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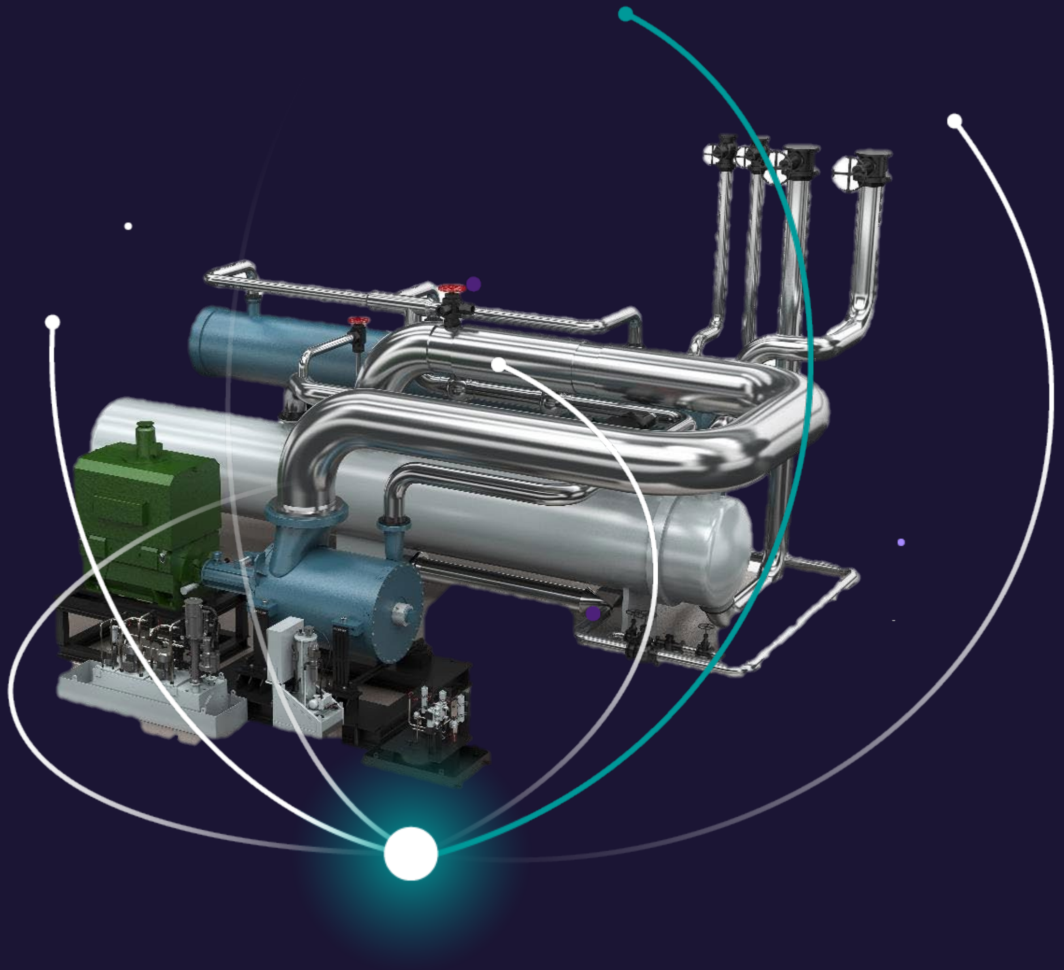
Heat Pumps for Industrial Process Heating

April 5th 2022
SWRI IPER Conference

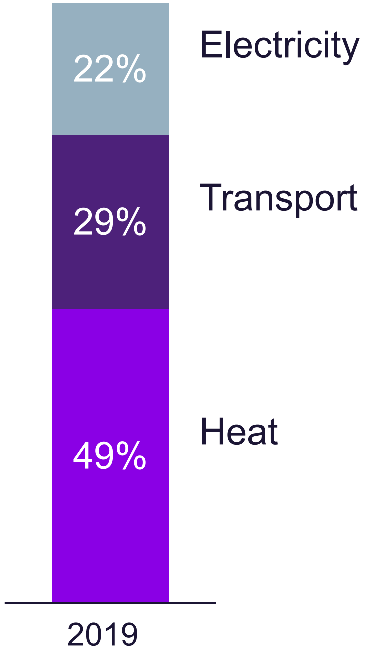


Agenda

1. Motivation: Emission Reductions for Industrial Process Heat
2. Basic Working Principles of Heat Pumps
3. Heat Pumps for Industrial Processes
   a) ‘Low’ Temperature 80-160°C
   b) ‘Mid’ Temperature 160-270°C
   c) ‘High’ Temperature 270°C and greater
4. Conclusion

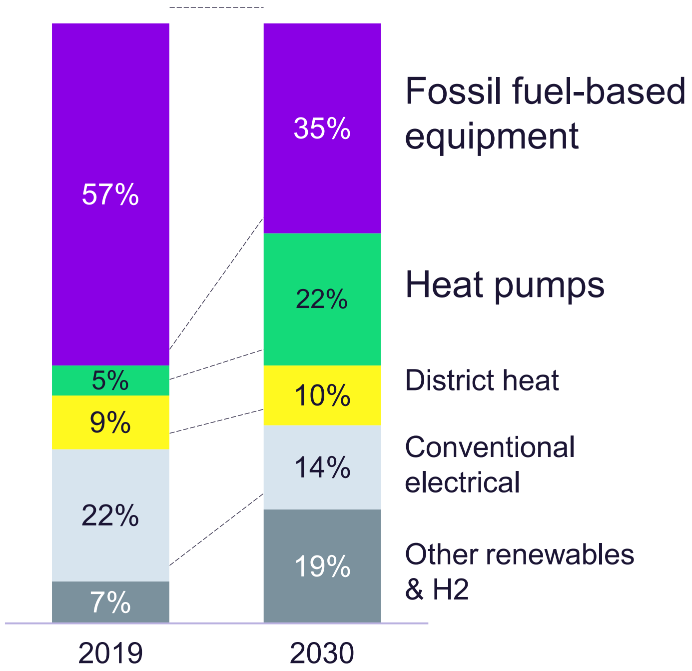
Global heat is largely produced from fossil fuels, technology must shift to achieve sustainability targets according to IEA

