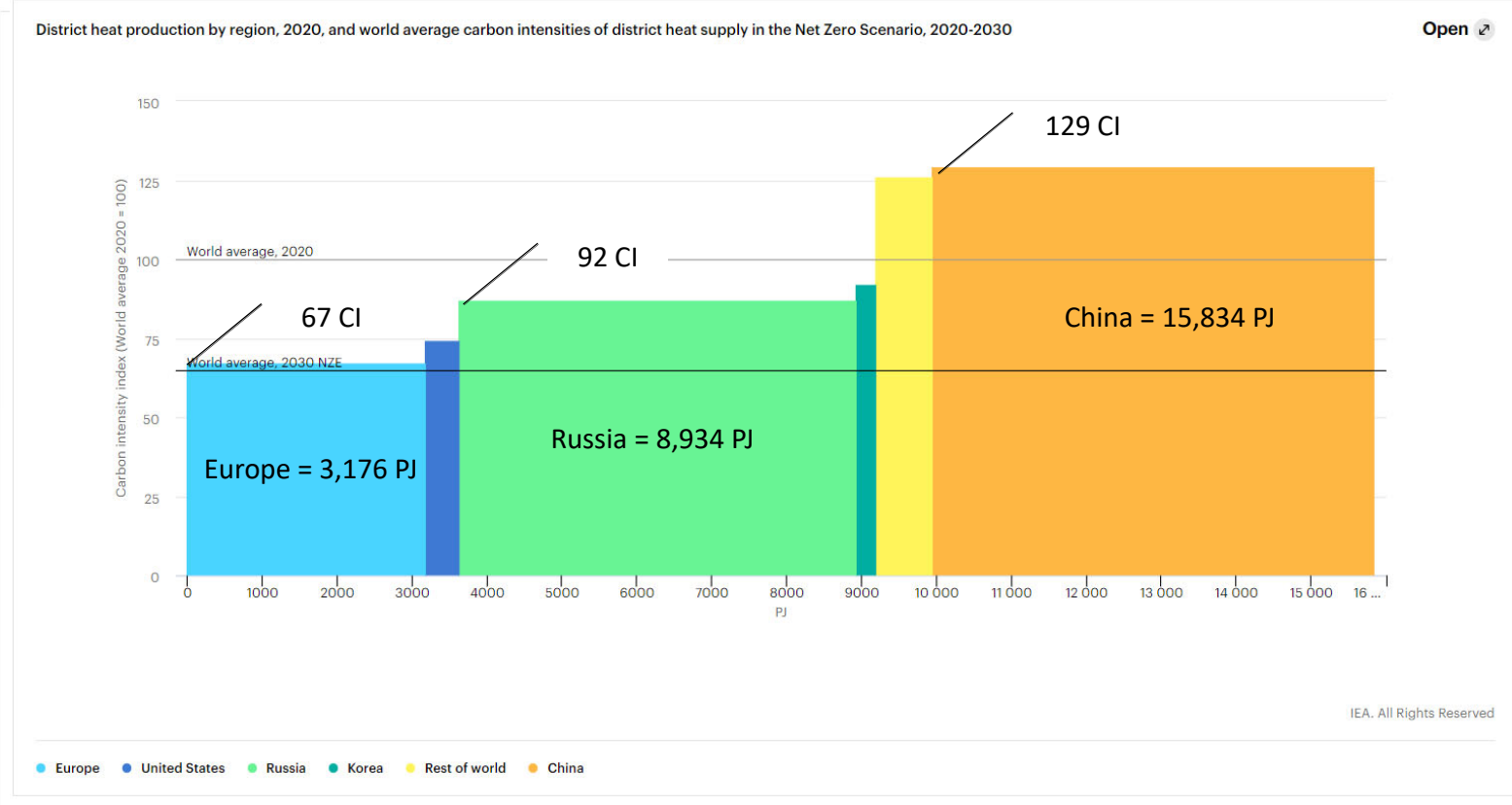
[1]Source: REN21, Renewables 2020, global status report based on OECD/IEA data; [2]LUT University, Energy Watch Group, Scenario of 100% renewable energy system in Europe in 2050

Energy Used in District Heating

Global

- In 2020, global district energy used 15.8 Exajolues (2.755 billion BOE)
- Nearly 90% comes from fossil fuels
  - 45% Coal
  - 40% Gas
  - 3.5% Oil
- Net Zero by 2050 requires renewables and electricity energy inputs to quadruple. Approx 35% of the total energy
- 35% * 15.8 = 5.53 Exajuoles

We need BIG Heat pumps!



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Electro Thermal Energy Storage (ETES)

& CO2 based Heat Pumps

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MAN ETES – charging cycle

Conversion of electricity in thermal energy – heat pump operation

(1) The HOFIM™ turbo-compressor runs on surplus energy from renewable resources, compressing CO_2 in the cycle, which is heated to 120°C.

