MAN Energy Solutions
Future in the making

Heat up Carbon down

Heat pumps as CO_2 neutral solutions

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Industries requiring heat...

Steam Production

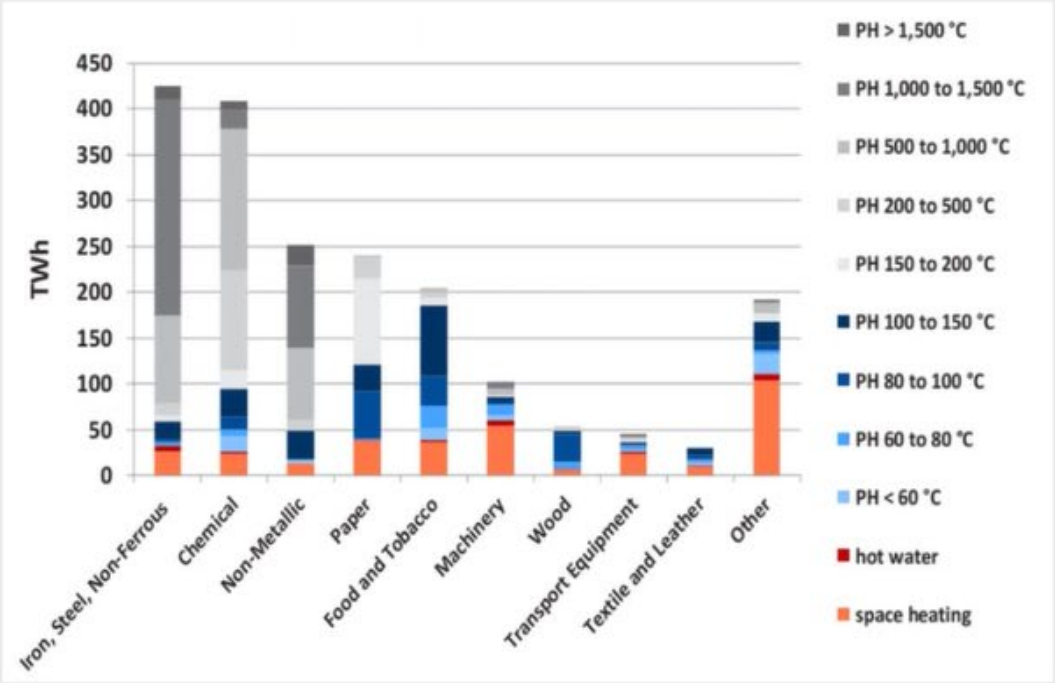
Focus: Paper, (petro)chemical, CCS

High and very high temperature segment

Process Heat

Focus: (Petro)chemical, CCS, other

High temperature segment



District Energy

Low temperature segment

Heating & Cooling

- Urban Areas
- Corporate Campus
- Large Multifamily

Decarbonization of heat – Heat pumps play increasingly important role

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

Power
17 %

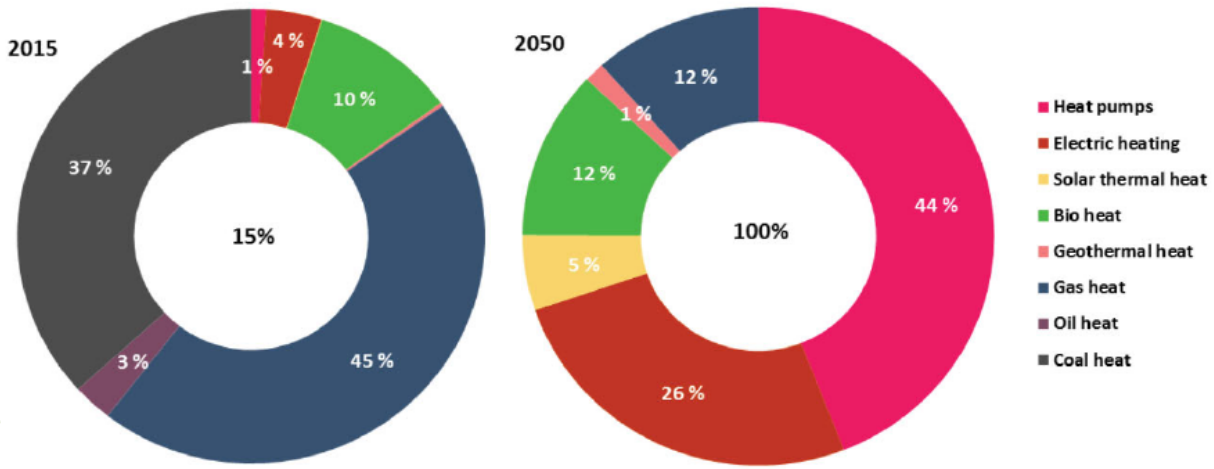
Transport
32 %

Thermal
51%

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

Decarbonization of thermal segment is critical to reduce global CO2 emissions

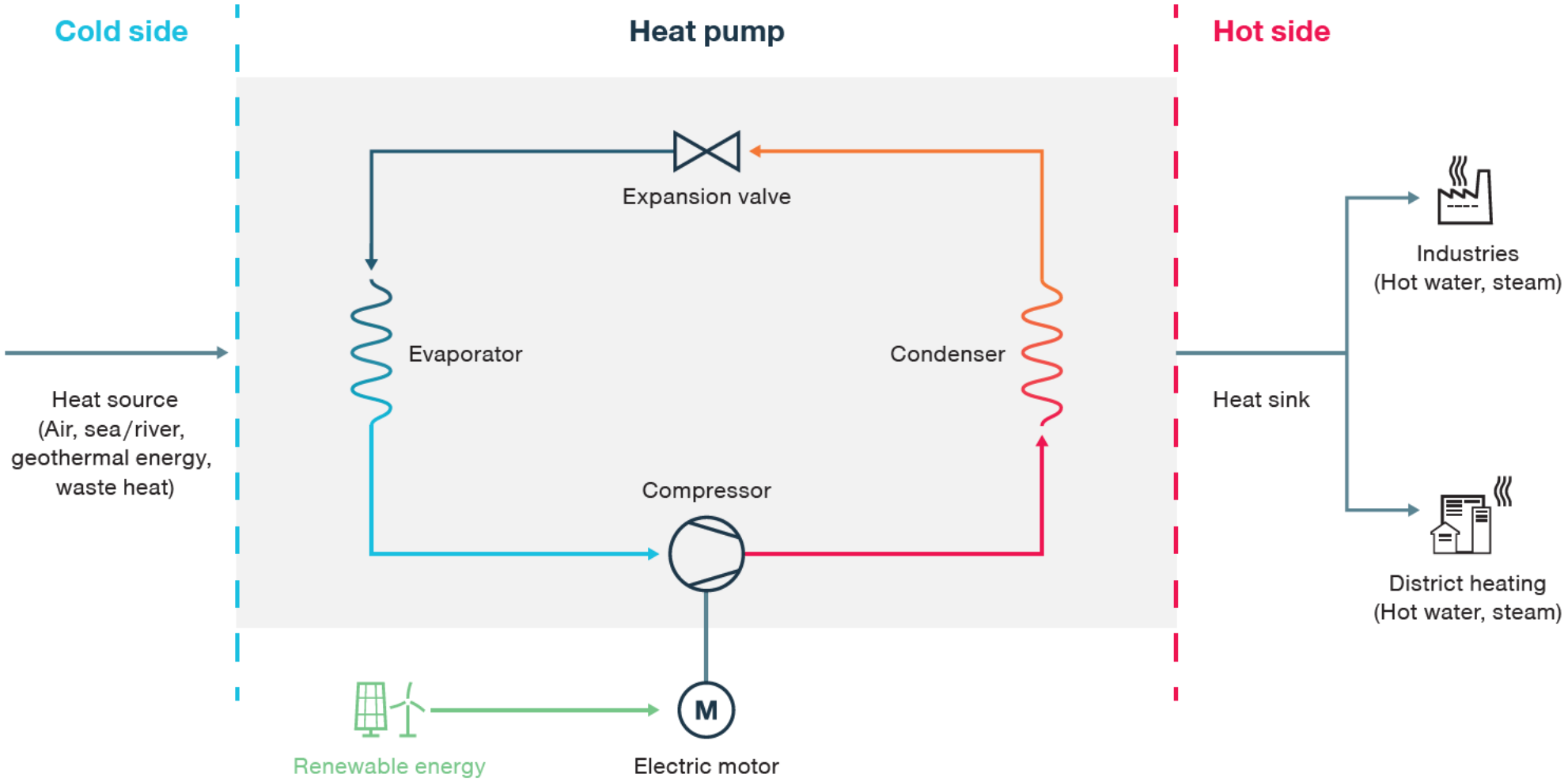
Scenario for a 100% renewable heat supply:[2]