FINAL GLOBAL ENERGY CONSUMPTION



Half of final energy use is heat → more than double compared to electricity

HEATING TECHNOLOGY MIX



>Half of heat is produced from fossil fuels → ~40% of energy related CO_2 emissions

Decarbonizing heat production requires:

1) Efficiency improvements (insulation, reduction of system losses, etc.)

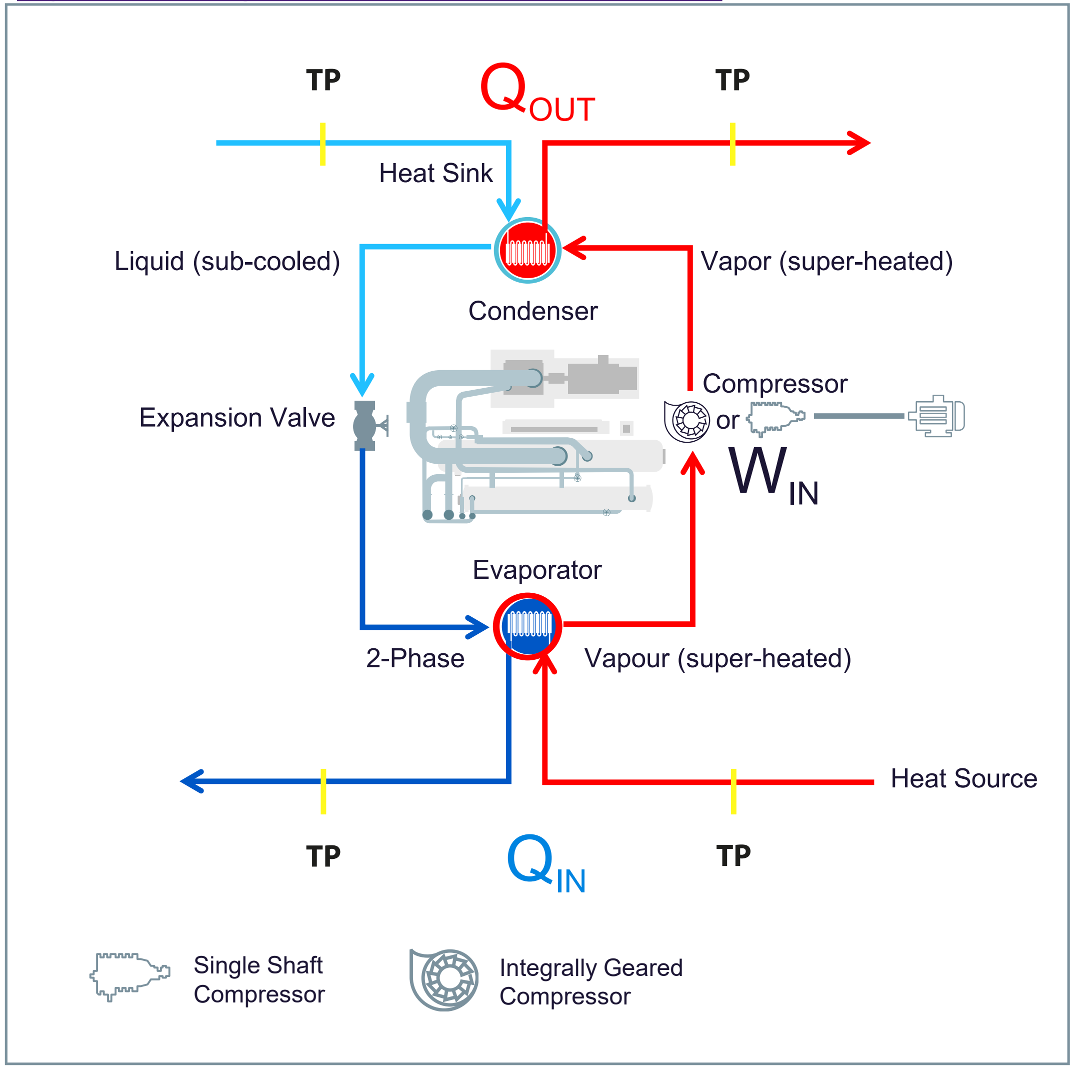
2) Replacement of fossil fuels with low-carbon-electrified heat supply

Source: IEA / IRENA 2020 (Renewable Energy Policies in a Time of Transition, Key World Energy Statistics).