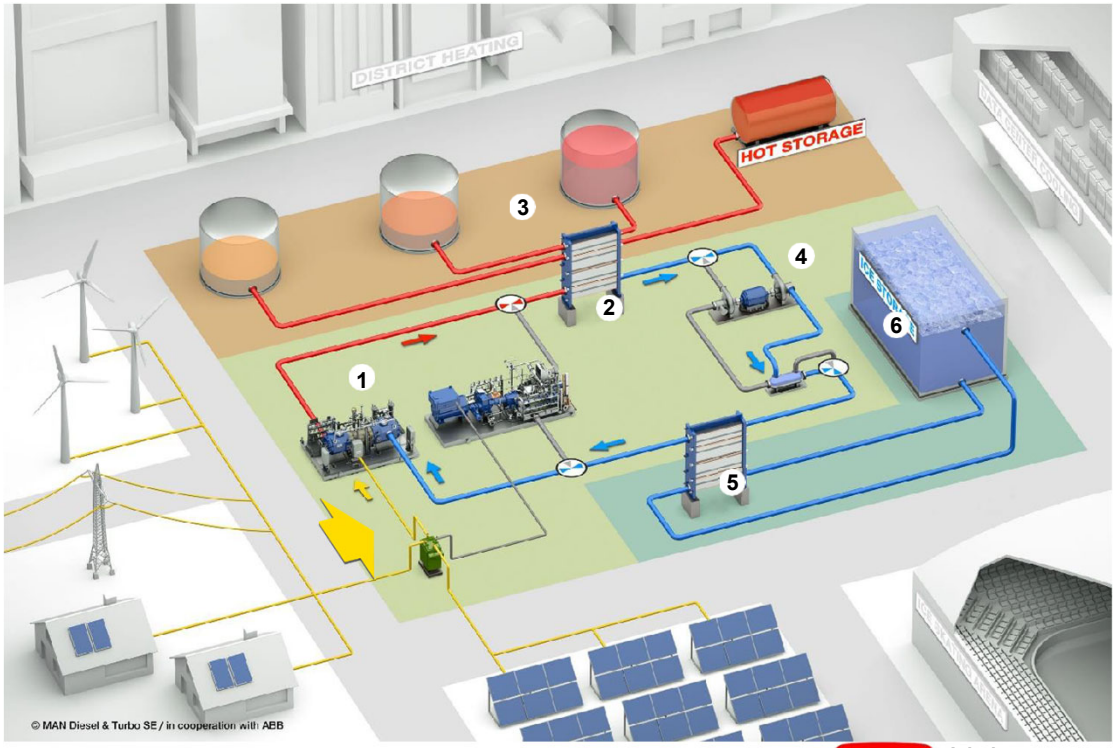
(2) The CO_2 is fed into a heat exchanger and heats the water.

(3) The hot water is stored in isolated tanks, each one at a separately-defined temperature level.

(4) Still under high pressure, the CO_2 is fed into an expander, which reduces the pressure – the CO_2 is liquefied and cooled.

(5/6) The liquefied CO_2 is again pumped through a heat-exchange system, this time on the cold side of the system. Heat is taken from the surrounding water and ice is formed in the ice storage tank.

Schematic is not to scale, only for demonstration purposes



Link to animation

MAN ETES – discharging cycle

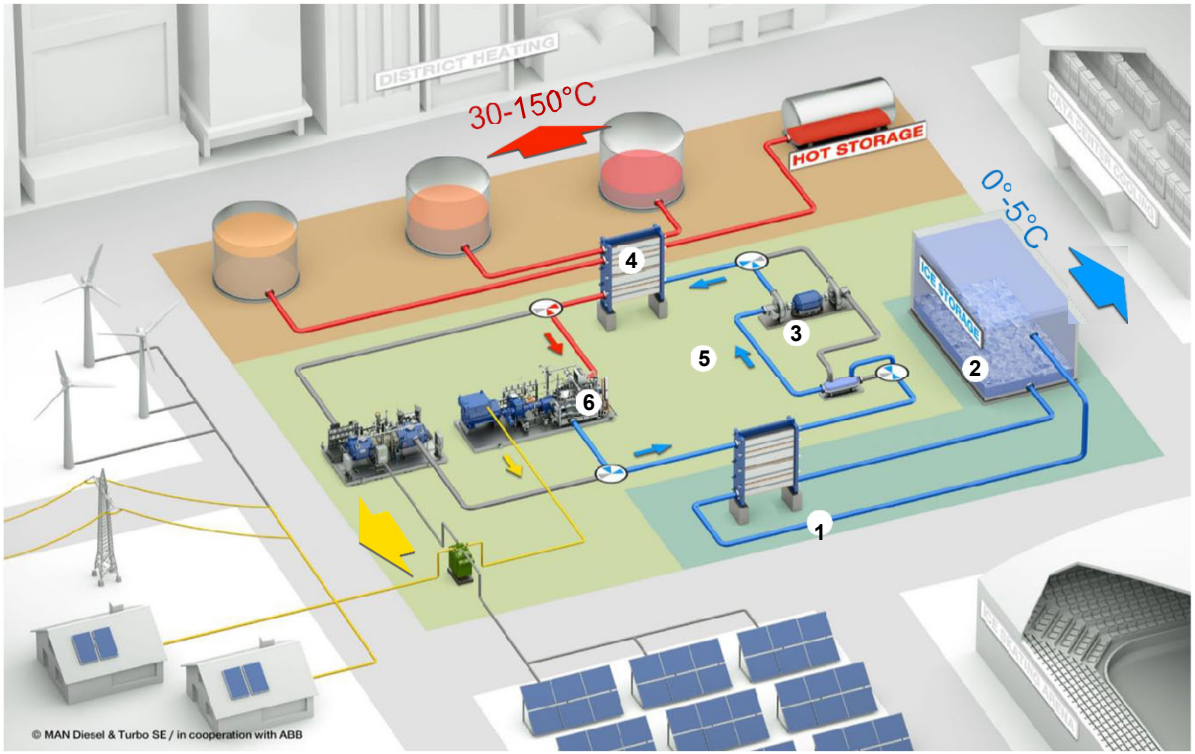
Conversion of thermal energy into electricity – heat engine operation