- 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

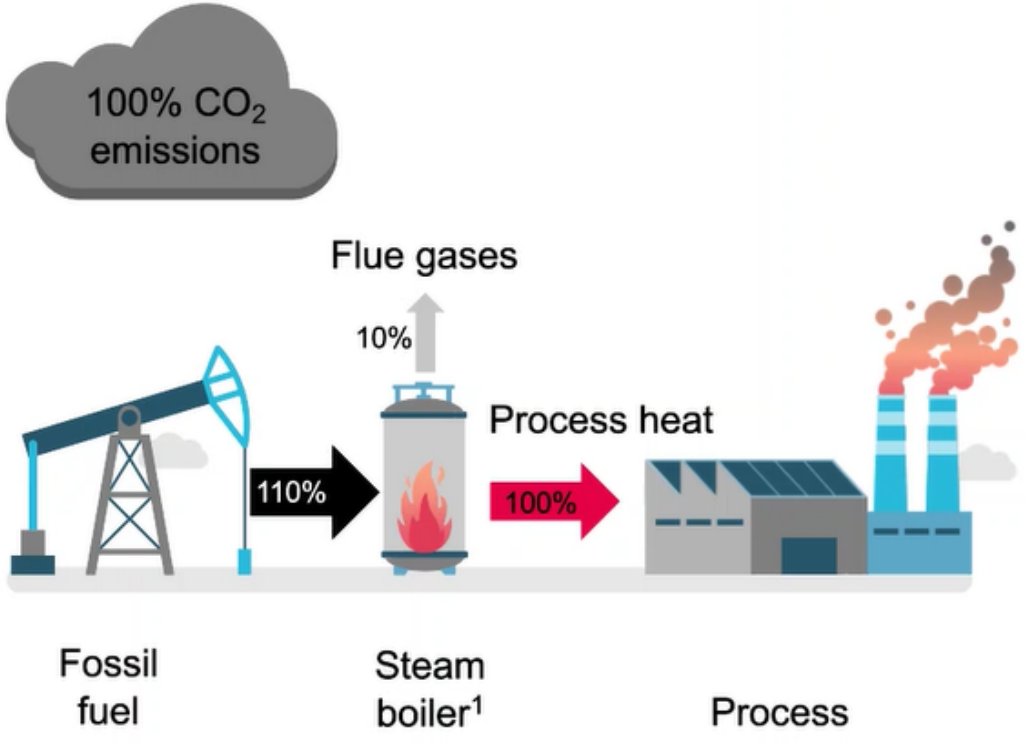
Heat Pump Concept



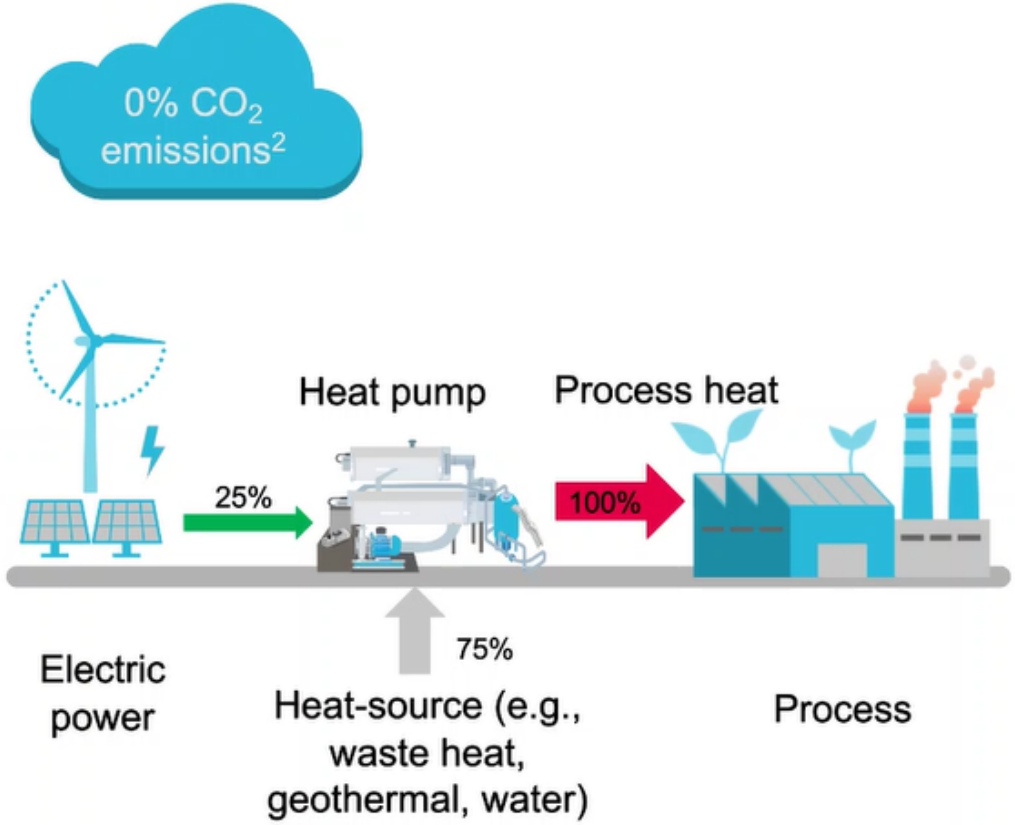
How Heat Pumps Decarbonize

Solution for zero emission heat

Fossil fuel driven process heat generation