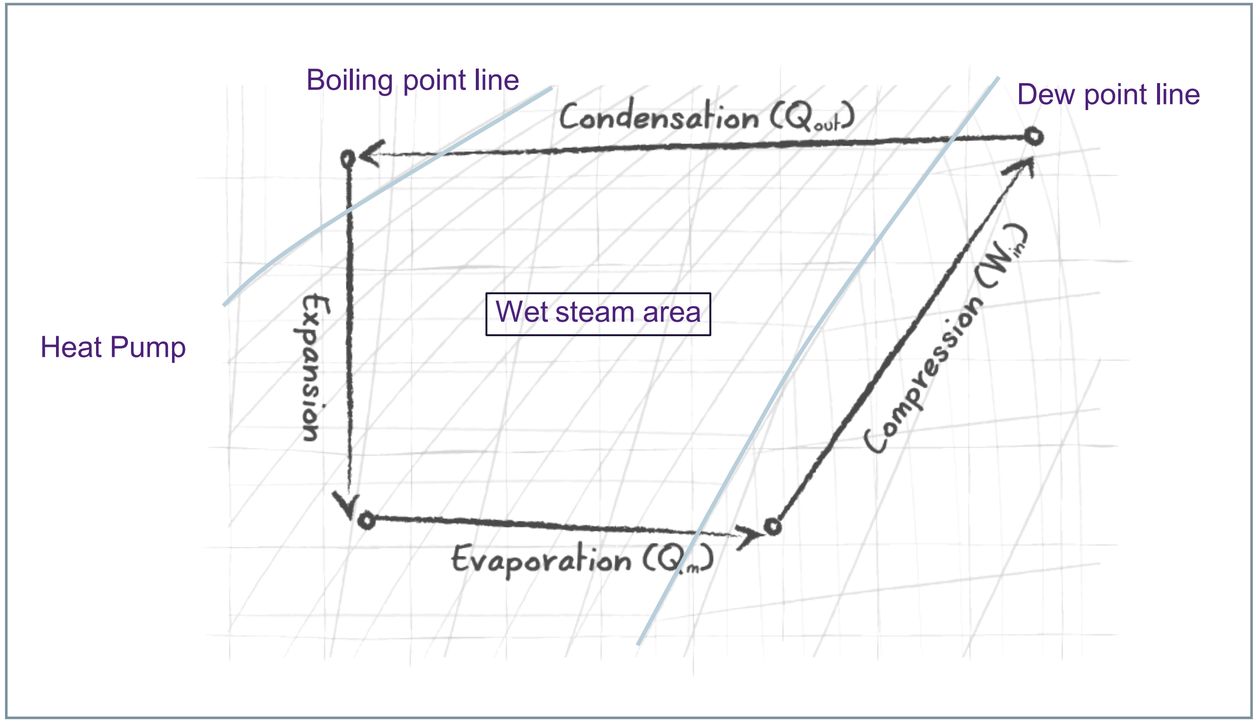
Basic Principle of Compression Heat Pumps

Cycle design, components, and typical terminal points

Cycle Design & Main Components:



P,H-Diagram:

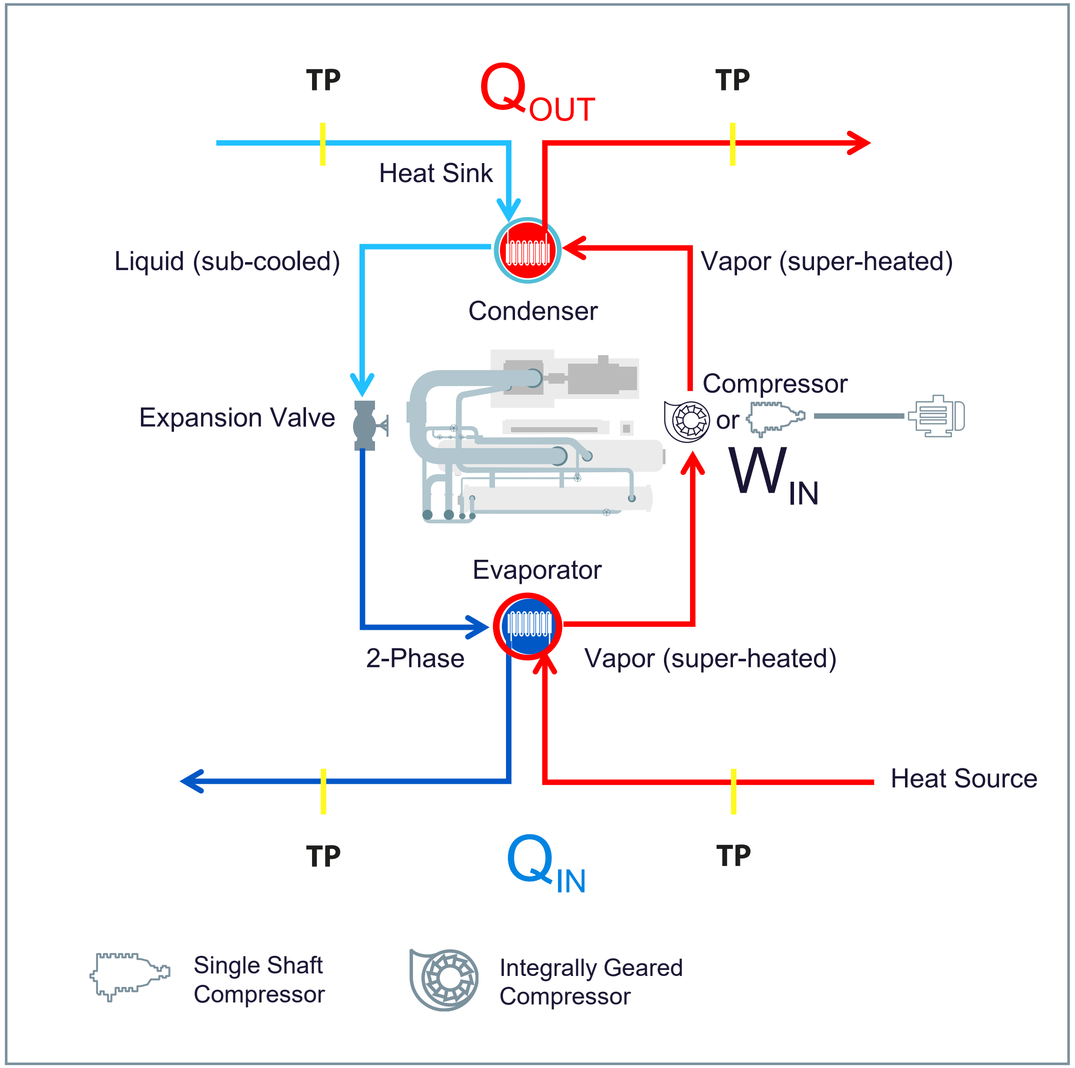


- Counter-clockwise cycle
- “Consumes” work to rise heat from a low temperature level to a higher temperature level

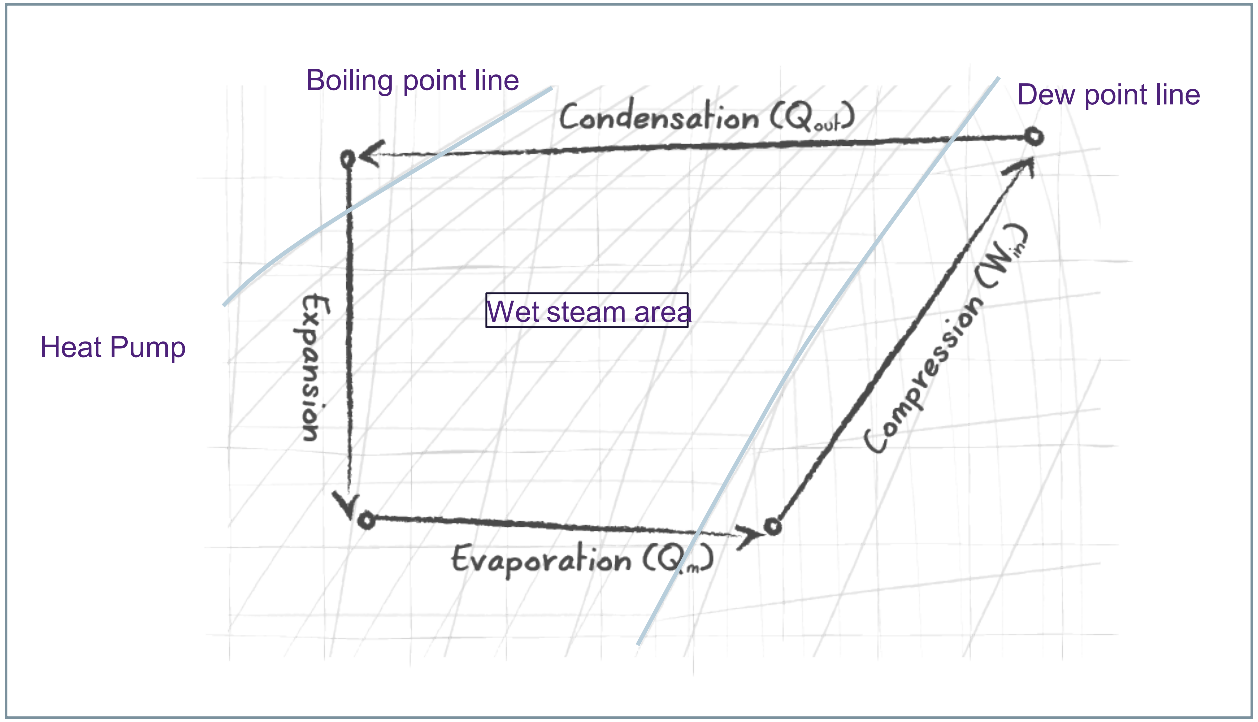
Basic principle of compression heat pumps

Cycle design, components and typical terminal points

CYCLE DESIGN AND MAIN COMPONENTS



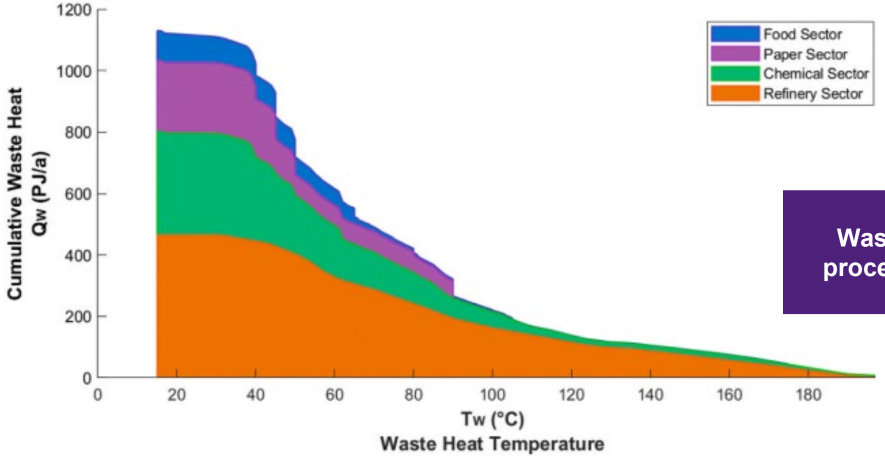
P,H-DIAGRAM



- Counter-clockwise cycle
- “Consumes” work to rise heat from a low temperature level to a higher temperature level