(1/2) Gaseous CO2 enters the heat exchanger on the cold side of the system where it condenses because of the cold from the ice-storage tank. The ice in the tank melts.

(3) The CO2 pump increases the pressure of the CO2 again.

(4/5) The CO2 passes through the heat exchanger and is heated by the water in the hot-water storage tanks.

(6) The heat from the heated CO2 is fed into the power turbine where the heat is converted back into electrical energy via a coupled generator. The electricity flows into the grid and is distributed to consumers.



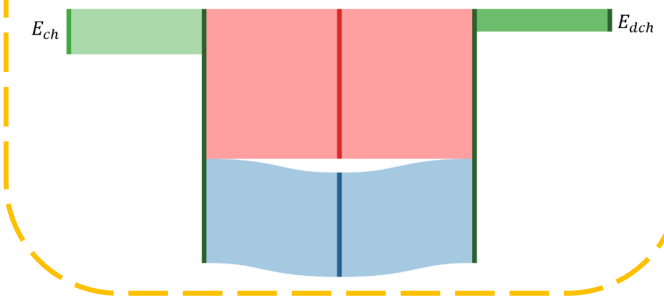
Schematic is not to scale, only for demonstration purposes

Link to animation

Possible configurations

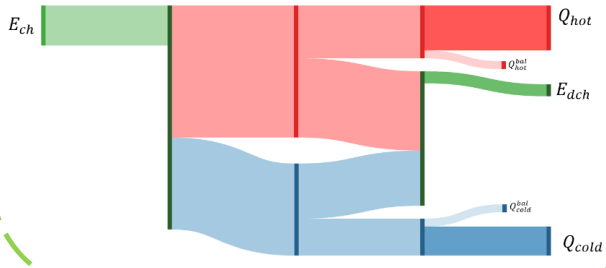
Pure electricity storage (ETES)

- Charging cycle
- Discharging cycle
- Thermal storage
- RT efficiency: 40-50%



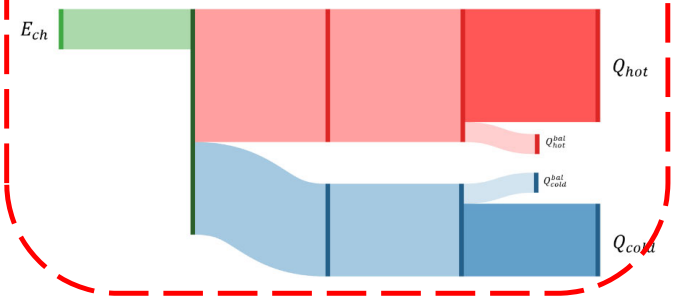
Tri-generation energy system (3-TES)

- Charging cycle
- Discharging cycle
- Thermal storage
- Thermal export



Heat pump unit (HPU)

