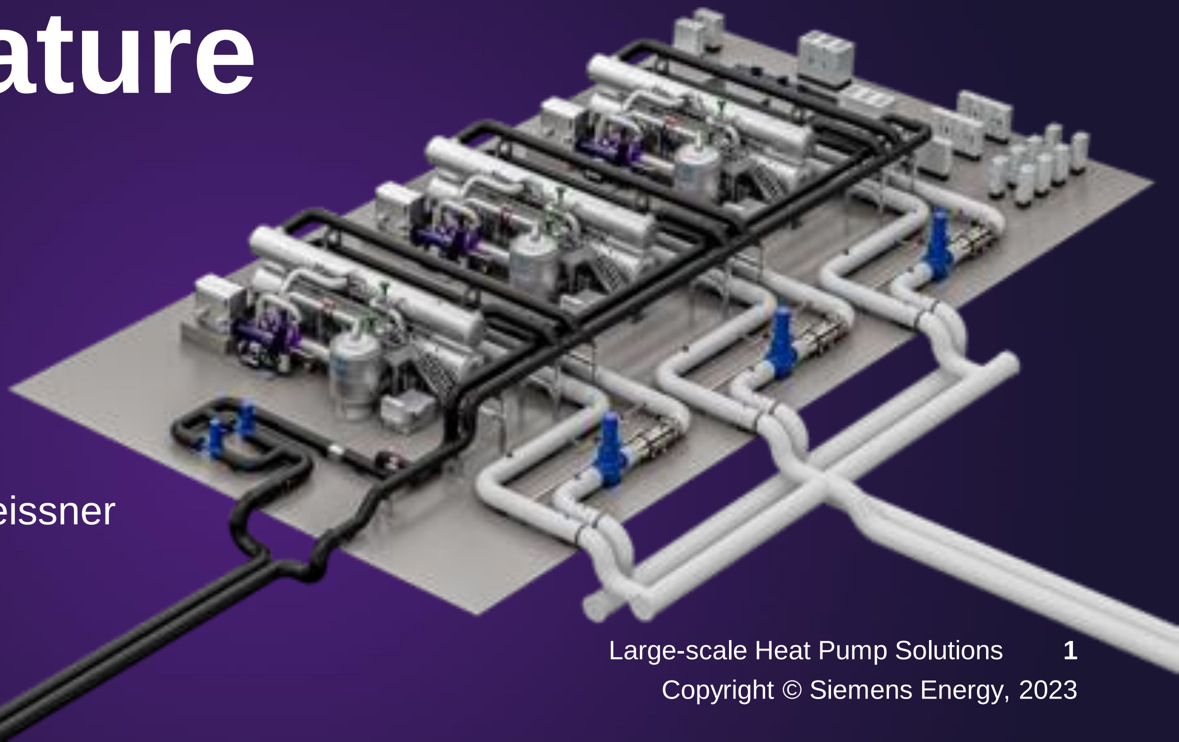
Making the most of waste heat with high-temperature industrial heat pumps



Presenter: Wim Van Den Mosselaer
Authors: Dr. Christian Hüttl, Norbert Wenn, Jürgen Voss, Dr. Florian Reissner

Siemens Energy, 2023

Agenda

1. Decarbonization of heat
2. Compression heat pumps – technology and products
3. Use cases
4. Contact us

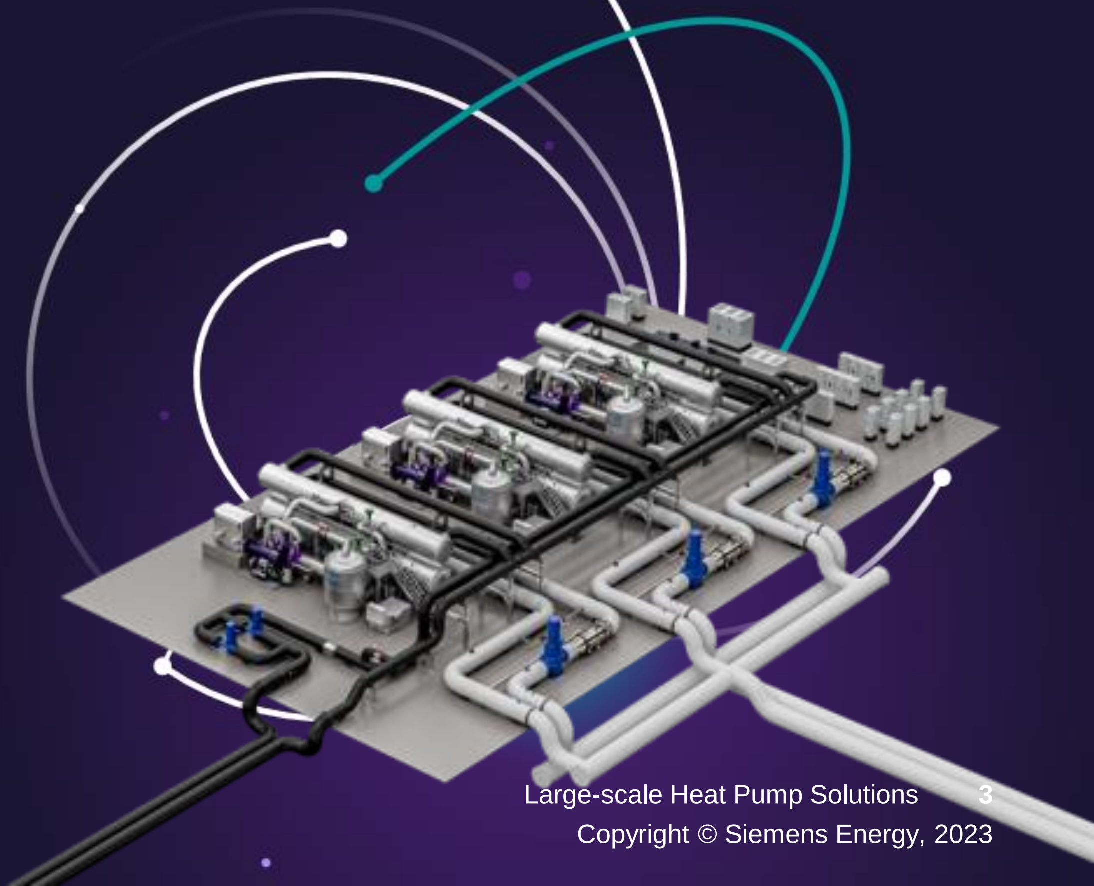
1 Decarbonization of Heat

2 Compression heat pumps – technology and products

3 Use cases

4 Contact us

Decarbonization of heat



Decarbonization of heating sector is essential to meeting global emissions targets **and requires usage of Renewable Electricity**

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~50%

of global final energy consumption is heat[1]

76%

from non-renewable sources[1]

40+%

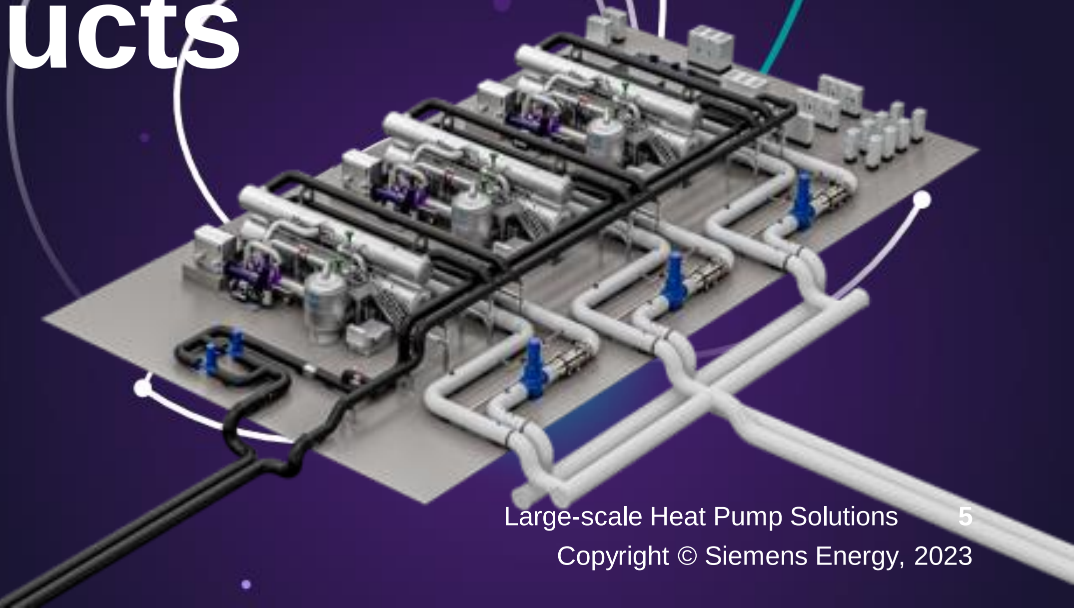
of global energy related carbon emissions[1]

e.g. IEA analysis[1]

Use of Renewable Electricity in Heating Sector is key!