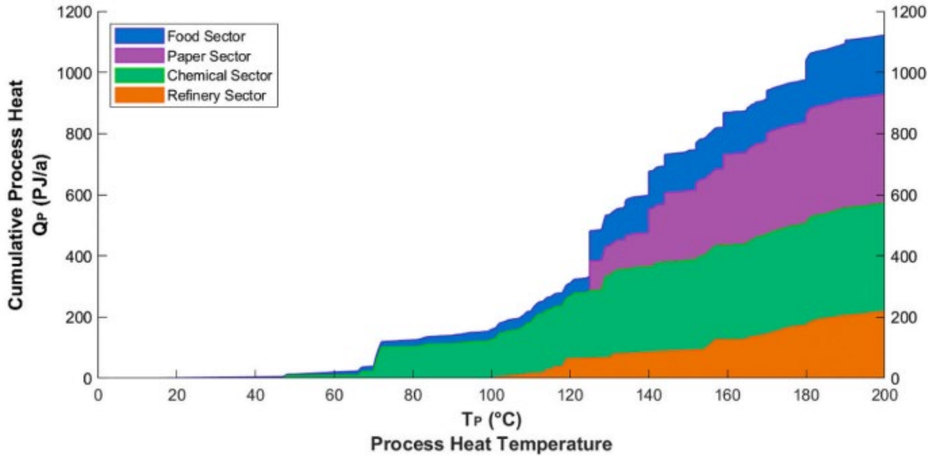
Industrial Heat Pumps for Process Heat at 80-160°C

Typical waste heat streams and heat sinks of selected industries

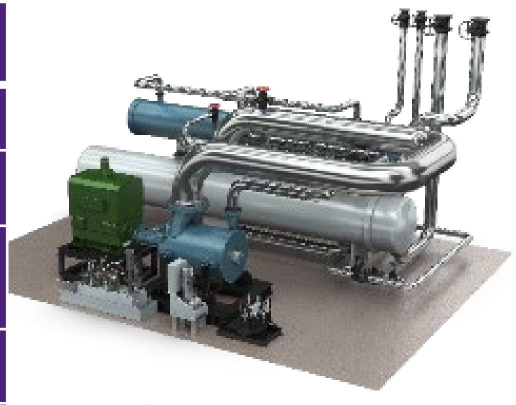


Waste heat or process cooling

Usable Heat for industrial processes



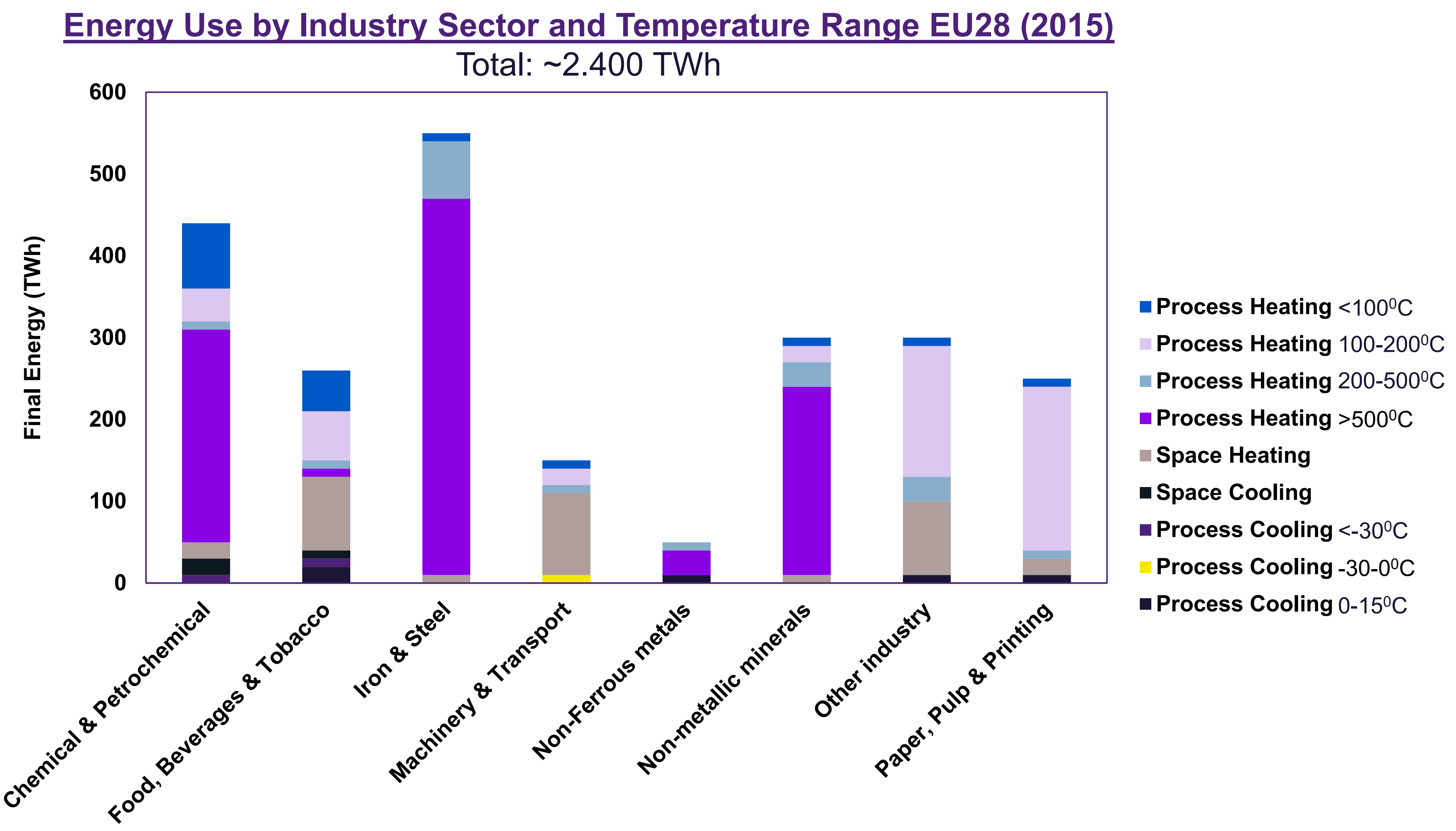
Sector	Processes	Typ. Range
Brewing	Hot water, process cooling	5-60 ^{o}C
Dairy	Hot water, process cooling	5-60 ^{o}C
Paper	Wastewater, wire pit water, hot condensate, exhaust air	30-100 ^{o}C
Brick	Exhaust air, waste heat	50-90 ^{o}C
Starch	Exhaust air, hot condensate	50-90 ^{o}C
Chemical	Waste heat, process cooling	60-120 ^{o}C
Sugar	Waste heat, hot condensate, process cooling	60-120 ^{o}C