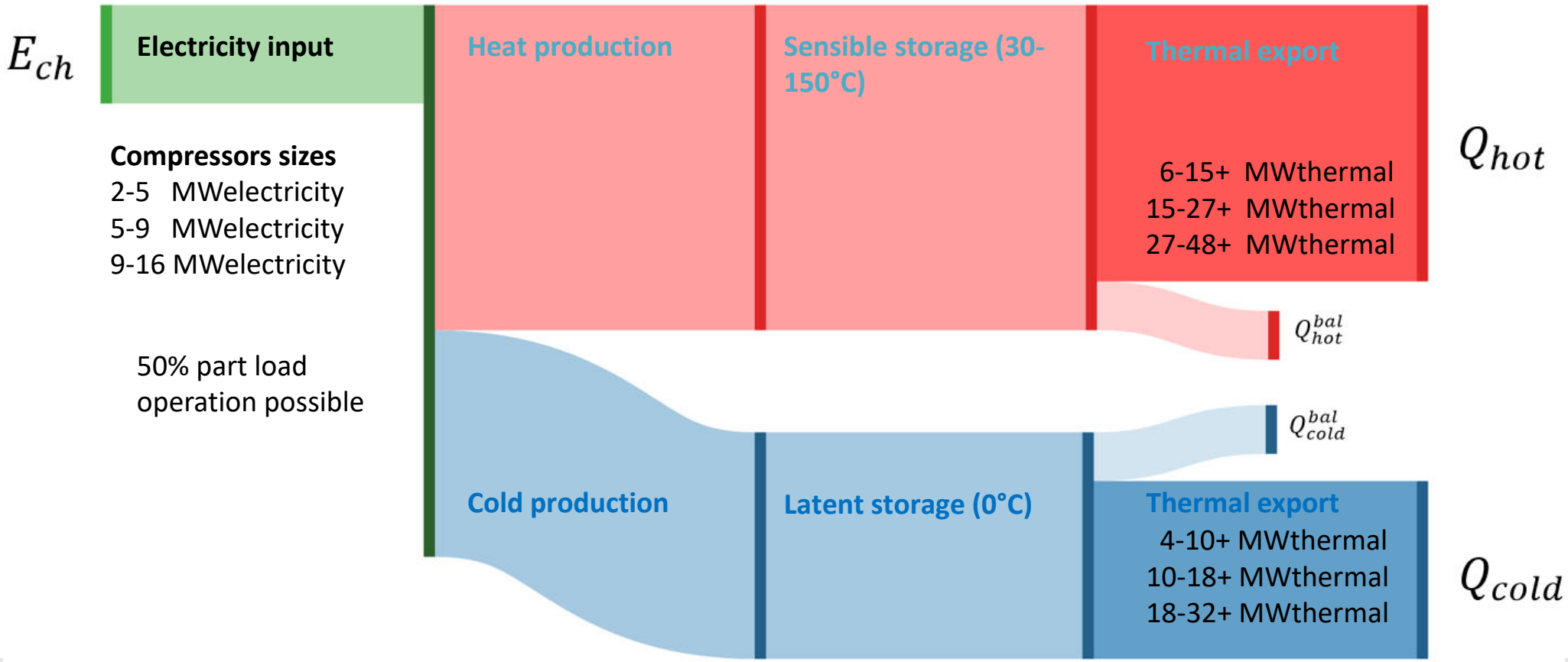
- Charging cycle
- Thermal storage optional
- Thermal export
- $Combined\ COP$: 3 – 12.5



Highly flexible and adaptable to specific electric and thermal demands!

Heat & Cold Supply Production and Storage

Thermal share: 100% (ETES Light)



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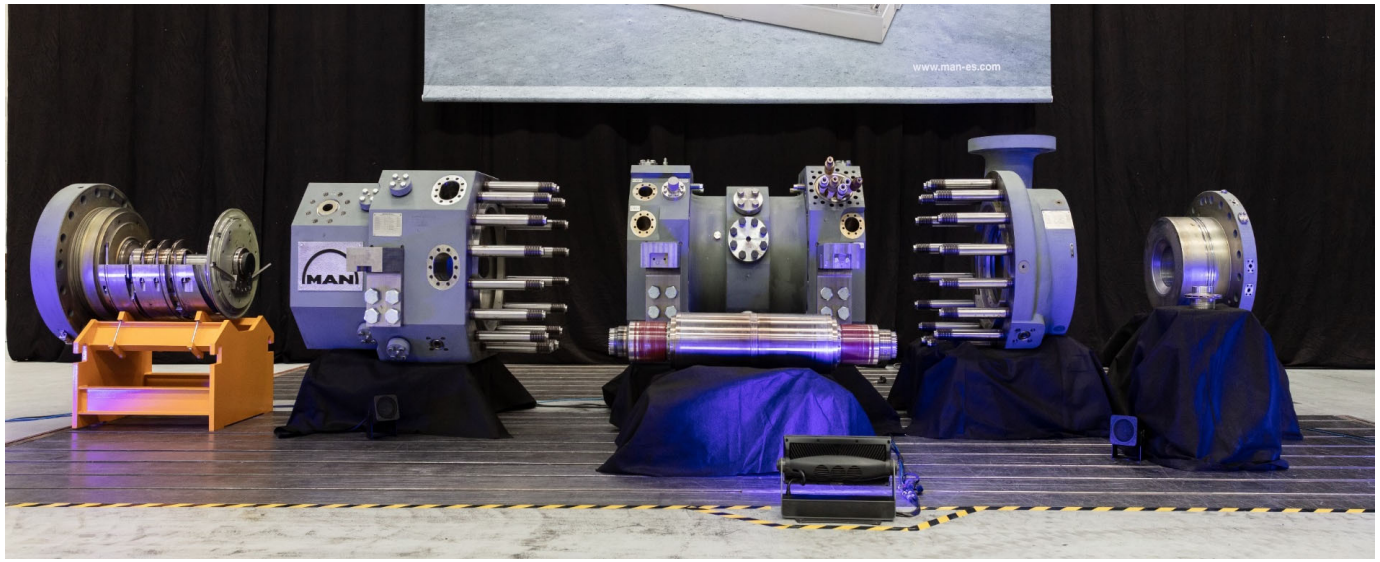
System Components