[1]IEA (2021), Renewables 2021, IEA, Paris https://www.iea.org/reports/renewables-2021

Compression heat pumps – SE technology and products



Basic principle of compression heat pumps
Performance and perspective for decarbonized heat production

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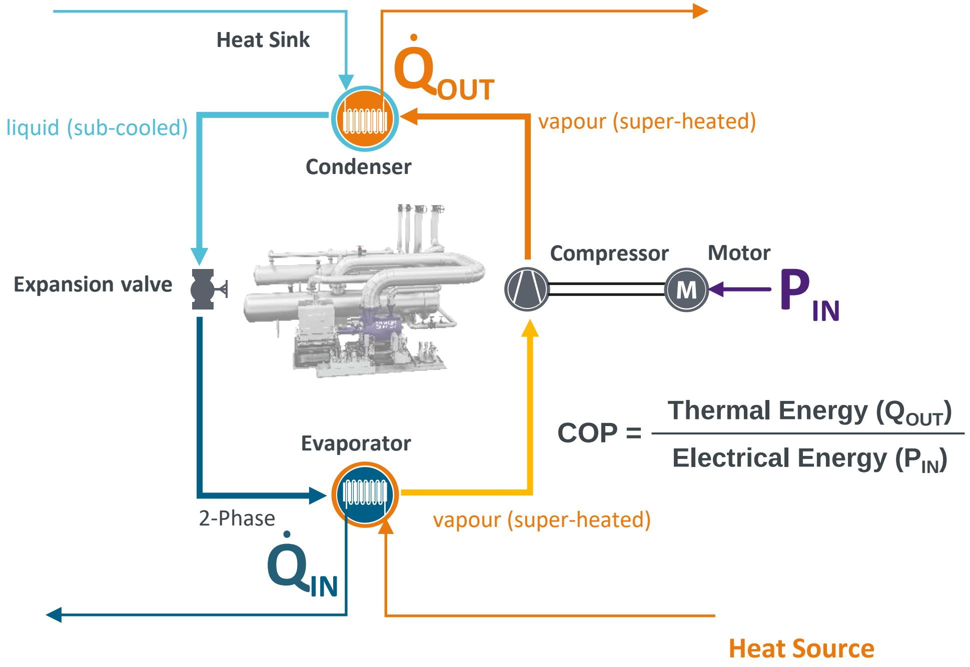
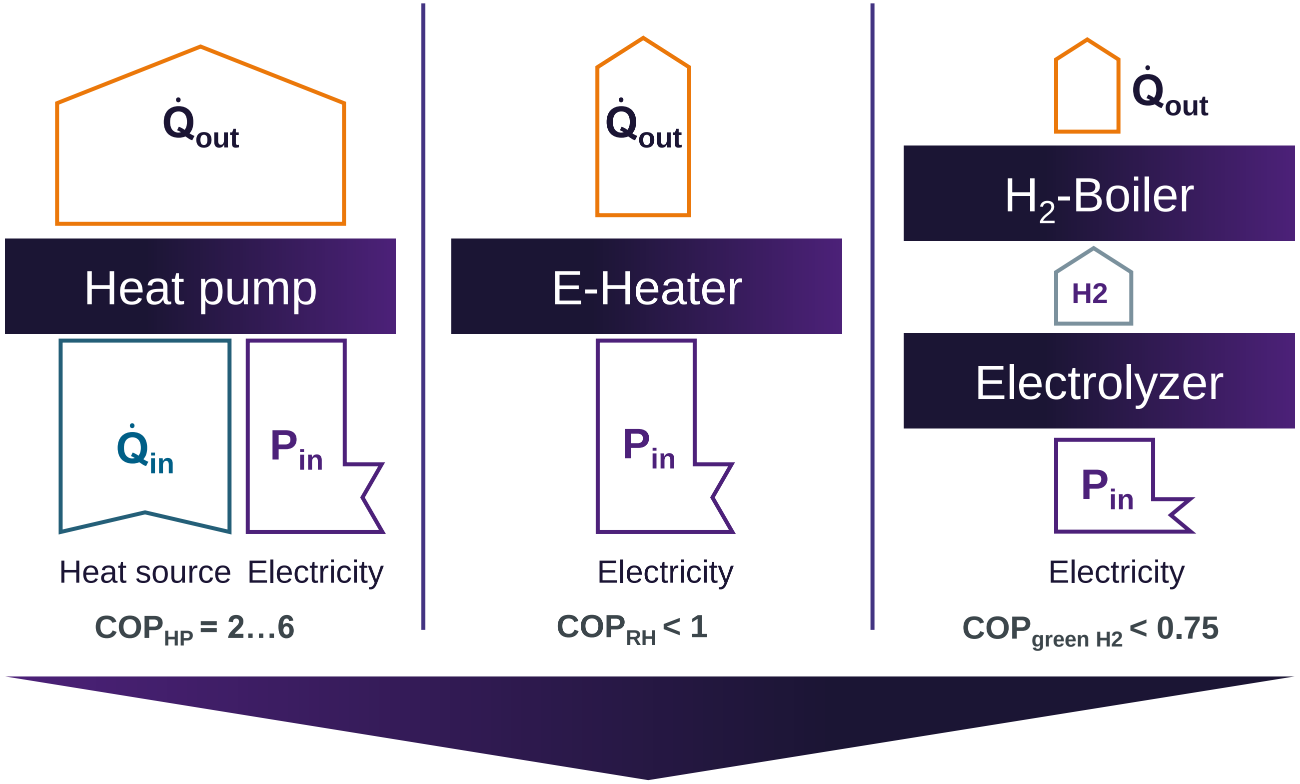
HEAT PUMP PROCESS SCHEME



DECARBONIZED HEAT PRODUCTION



WORKING PRINCIPLE

Heat flows naturally from a higher to a lower temperature. Heat pumps, however, are able to force the heat flow in the other direction, using a relatively small amount of high quality drive energy, e.g. electricity. Thus heat pumps can transfer heat from a low temperature to a high temperature level[1].

Heat pumps offer the most efficient way to Decarbonize heat !

Industrial scale heat pumps from Siemens Energy
Address both district heating and industry applications

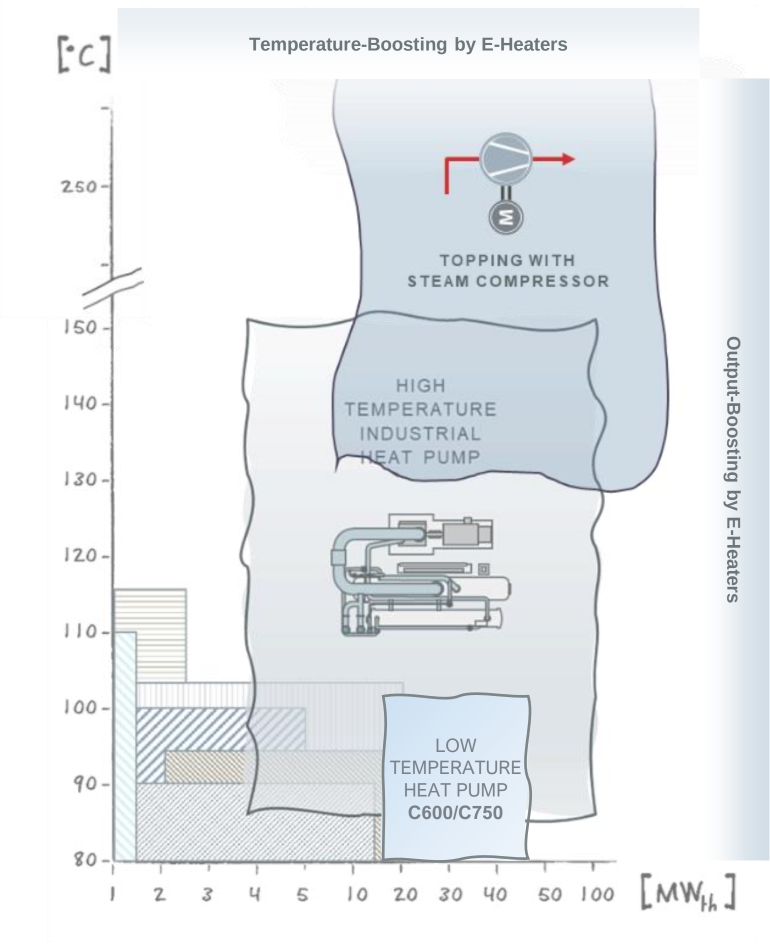
SIEMENS energy

Two complementary product lines …

…with enhanced features…

SHP-STC-XX W/S

SHP-C600/C750



… to serve the needs of our customers

Heat supply
~12 – 70 MW$_{th}$ per unit

Temperatures
up to **150°C** directly from heat pump

Environment friendly work medium
low **GWP**[1] and **ODP**[2]