Heat pump driven process heat generation



1. Efficiency of about 90%
2. Using renewable electricity, ~30% CO2 emissions based on current electricity mix

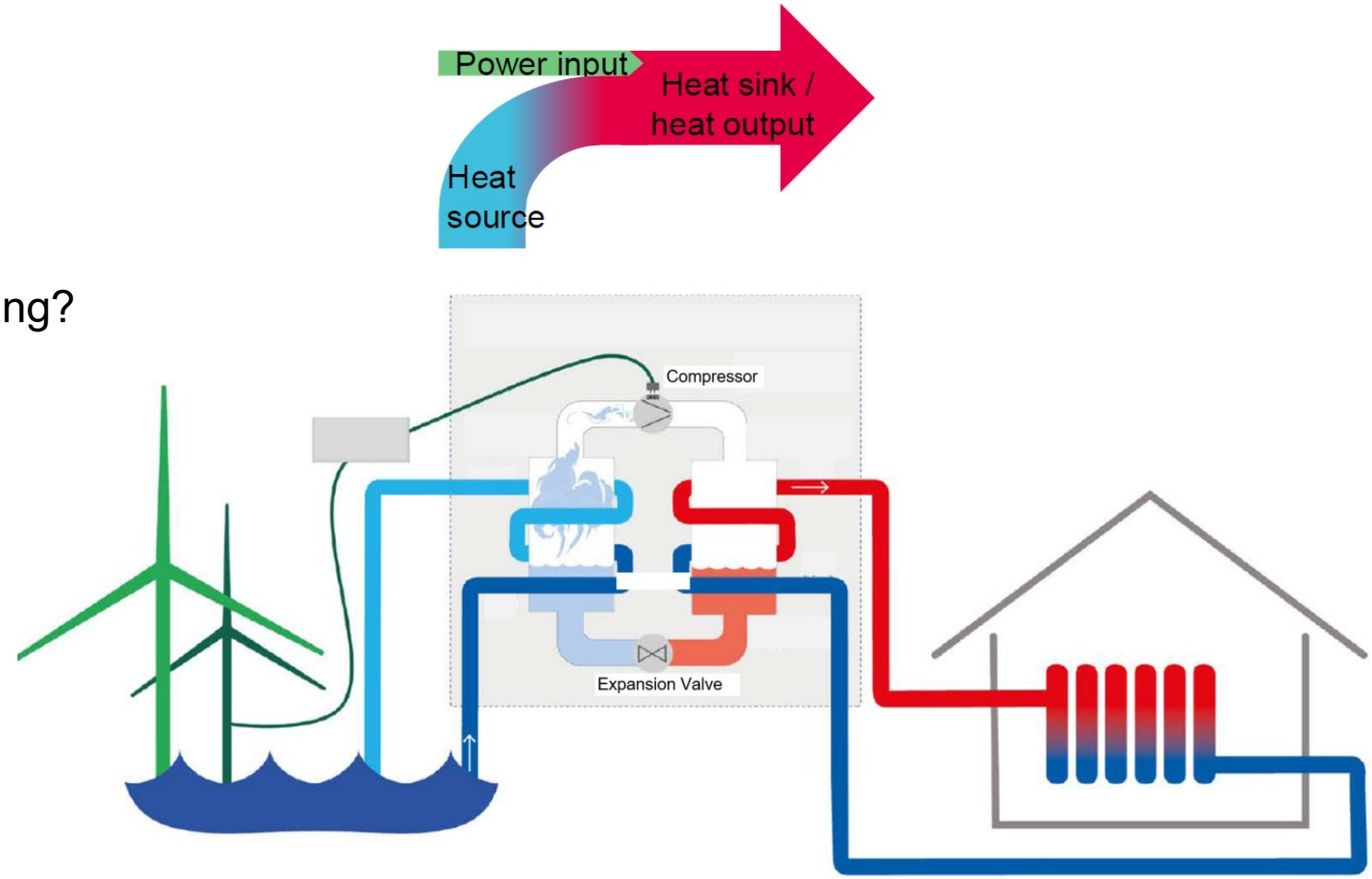
Coeffcient of Performance (COP)