CO_2 Compression & Expansion with HOFIM™

The **heart** of the ETES heat pump system



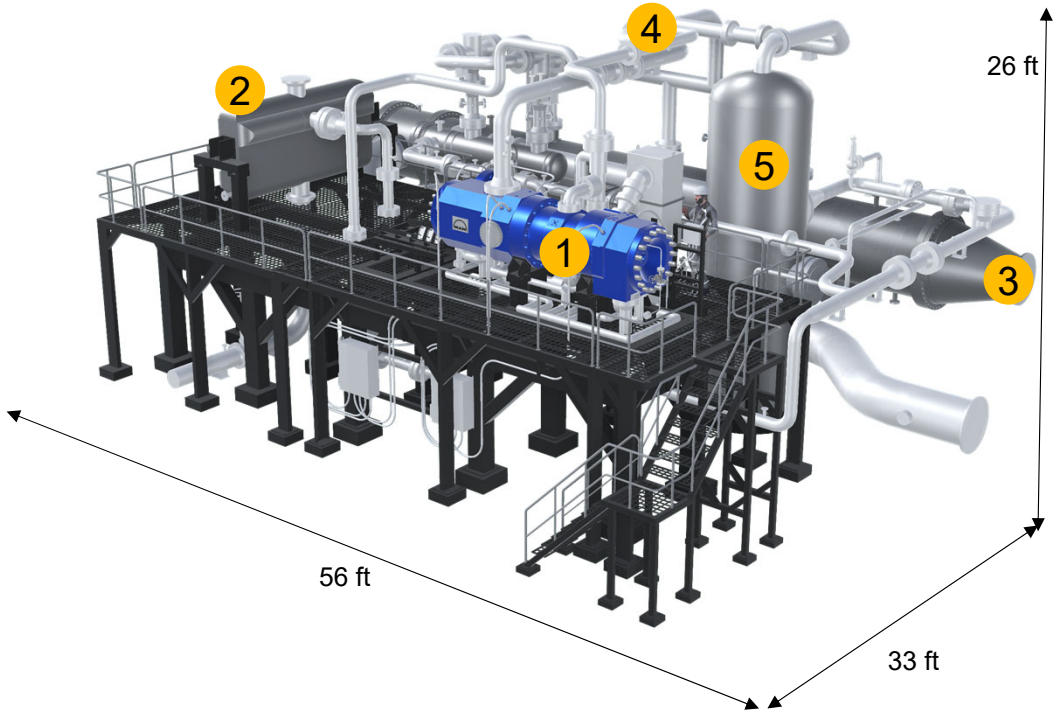
- Barrel compressor – **robust, reliable & compact**
- Integrated Expander – **increase process efficiency**
- High-speed motor – **flexible & dynamic operation**
- Motor cooled by process gas – **heat losses reintroduced into process**
- Running on MECOS magnetic bearings – **no lube oil, no wear**
- Reduced auxiliaries – **increased reliability, reduce OPEX**
- Fully electric – **remote control**
- Hermetically sealed – **no emissions**

Typical HOFIM™ (High speed Oil Free Integrated Motor compressor) skid

We deliver the complete system

Extended scope excluding civil and building works

1. Motor-Compressor HOFIM® with integrated expander
2. Hot Heat Exchangers
3. Evaporator
4. Complete piping and steel structure
5. Valves, instrumentation, connecting cables, refrigerant tank
6. DH water pumps, seawater pumps
7. Complete electrical scope
8. Complete control system
9. FAT of main equipment
10. Installation and commissioning
11. On site testing



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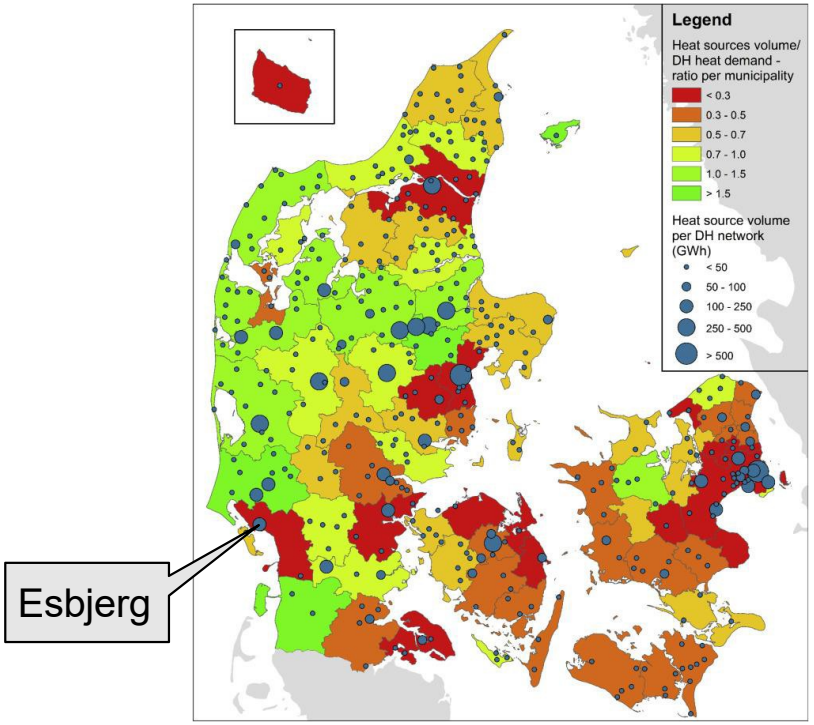
Esbjerg

Port of Esbjerg, Denmark

Denmark: Highest renewable power production & largest district heating network

Electrify the heat!