Various drive concepts
Electrical or **mechanical**

Combination with steam compression
→ **higher temperatures** and **pressures > 3.7 bara** (process steam production **up to 55 bara**, **270°C**)

Scope of supply
Component up to **turnkey supply**

[1] GWP = Global Warming Potential
[2] ODP = Ozone Depletion Potential

Industrial scale heat pumps from Siemens Energy
Address both district heating and industry applications

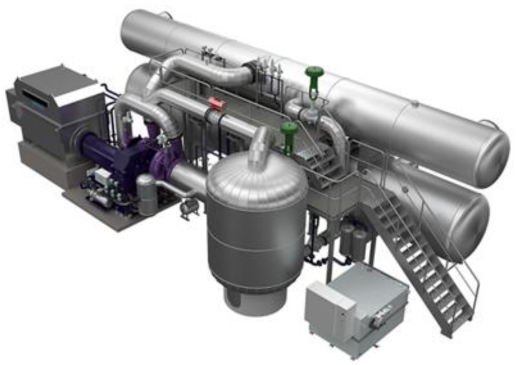
SIEMENS energy

Two complementary product lines …

SHP-STC-XX W/S
High **T**emperature **H**eat **P**ump
12 – 70 MW_{th}, Up to 150 °C (hot water OR steam up to 3.7 bara)

1st reference: Potsdamer Platz
- 8 MW thermal output
- Customer: Vattenfall Wärme Berlin

SHP-C600 / C750
Based on PROVEN design (since 1980s)
15 – 45 MW_{th}, up to > 100 °C (hot water)



Latest reference: Reallabor GKM
- 20 MW thermal output
- Customer: GKM Mannheim

… to serve the needs of our customers

Heat supply
~**12 – 70 MW_{th}** per unit

Temperatures
up to **150°C** directly from heat pump

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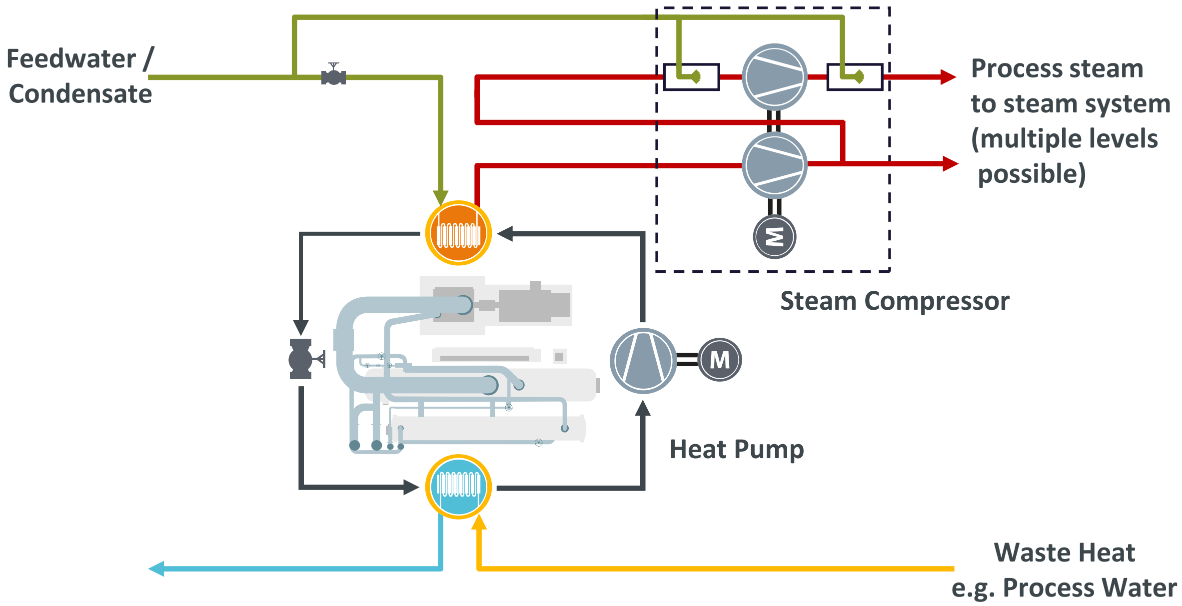
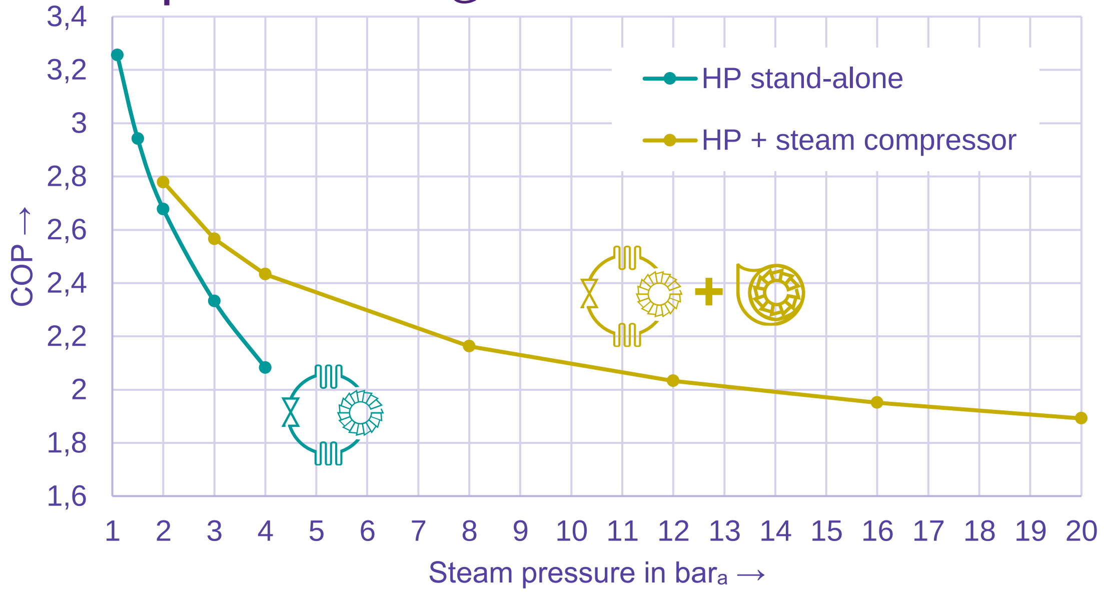
Industrial Heat Pumps @ Industry
Use Cases @ refinery and chemical industry