Typ. Range	Processes	Sector
60-120 ^{o}C	Hot water/steam for brewing, filling, and cleaning processes	Brewing
80-150 ^{o}C	Hot water/steam for pasteurization	Dairy
80-160 ^{o}C	Water/steam preheating, hot air for drying, boiling and bleaching	Paper
110-140 ^{o}C	Hot air for brick drying	Brick
140-160 ^{o}C	Hot air for starch drying	Starch
80-270^{0}C	Hot water/steam for boiling, compression and distillation	Chemical
80-160 ^{o}C	Hot water/steam for preheating of thick juice	Sugar

Source: An estimation of the European industrial heat pump market potential. A. Marina et al.

Strong Demand for Process Heat above 200°C



Source: European Commission Eurostat © 2015 ec.Europa/eu/Eurostat.

HTHP Steam generation + Steam Compressor

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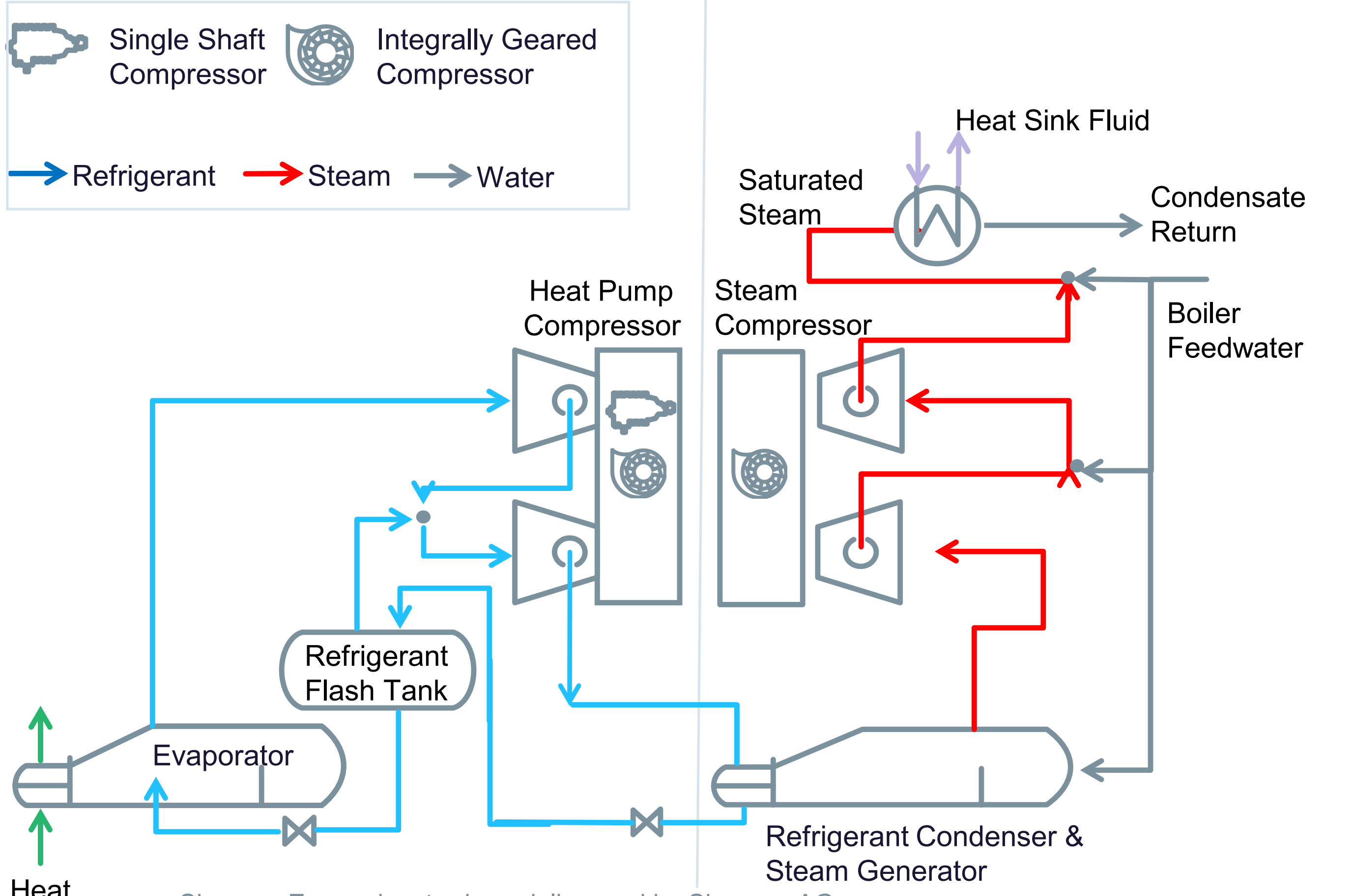
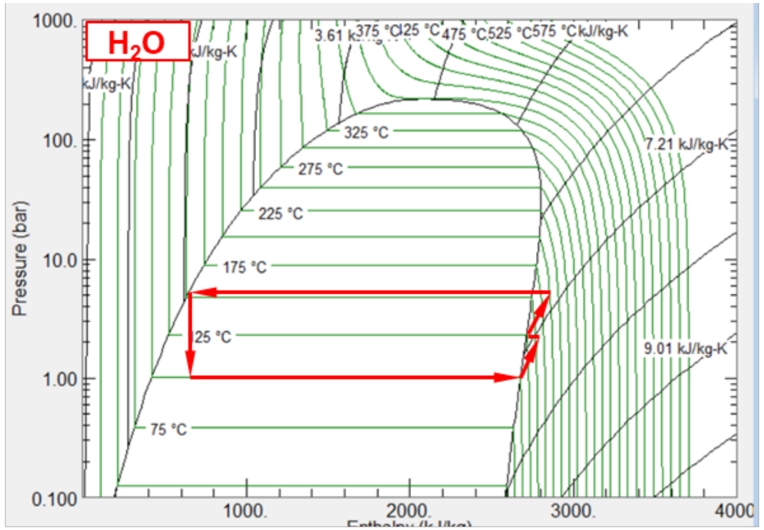
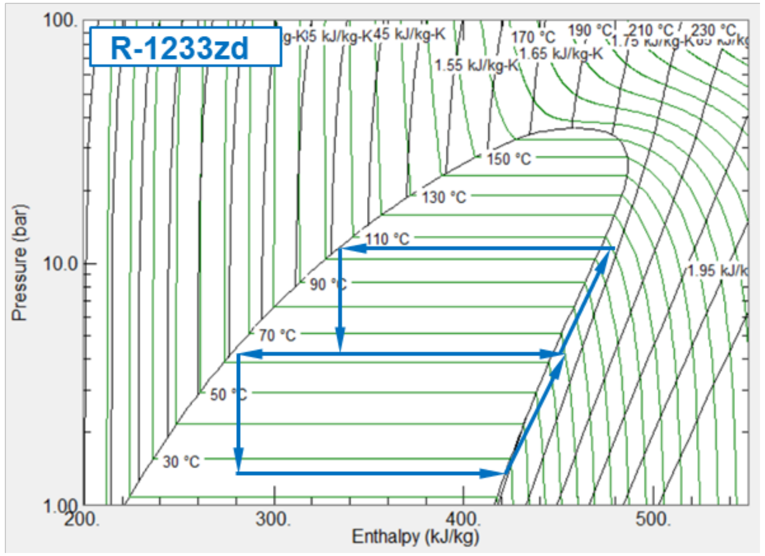
HEAT PUMP TEMPERATURES UP TO 140°C