Wind and solar generation met up to 50% of Denmark's electricity demand during 2019



District heating coverage in Denmark

Esbjerg at a glance

Seawater Heat Pump replacing coal

Heat Pump Building

District Heat
T_2

Green electricity

T_1

Sea as heat source

MAN ES scope of supply

Coal power plant supplying heat to be shut down in 2023

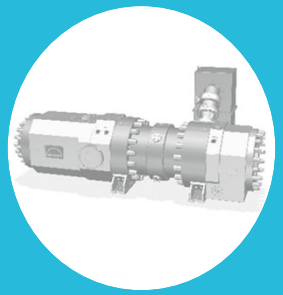
At a glance:

- District Heat for 25‘000 house holds
- CO_2 savings:100‘000 t = ~20‘000 cars
- CO_2 tax savings = ~ 120 Mio € (18 years)

Success factors:

1. Environmental friendly and safe refrigerant CO_2
2. Compact, reliable, future proof technology based on oil&gas industry standards
3. MAN ES and ABB as strong partner

Esbjerg HOFIM (March 2022)



Core Machine

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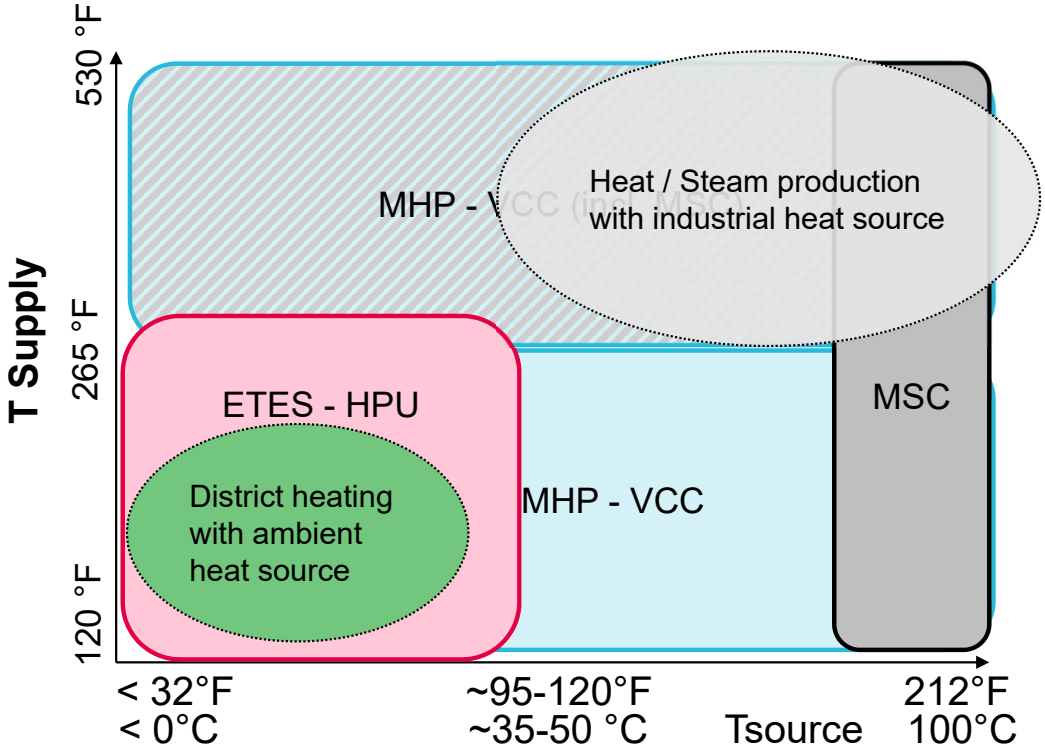
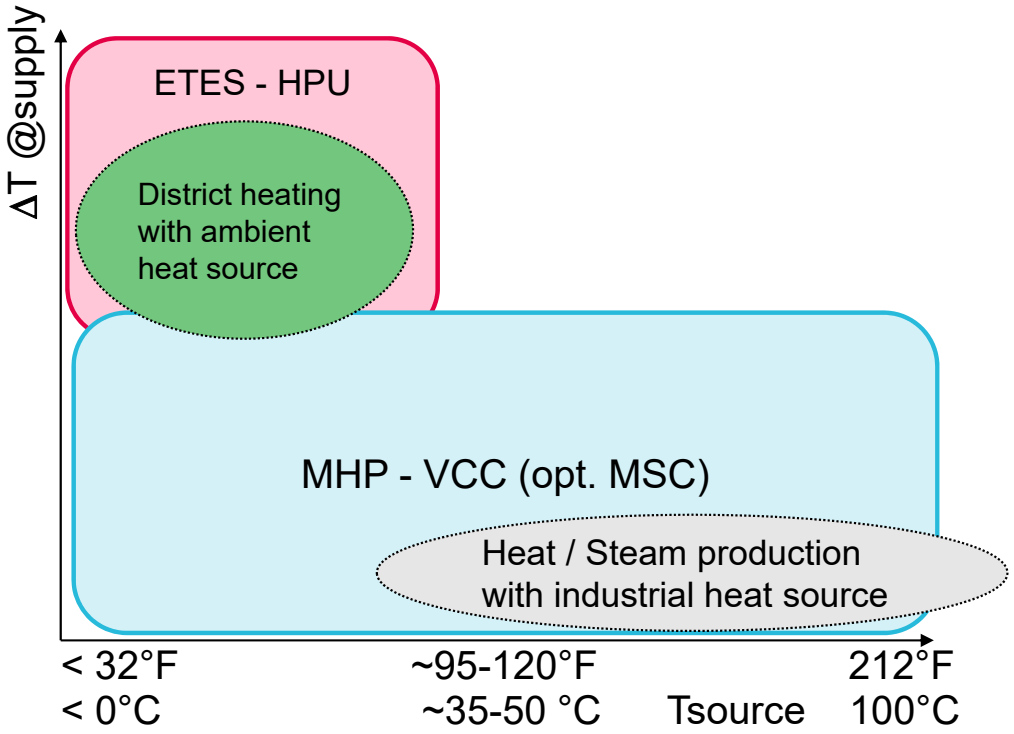
Alternatives to CO2