HEAT PUMP + STEAM COMPRESSION FOR STEAM GENERATION

Example: Steam from Waste Heat



Impact of additional steam compression, Example: Waste Heat @ 45 °C → 35 °C



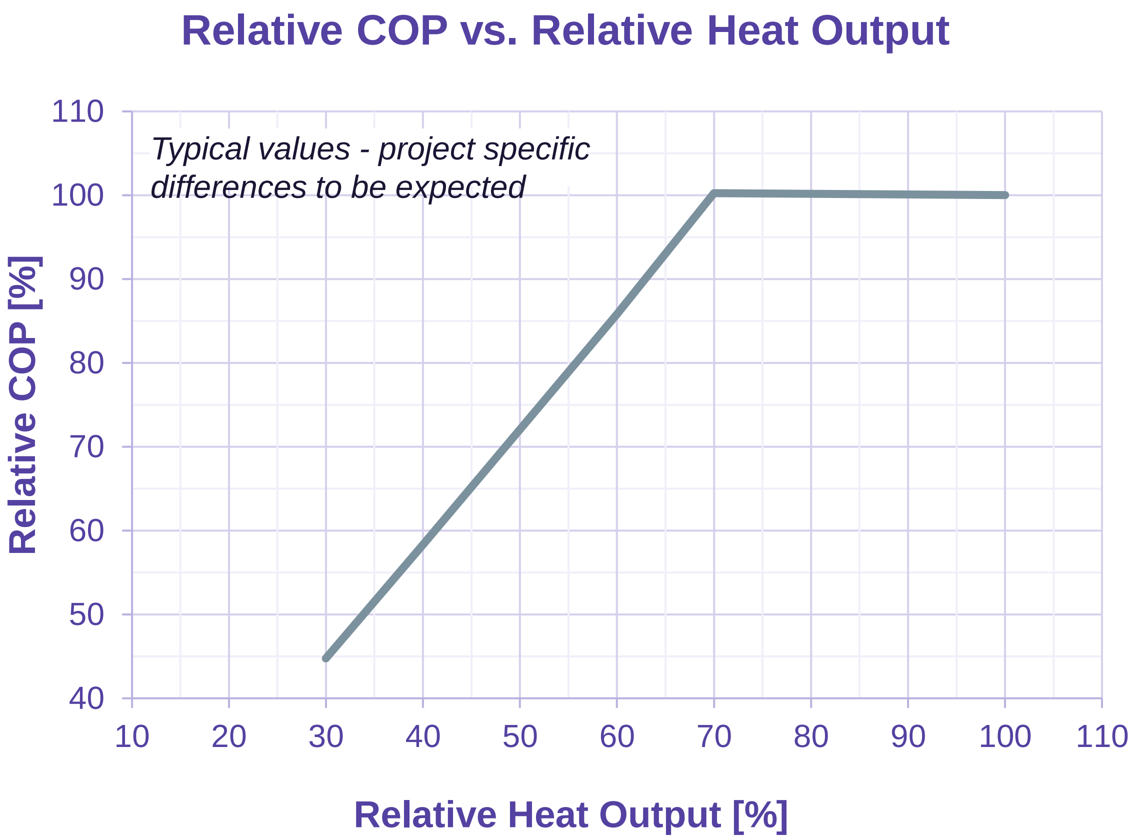
WORKING PRINCIPLE

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

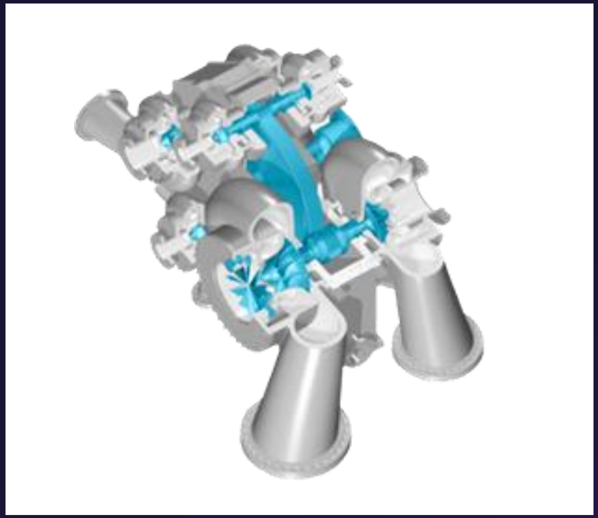
MAIN LEVERS ON COP

- **Required steam pressure: the higher the steam pressure the lower the COP → Every 0.5 bar counts**
- Temperature level of waste heat: the lower the temperature level of the waste heat the lower the COP

High temperature heat pumps – technical features
Part load behavior



HTHP Main Component
Turbocompressor



Applications

Air separation
CCS
CAES
Refineries
Ammonia
Synthetic fibers
Petrochemicals
Metallurgy

Technical Data

Max. volume flow:	1,000,000 m³/h 590,000 cfm
Max. discharge pressure:	200 barg / 2,900 psig
Max. power requirement:	60 MW / 80,000 hp
Drive options:	E-drive, steam turbine or gas turbine
Reference situation:	More than 2,500 units

Benefits

- Increased production and reduced energy costs - highest efficiency and widest operating range in the industry
- Maximum reliability due to flexible design concepts combining custom-tailored design with standardized components
- Exceptional technical expertise with proven technology and extensive experience since 1948
- Ensuring fast support and the highest quality of service by being the sole supplier for a complete solution including proprietary gear technology

Product Description

- Solutions with high efficiencies and pressures up to 200 bar (1,900 psi)
- Designed according to customer specifications and to API 617 and API 672
- Highest quality and technical standards for a broad range of industrial applications
- Powerful and robust design, with integrated expander option

HTHP Main Component
STC-GV

1 Decarbonization of heat

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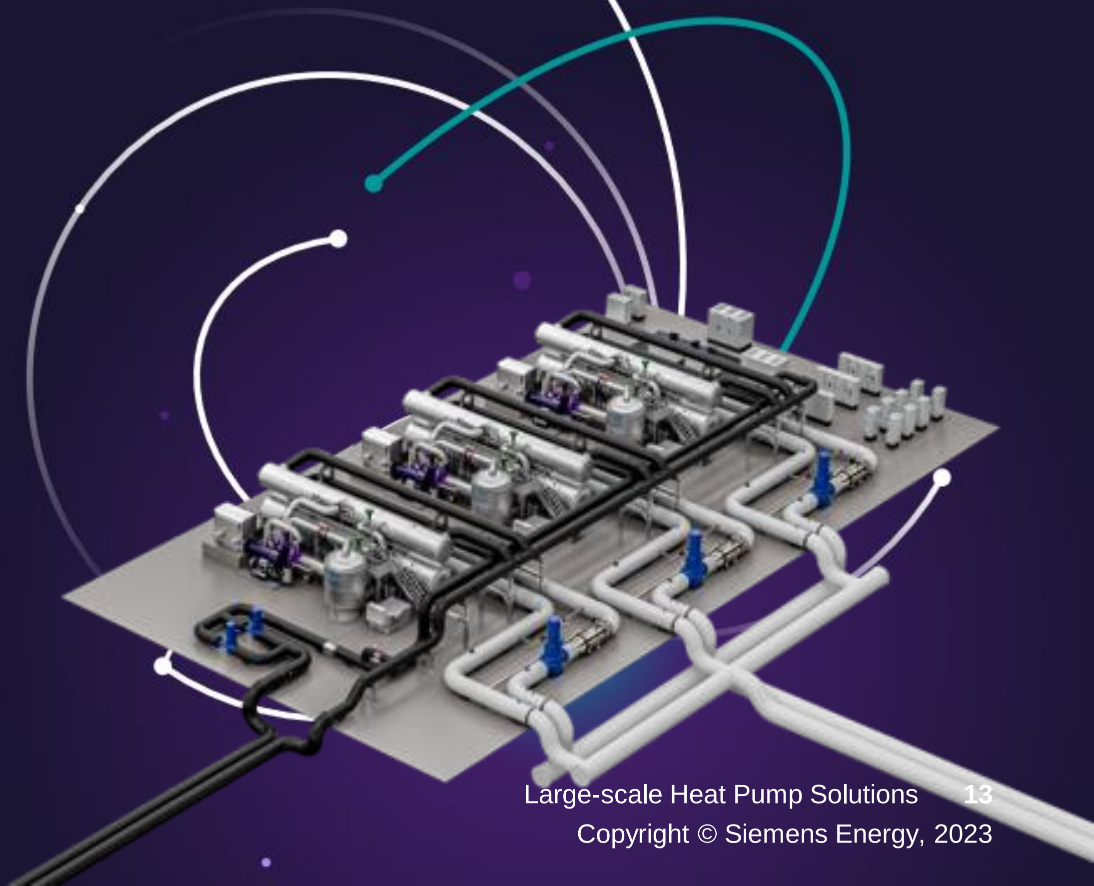
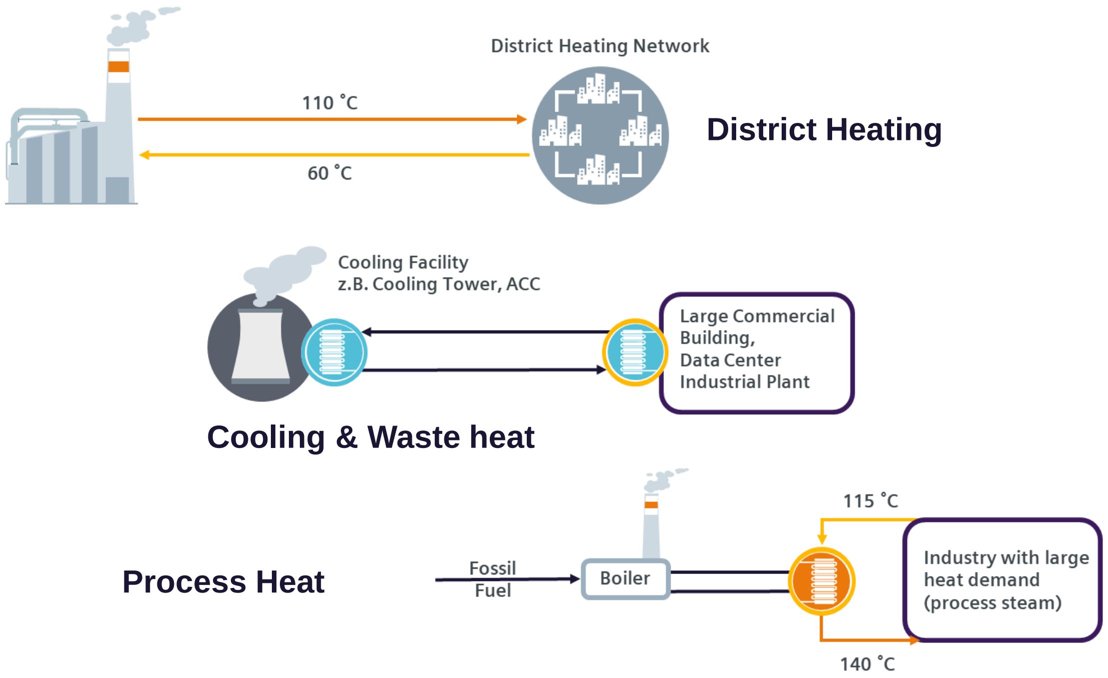
Use Cases