STEAM COMPRESSOR TEMPERATURES UP TO 270°C

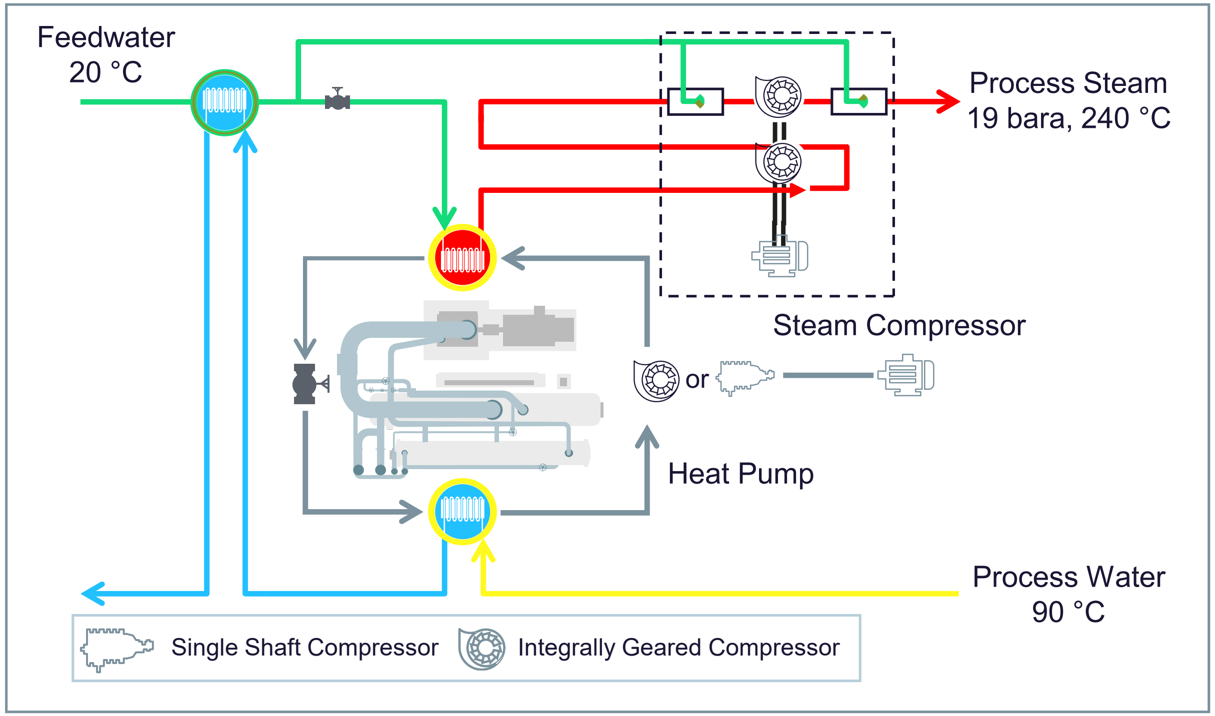






Integration of Industrial Heat Pump
Process Steam Production in chemical plant | Overview & key figures