Key question when measuring heat pump performance:

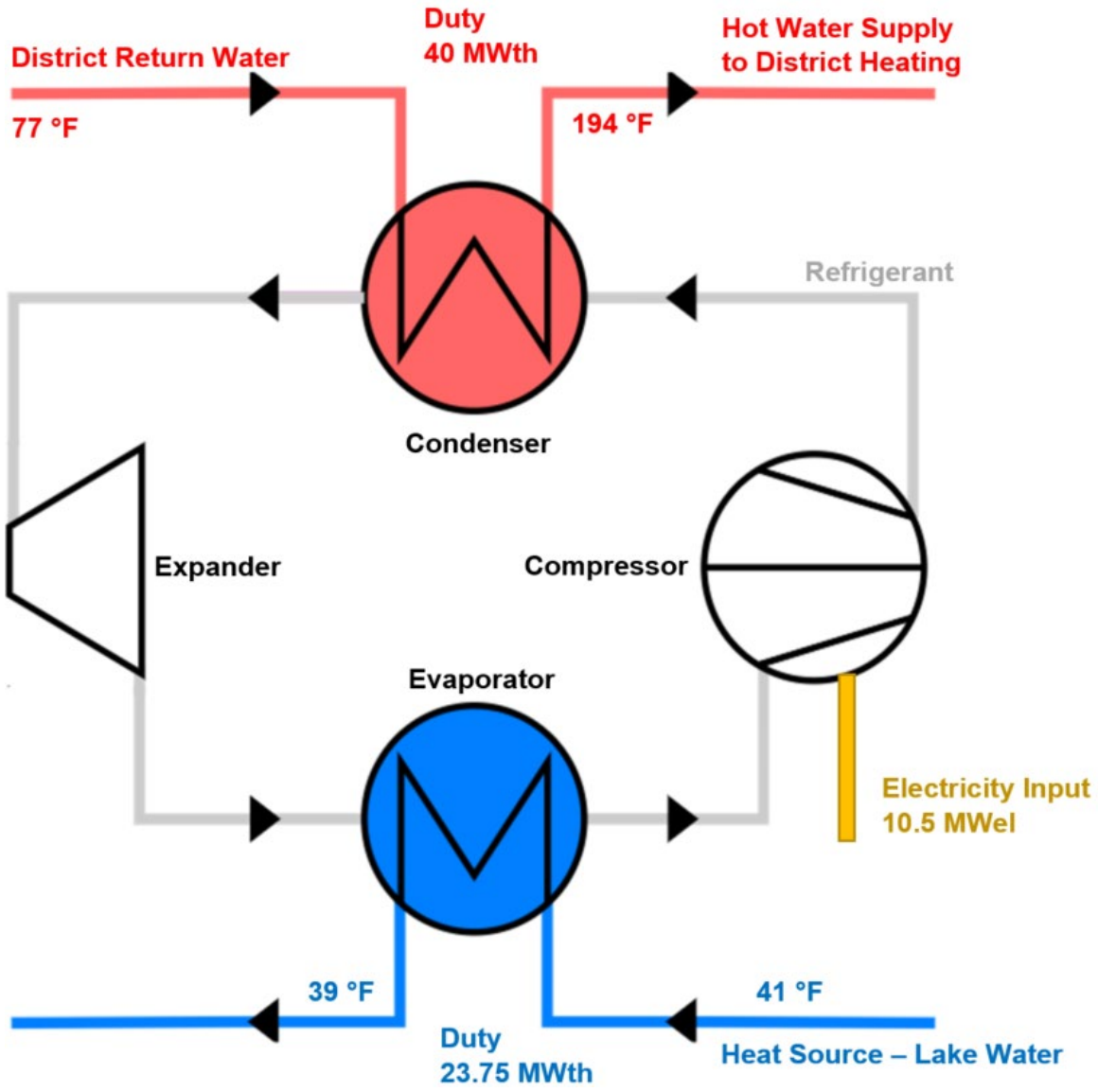
How much electricity (preferably from renewable energy sources) is needed to achieve the desired level of heating or cooling?

$$COP = \frac{heat\ output}{power\ input}$$

The COP is the ratio of the useful heating output of a heat pump to the compressor's electric power expenditure.