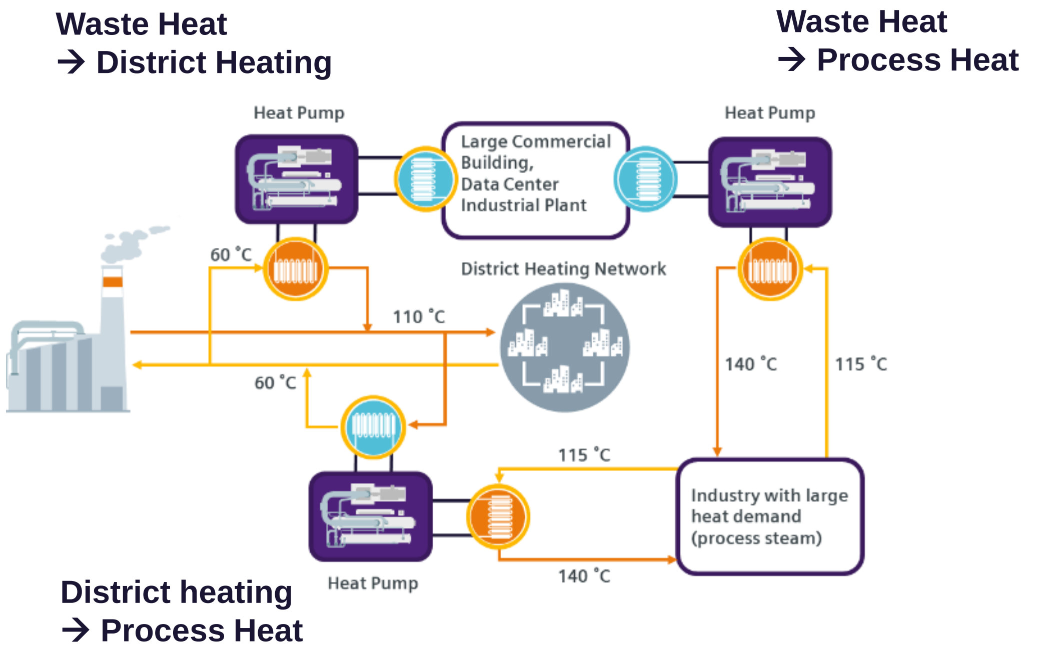


Industrial heat pumps @ district heating & industry
Principle Use Cases

Situation Today – Separated Systems



With Heat pump – Integrated Heat approach

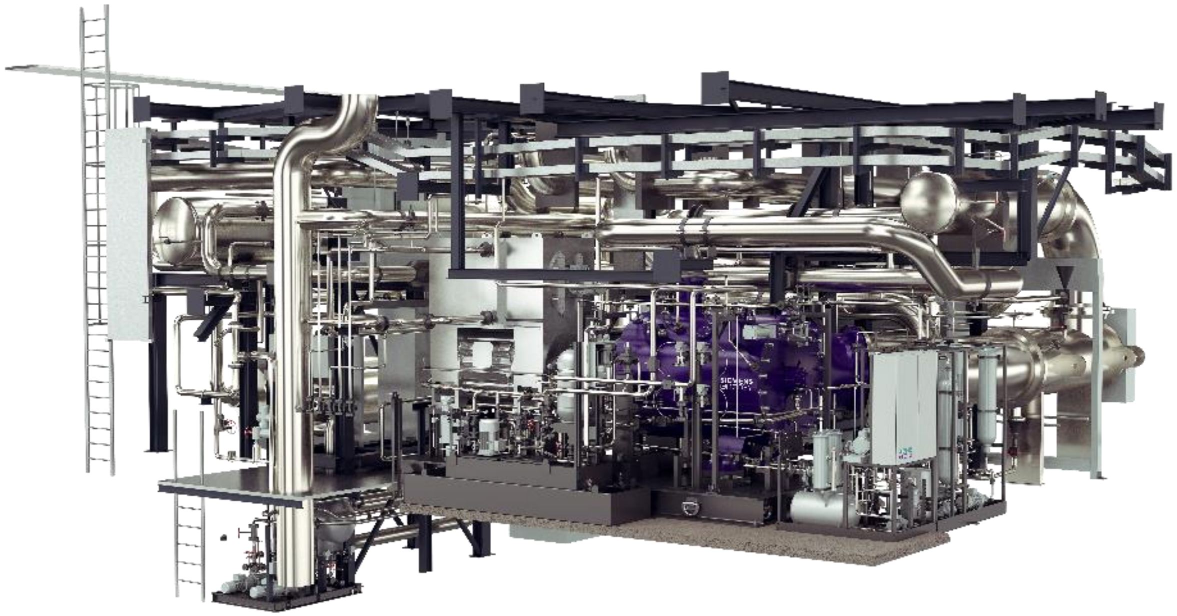


Benefits

- Waste heat from large commercial buildings, data centers and industry can be utilized for district heating or process heat
- Utilize district heating systems as heat source for process heat
- Combined-Heat-and-Power-and-Cooling → re-use of waste heat → reduced heat rejection to ambience
- no additional cooling facilities needed anymore → e.g. reduction of aux. consumption, make-up water
- "cooling" as additional product for heat pumps

Industrial High Temperatur Heat Pumps

New Project | QWARK3 | Berlin Potsdamer Platz



Joint Press Release

Berlin, March 25, 2021

Press release by Vattenfall Wärme Berlin AG and Siemens Energy

Vattenfall and Siemens Energy help advance a climate-friendly heating supply for Berlin with large-scale heat pump

- Joint trial of a large-scale, high-temperature heat pump in district heating network
- Waste heat and renewable electricity utilized to achieve heating transition in Berlin
- Federal government-funded project links heat, cooling, and electricity