Cycles & Refrigerants

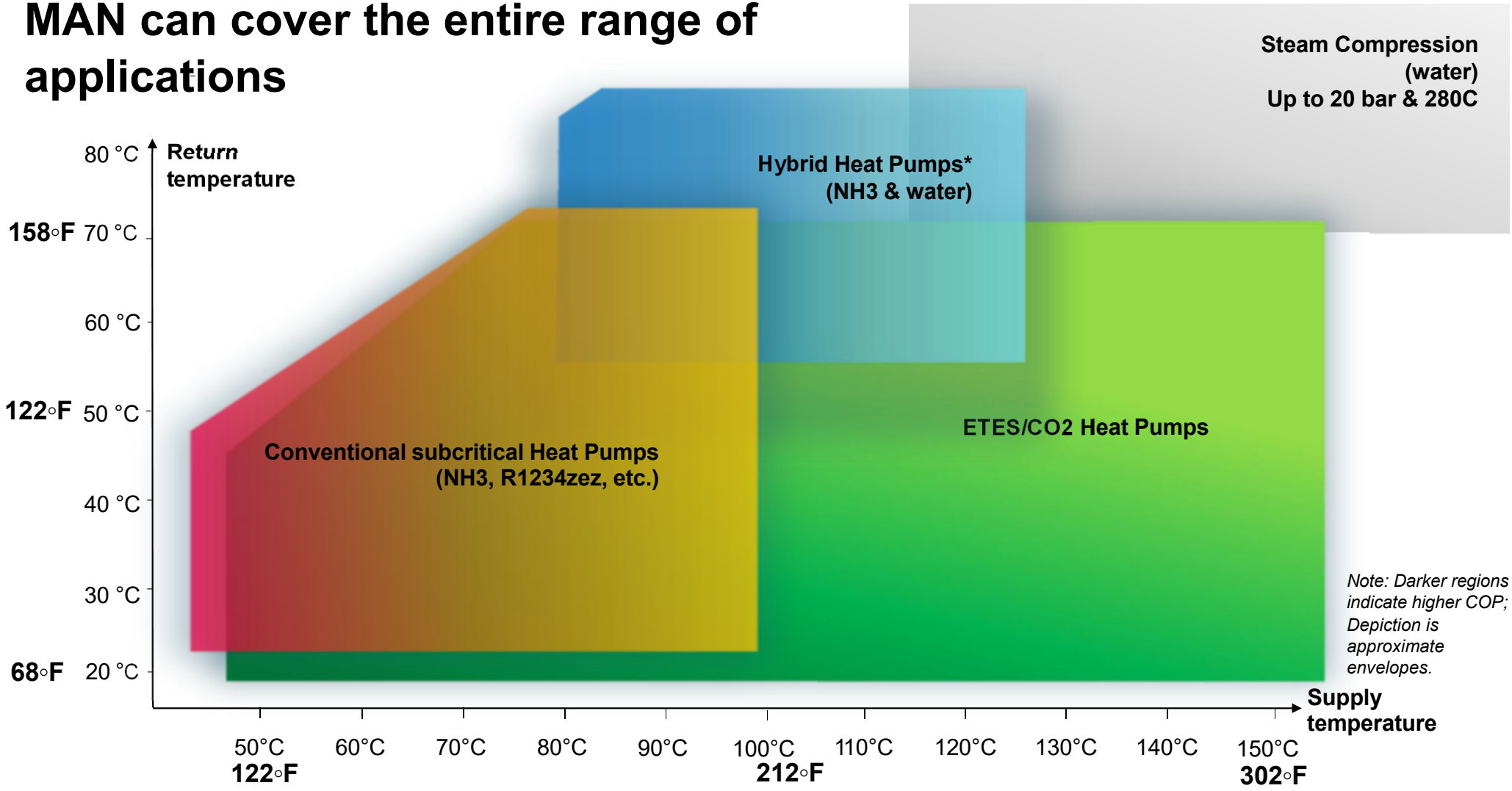
MAN ES Heat Pumps

Application Map: ETES - HPU: MAN ES Heat Pump based on transcritical CO2 process
MHP - VCC: MAN ES Heat Pump based on vapor compression cycle
MSC: MAN ES Steam Compression