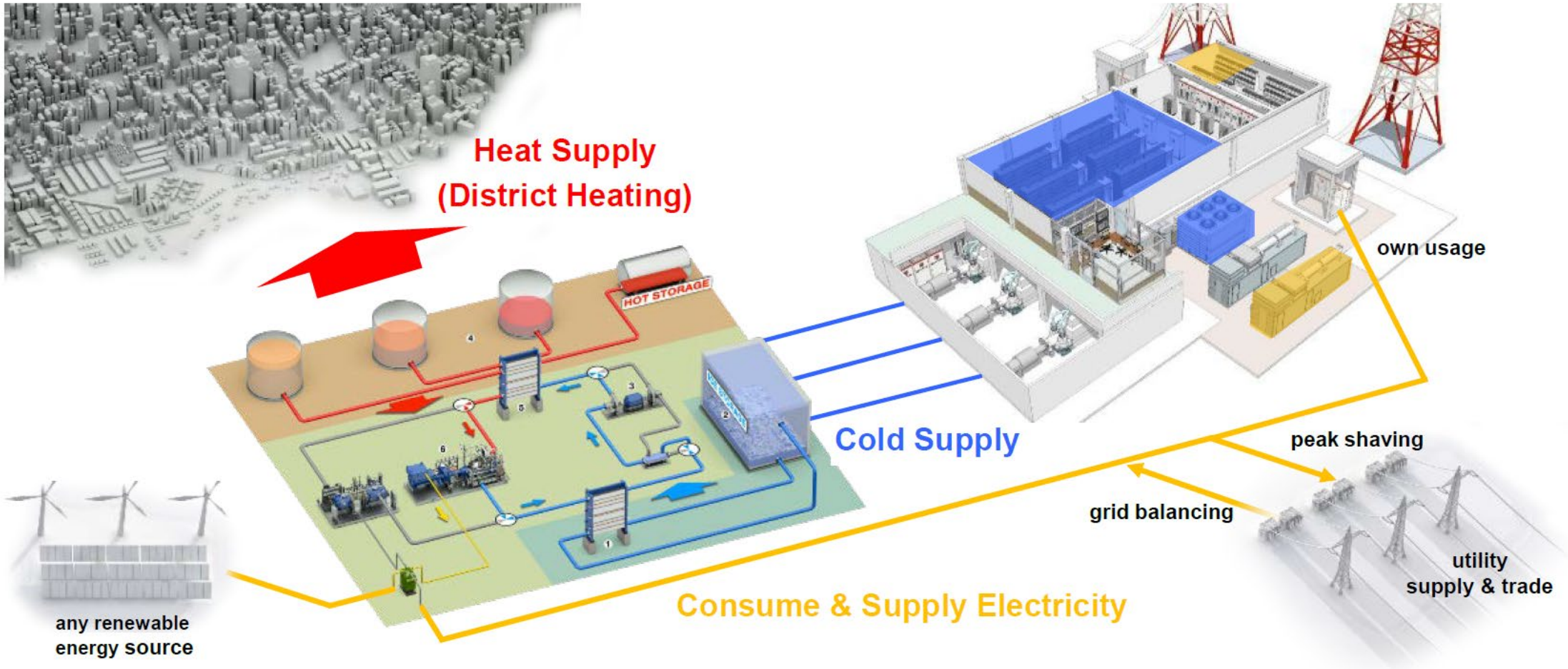


District Heating Example



$$\text{COP} = \frac{40\ \text{MWth}}{10.5\ \text{MWel}} = 3.8$$

Coupling Heat Pumps with Energy Storage



Summary

- Global energy demand for heating and cooling presently accounts for over 50% of total energy consumption and contributes to 40% of CO_2 emissions.
- Heat pumps present a compelling solution for lowering heating costs and CO_2 emissions in utilities and process industries, especially when driven by renewable electricity.
- Heat pumps use a waste heat source or an ambient heat source to generate heat or to produce steam.
- A COP (coefficient of performance) of 4 means 1 kWh of electric energy will be converted to 4 kWh of heat.
- Especially when coupled with energy storage systems, heat pumps contribute to greater flexibility and efficiency in an overall energy management system.

Thank You for your interest!

Keynote #5 at 8:10 AM tomorrow morning will include a progress update on an industrial heat pump installation in Norway.

Why Heat Pumps

Global Energy Demand

Global Energy Consumption: Total 165,319 TWh (2021)

- **Heat & Cooling** is **50% of global energy** consumption
- **Heat** contributes **40% of global carbon dioxide** (CO2) emissions.