Heat Output
8 MW_{th}
DH supply temperature (fexible)
85 °C bis 120°C

DH heat production
~ 55 GWh/a

CO_2 savings
~ 6500 t/a
Savings on cooling water
~ 120 000 m^3/a

Siemens Energy - Industrial Heat Pumps
QWARK3 | Berlin Potsdamer Platz

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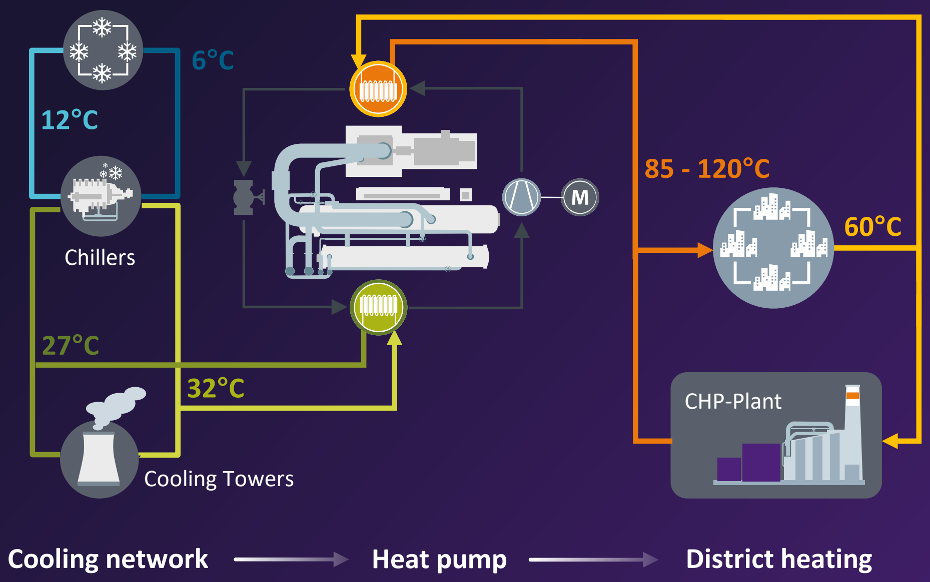
QWARK3 – Quartiers-Wärme-Kraft-Kälte-Kopplung



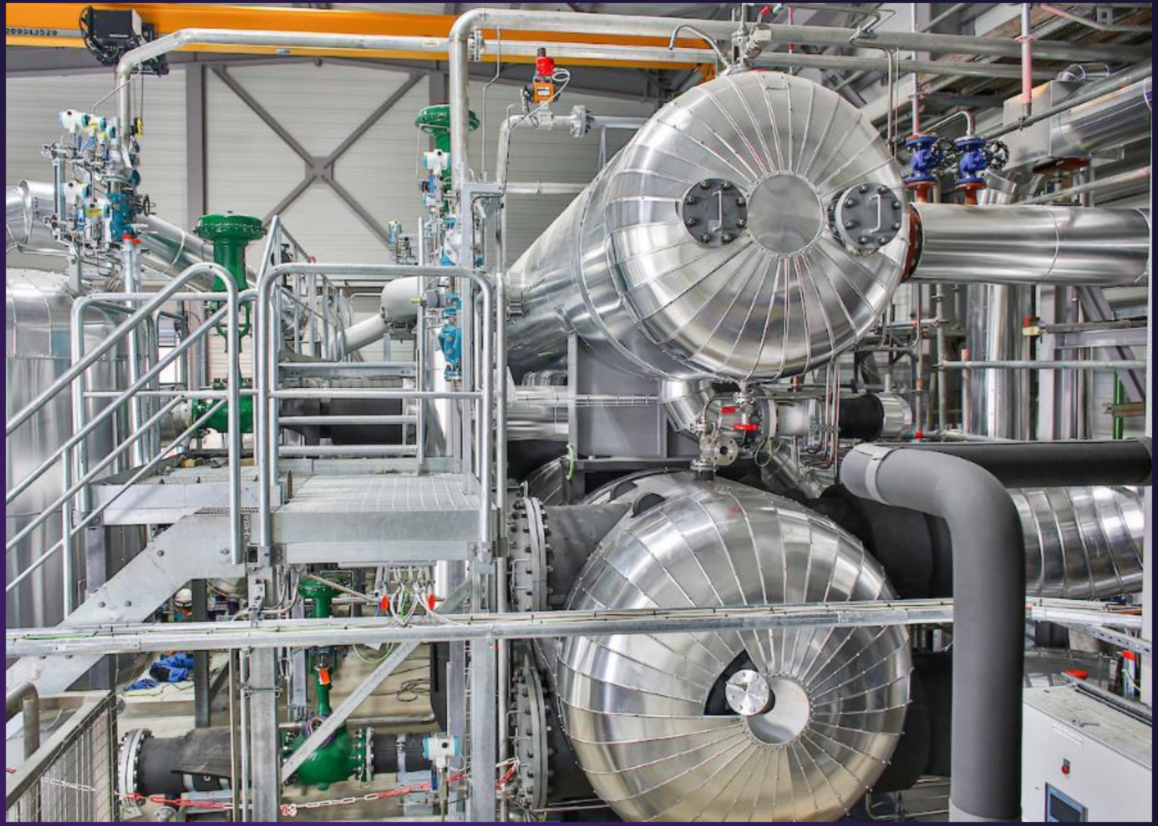
BACKGROUND

- Heat pump lifts heat from the temperature level of cooling water of chillers to the temperature level of district heating system of Berlin
- Publicly funded project (BMWK and PtJ) in cooperation with Vattenfall Wärme Berlin
- Execution ongoing

KEY FIGURES

CAPACITY	8 MWth
AVERAGE COP	~ 3.0
REFRIGERANT	Hydro-(-chloro)-fluoro-olefin (H(C)FO)
ARRANGEMENT	Brownfield (integration in existing building)
HEAT SOURCE	Cooling Water Return from Chillers (32 → 27 °C)
HEAT SINK	District Heating (50 °C → 85 - 120 °C)
COMPRESSOR	single shaft centrifugal vertically split radial compressor
LUBE & SEAL OIL SYSTEM	Separated lube and Seal Oil System
HEAT EXCHANGER	Semi-welded plate type heat exchangers (Evaporator, Condenser, Subcooler)
I&C SYSTEM	T3000 compact

Grosskraftwerk Mannheim (GKM) MVV/GKM River Water Heat Pump



Siemens Energy and MVV with GKM using a large-scale heat pump to do the first step towards green district heating

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CO_2 > 10,000 tons CO_2/a savings

Customer Challenge/Driver

Decrease the use of coal at GKM power plant by installation of a heat pump using the river as energy source. The new heat pump is the first step towards the goal of green district heating. MVV and the City of Mannheim is targeting to become CO_2 neutral in the district heating production by 2030.

Portfolio Elements

Low temperature heat pump SHP-C600 from Finspång (20 MW_{th}) enabling temperature levels up to 99 °C, compressor with gear, electrical motor, heat exchangers, storage tank & control system

Scope

Delivery of a complete heat pump SHP-C600 including full installation and commissioning

Customer Benefit

- Decrease the use of coal
- Use the river Rhine as heat source
- Provide 50 GWh/a heat for the district heating network
- More than 10,000 t of CO_2 emissions savings per year versus heat from a gas boiler at 2,500 full operating hours