OVERVIEW



KEY FIGURES

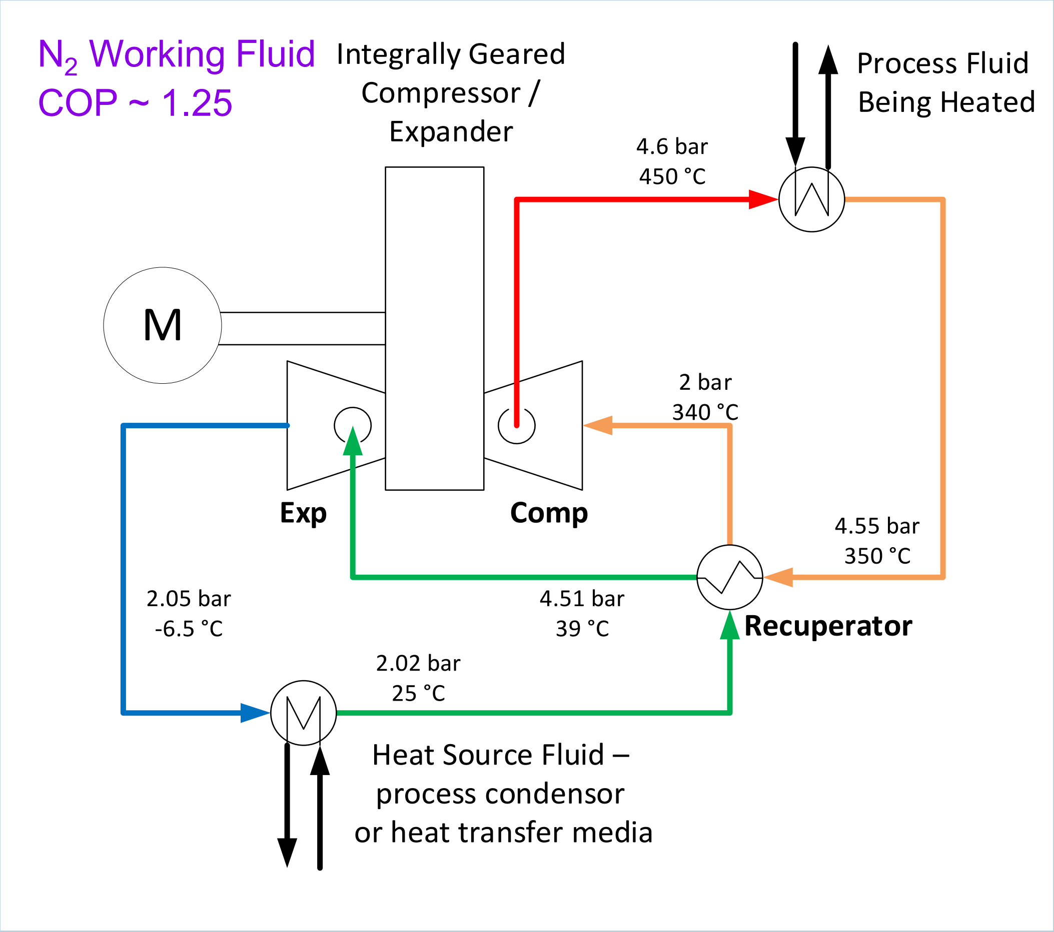
CAPACITY	36 MWth HP & Steam Compressor = 50 MWth
AVERAGE COP	~ 2.5 (incl. steam compression)
REFRIGERANT	Hydro-(-chloro)-fluoro-olefin (H(C)FO)
ARRANGEMENT	Brownfield (integration in existing building)
HEAT SOURCE	Process water return from reactors (90 → 70°C)
HEAT SINK	Process Steam (20°C → 19 bara, 240°C)
COMPRESSOR	Geared type radial compressor
LUBE & SEAL OIL SYSTEM	Combined lube and Seal Oil System
HEAT EXCHANGER	Shell & Tube Heat Exchangers (Evaporator, Condenser, Subcooler)

BACKGROUND

- High temperature heat pump utilizes waste heat from process water of reactors to produce saturated steam from feedwater
- Saturated steam is fed to steam compressor (multi-stage intercooled/attemporated)
- Final adjustment of steam parameters by attemporation

Future Applications: Temperatures above 270°C

- Steam topping enables higher sink temperature than HFO-based heat pumps alone.
- Steam topping would require significant head to reach temperatures in the 300°C - 500°C range. In this range, schemes based on ideal gas are likely preferred.
- Elevated pressure leads to improved heat transfer and reduces heat exchanger size and cost compared to a fired heater with atmospheric pressure flue gas.
- Further benefit possible if a process has simultaneous cooling need.



Conclusion

- Decarbonization of process heat is essential to meet climate goals.
- Heat pumps are a leading technology to improve efficiency in heat delivery and to electrify heat.
- Heat pumps can already be implemented for process heating needs up to 270°C with high COPs.
- Developments for temperatures above 270°C are still needed. Cycles based on ideal gases are likely to show the greatest benefit.

Contact page

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