Global Heat Consumption: 82,659 TWh (2021)

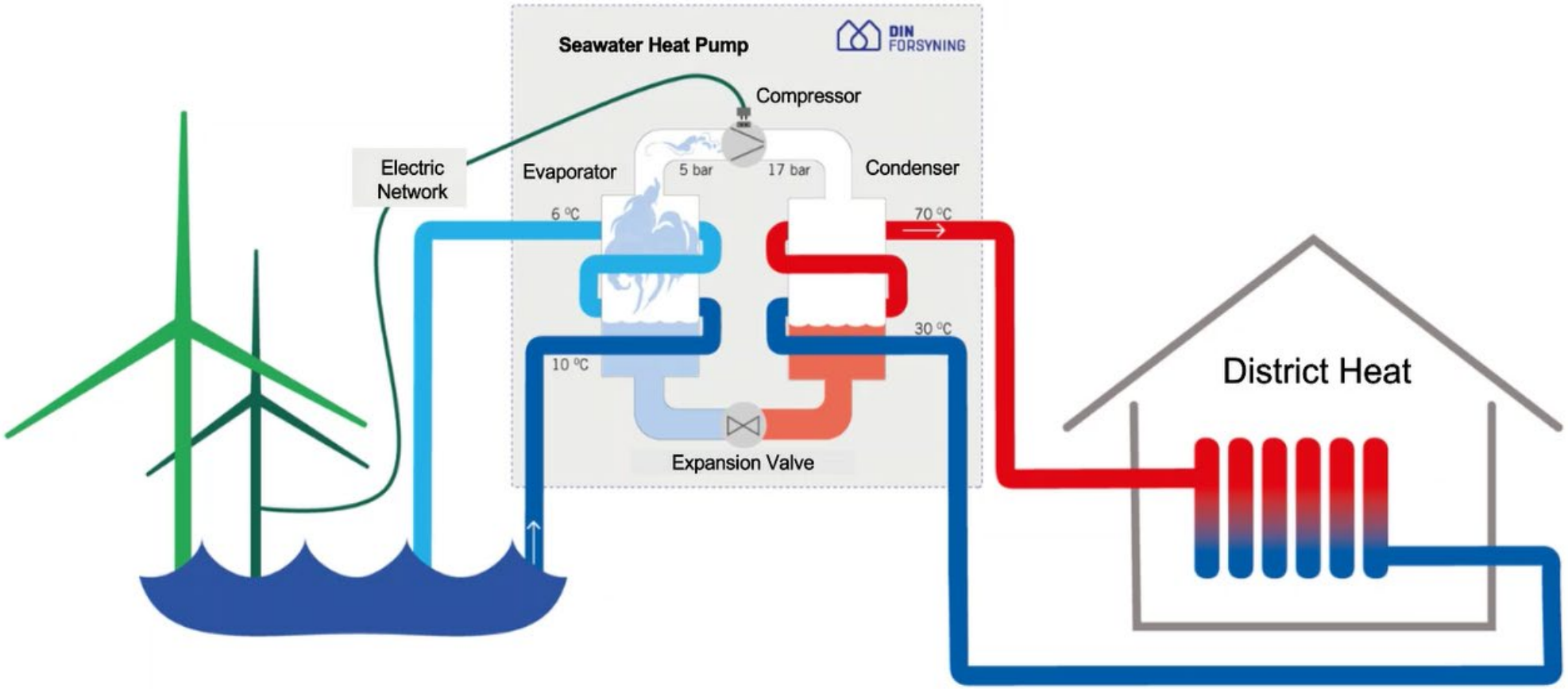
- **50%** of total heat produced was used for **industrial processes**
- **46%** was consumed in **buildings for space and water heating** and, to a lesser extent, for cooking
- **Fossil fuels continue to dominate heat supplies**
  - Modern renewables (i.e. excluding the traditional use of biomass) met only 10% of global heat demand.

Decarbonisation of thermal energy segment is critical to reduce global CO2 emissions

Source: IEA – World Energy Outlook (2022) and Statista (2022)

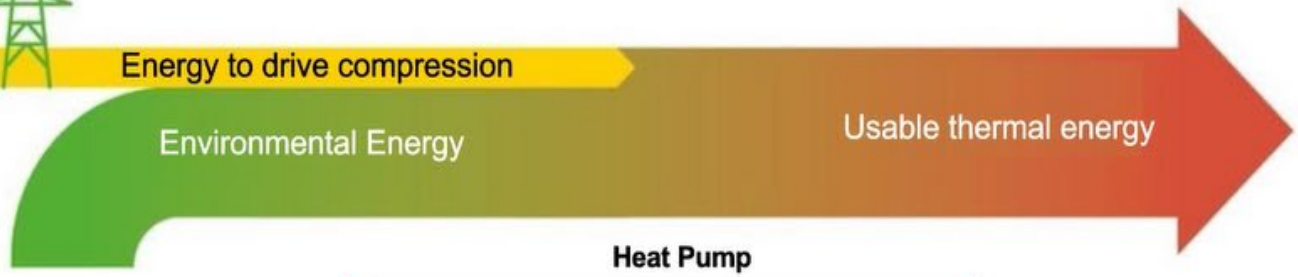
What is a Heat Pump?