PROJECT TYPE

Heat & Green Municipalities

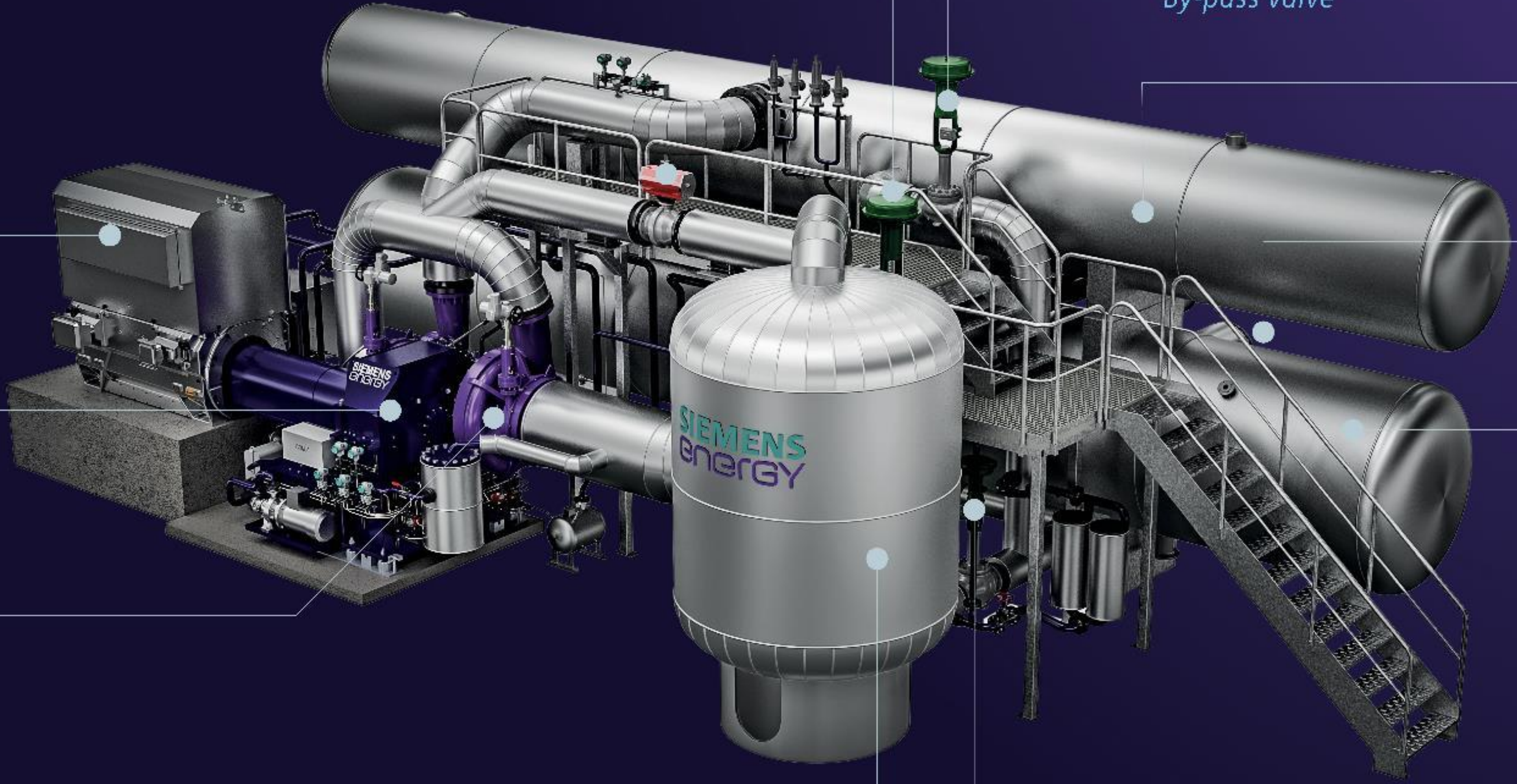
Combined heat and power | Heat pumps | Efficiency | CO_2-savings

Großwärmepumpen

Large-scale heat pumps

Eine Schlüsseltechnologie zur Dekarbonisierung der Fernwärme

A key technology for decarbonization of district heating



Funded by the European Union
NextGenerationEU

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

GKM Grosskraftwerk Mannheim Aktiengesellschaft

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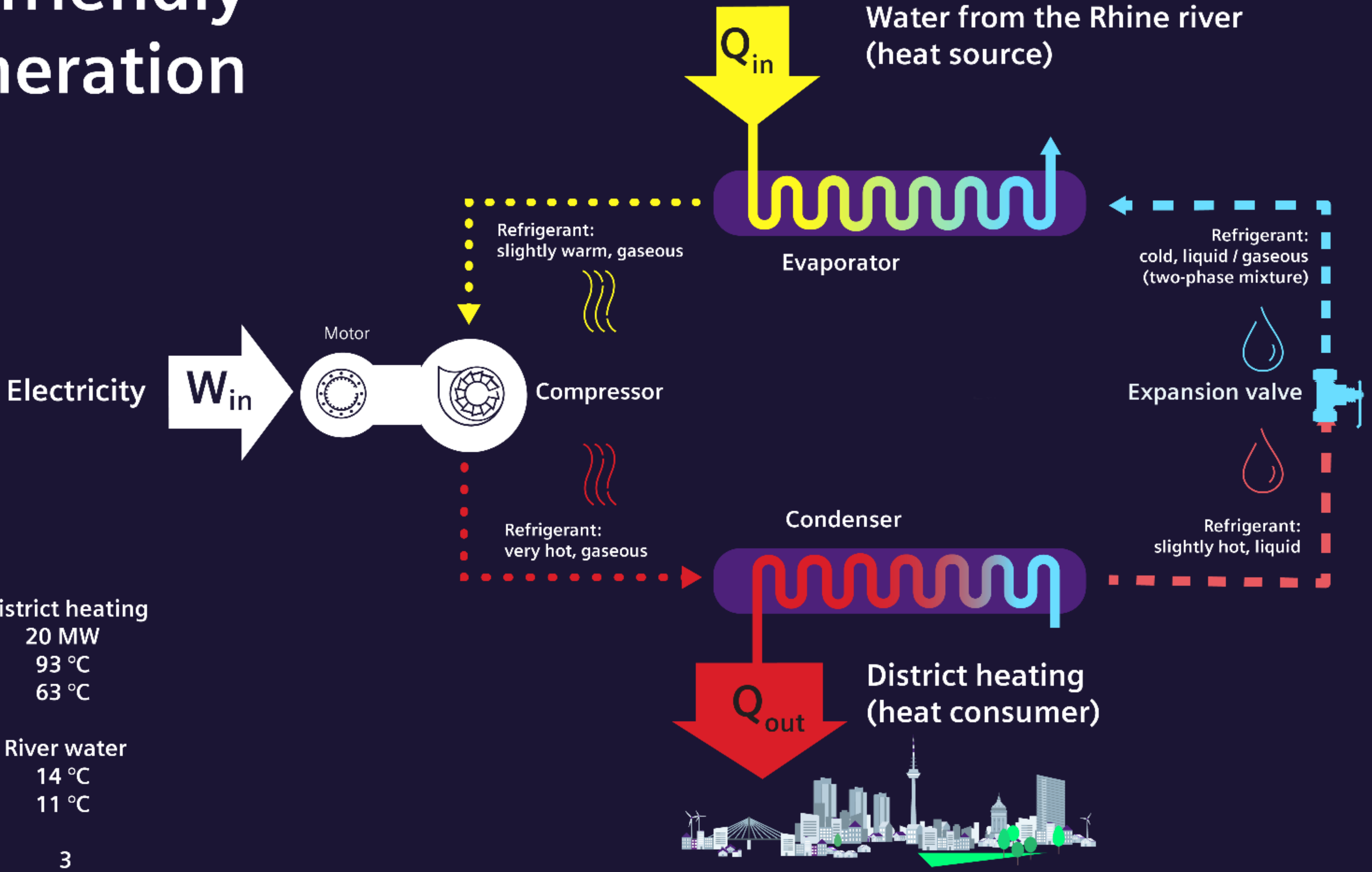
Climate-friendly heat generation

Basic principle of the river heat pump in Mannheim



Example of a fall load:

Heat sink:	District heating
Heat output:	20 MW
Flow temperature:	93 °C
Return flow temperature:	63 °C
Heat source:	River water
Inlet temperature:	14 °C
Return temperature:	11 °C
COP:	3