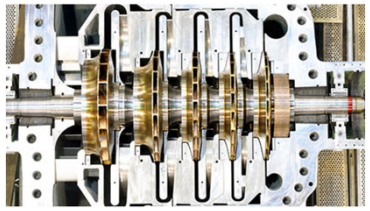
MAN can cover the entire range of applications

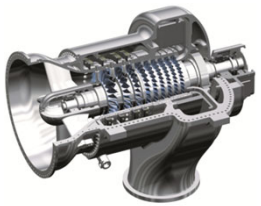


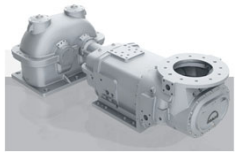
MAN ES Heat Pumps

Compressor Casing Type

Heat Pump Cycle	Compressor				Compander	Expander	
	Axial	Centrifugal	Geared	Screw	Centrifugal	Axial	Centrifugal
Vapor Compression Cycle	(AxM)	RH/RB	RG	(X)			
Transcritical CO2 Cycle		RB/HOFIM	RG		RB/HOFIM		ER
Superheated/-critical Cycle	AxM	**RH/RB**	**RG**		RG	*	ER
(Steam Compression)			**RG**				



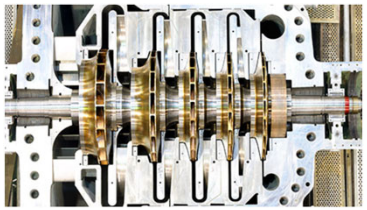


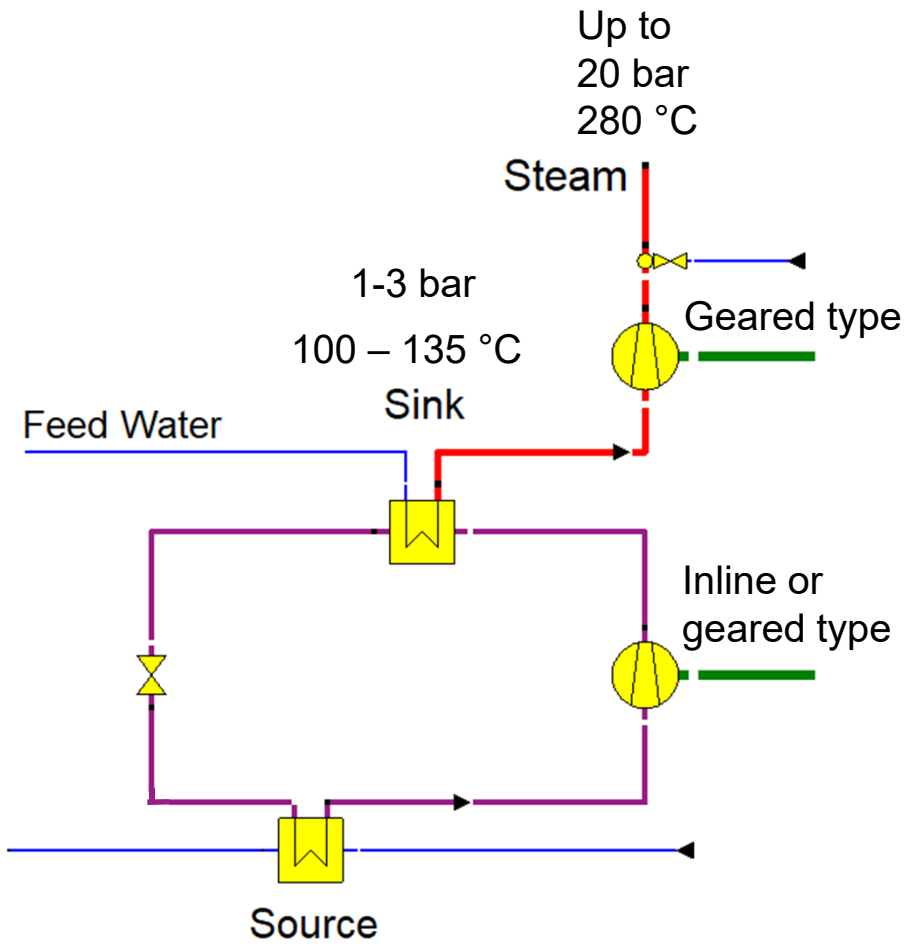


MAN ES Industrial Heat Pumps

MHP-VCC & Steam Compression

- Engineered solutions
- Wide range of natural and future proof synthetic working fluids
- Heat Source temperature range up to 100 °C
- Heating and steam production
- Optional combination with steam compression
- Based on MAN well referenced inline and geared / multishaft compressor technology





Concept layout only.

Thank you!

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