Functional Principal

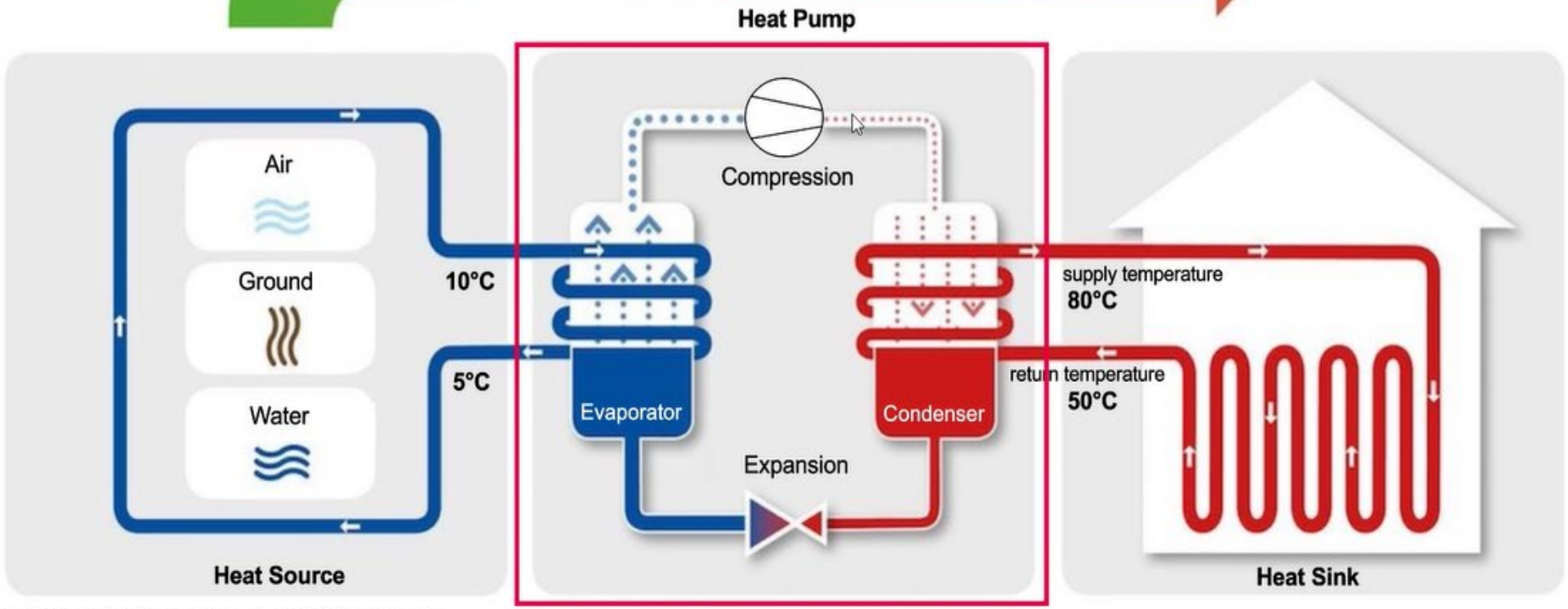


Functional principle of a heat pump

Transfer energy from low to high temperature level by using power from the grid



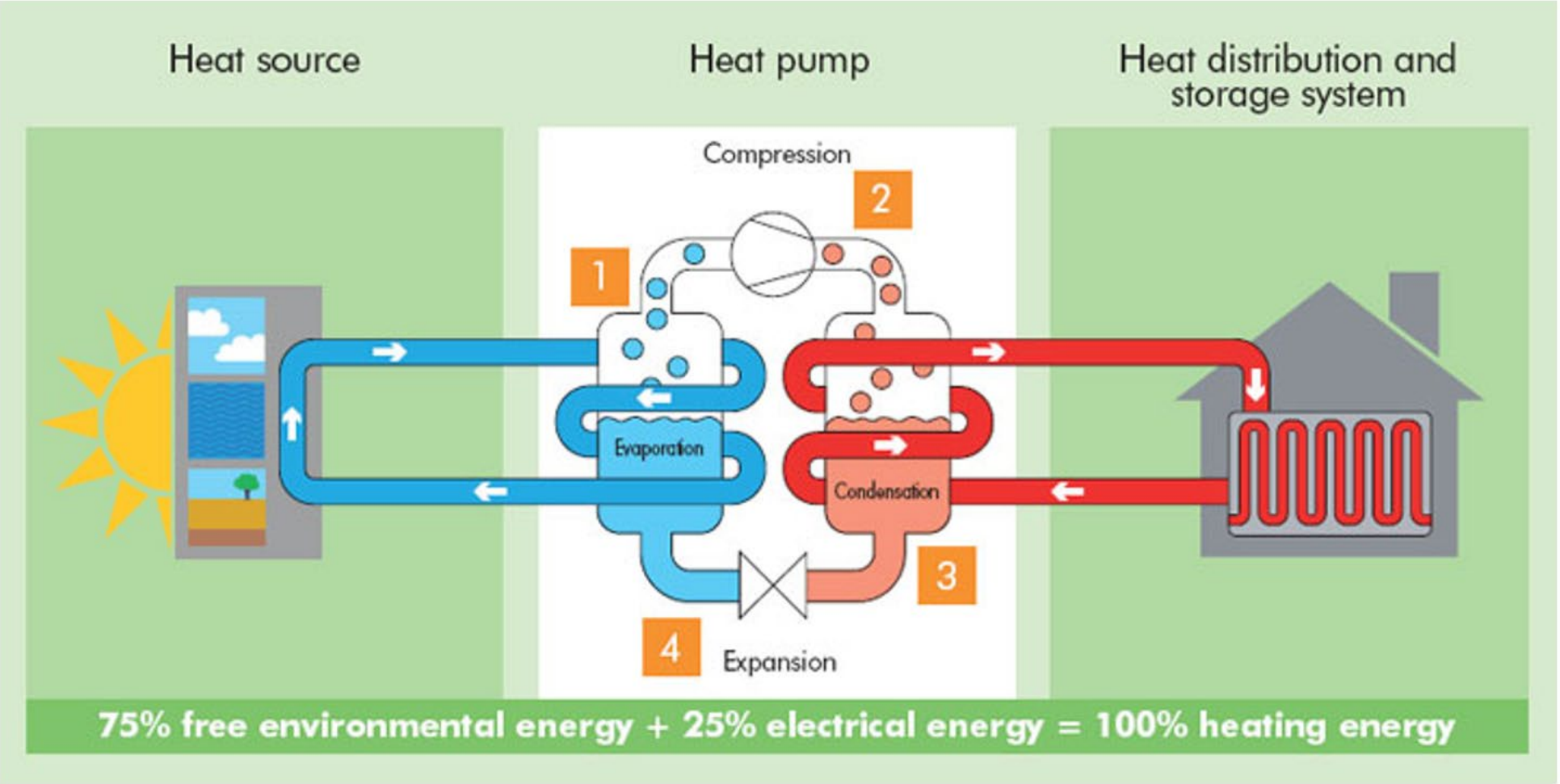
$$COP = \frac{heat\ output}{power\ input}$$



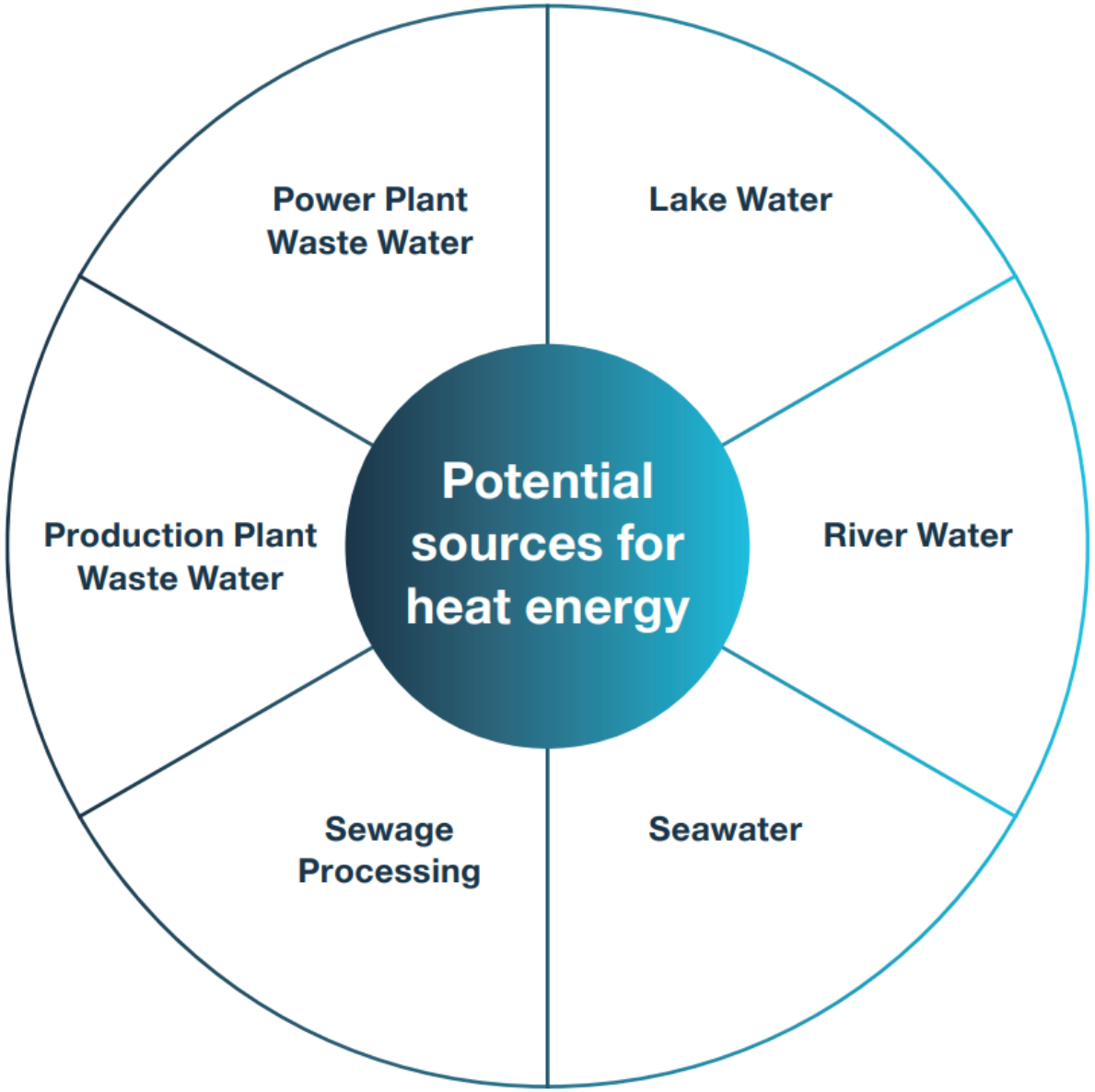
Source: Https://www.waermepumpe.de/waermepumpe/funktion-waermequellen/

Heat Pumps 101

Concept of Heat Energy



Heat Sources



Refrigerants

Different types of heat transfer fluids can be used under considerations of:

- Environmental aspects
- Global Warming Potential (GDP)
- Zero Ozone Depletion Potential (ODP)
- Safety Concepts

Refrigerant	Synthetic or Natural?	Commonly Used	ODP	GWP	Flammability	Toxicity
CFC	Synthetic	Commonly recognized as Freon (R11, R12, R113, R114, R115, R502)	.05 to 1	10,000+	Low	Low
HCFC	Synthetic	R22, R123, R401a	.02 to .1	1,000 to 5,000	Low, but higher than CFCs	Low
HFC	Synthetic	R134a, R404a, R407C, R410a	0	<1 to 12,500	None	Low
HFO	Synthetic	R1234yf, R1234ze(E), R1234ze(Z)	0	<1	Low	Low
Ammonia (NH_3)	Natural	R717	0	0	Low	High
Carbon Dioxide (CO_2)	Natural	R744	0	1	None	Low
HC	Natural	R290, R600a, R170, R1150, R600, R601	0	<1	High	Low