Siemens Energy – Industrial heat pumps
Steam Production | Chemical Plant

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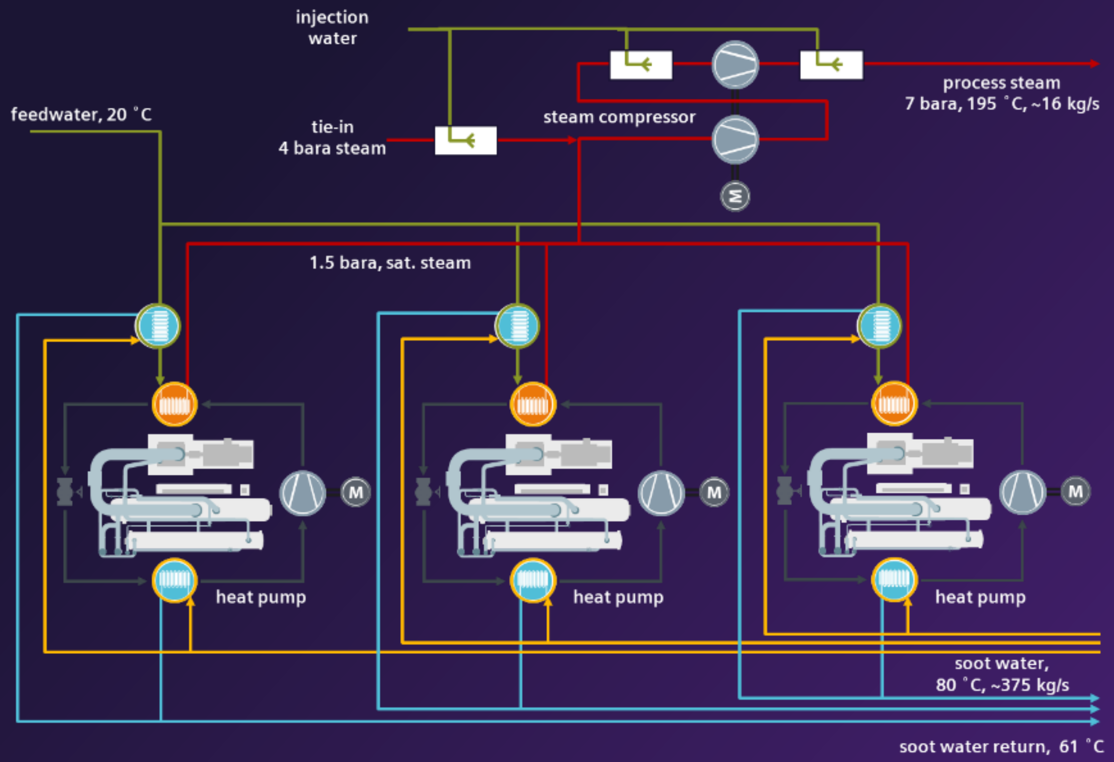


Background

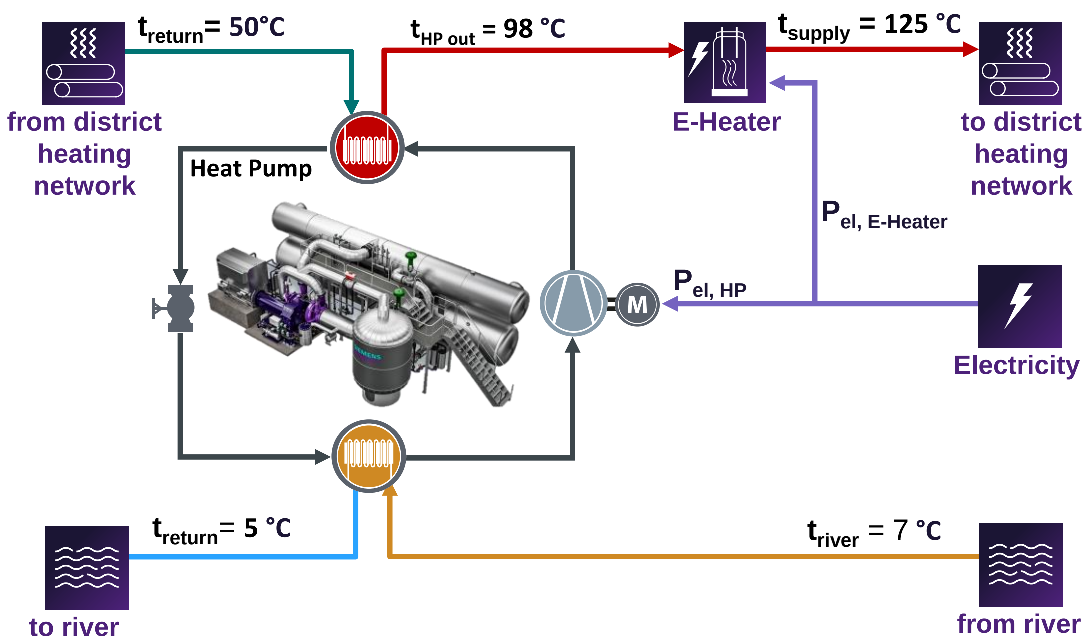
- High temperature heat pump utilizes waste heat from process water of reactors to produce saturated steam from feedwater
- Saturated steam is fed to steam compressor (multi-stage intercooled / attemperated)
- Final adjustment of steam parameters by attemperation

Key Figures

Capacity	44 MWth HP & Steam Compressor
Average COP	~ 2.8 (incl. steam compression)
Refrigerant	Hydro-(-chloro)-fluoro-olefin (H(C)FO)
Arrangement	Brownfield (integration in existing building)
Heat source	Process water return from reactors (80 → 61 °C)
Heat sink	Process Steam (20 °C → 7 bara, 195 °C)
Compressor	SIEMENS geared type radial compressor
Lube & Seal Oil System	Seperated lube and Seal Oil System
Heat Exchanger	Shell & Tube Heat Exchangers (Evaporator, Condenser, Subcooler, Pre-Heater)
I&C System	T3000 compact

District Heating Supply with Low Temperature Heat Pump
Combination of Heat Pump + Electric Heater

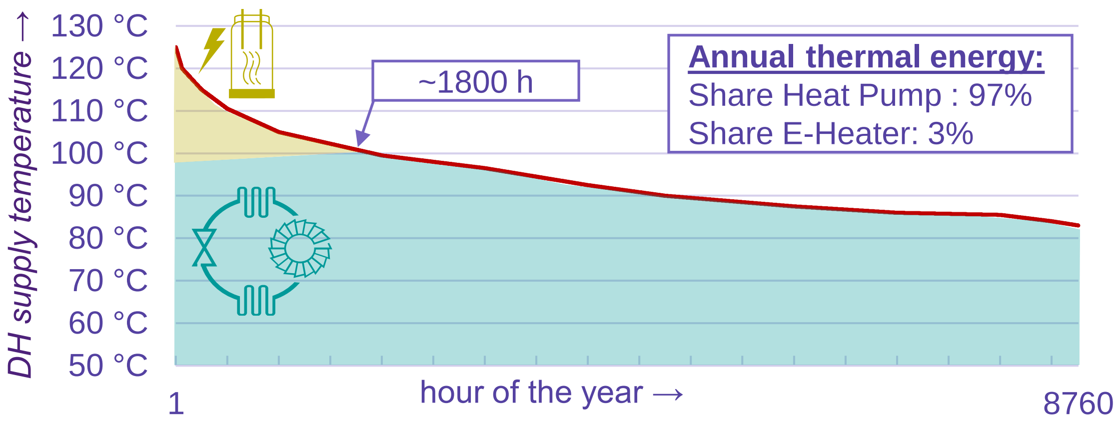
TEMPERATURE TOPPING WITH E-HEATER



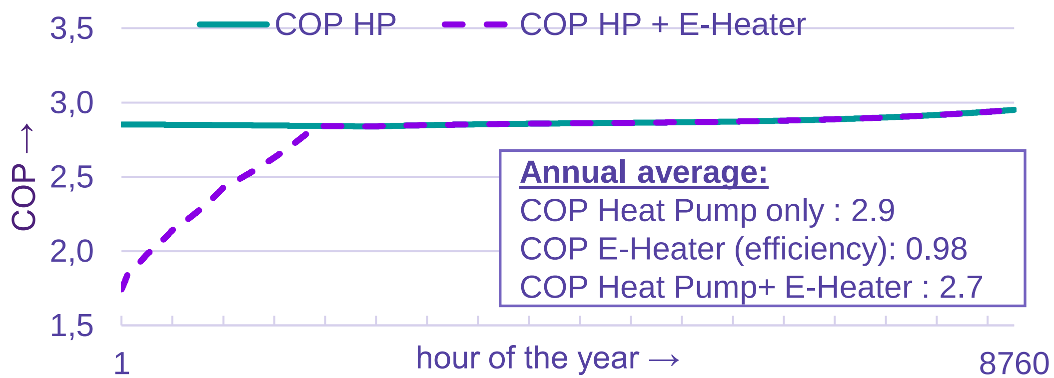
BENEFITS

- **Higher DH supply temperatures can be obtained with E-Heater**
- **Optimum cost-benefit ratio due to appropriate sizing of CAPEX intensive but high efficient equipment**
- **Optimum operation scheme of heat pump, high full load hours**

EXEMPLARY CASE WITH GLIDING DH SUPPLY TEMPERATURE



EFFECT ON OVERALL EFFICIENCY



Concept | Waste Heat Utilization from Electrolysers for Steam Production

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OVERVIEW

Principle:

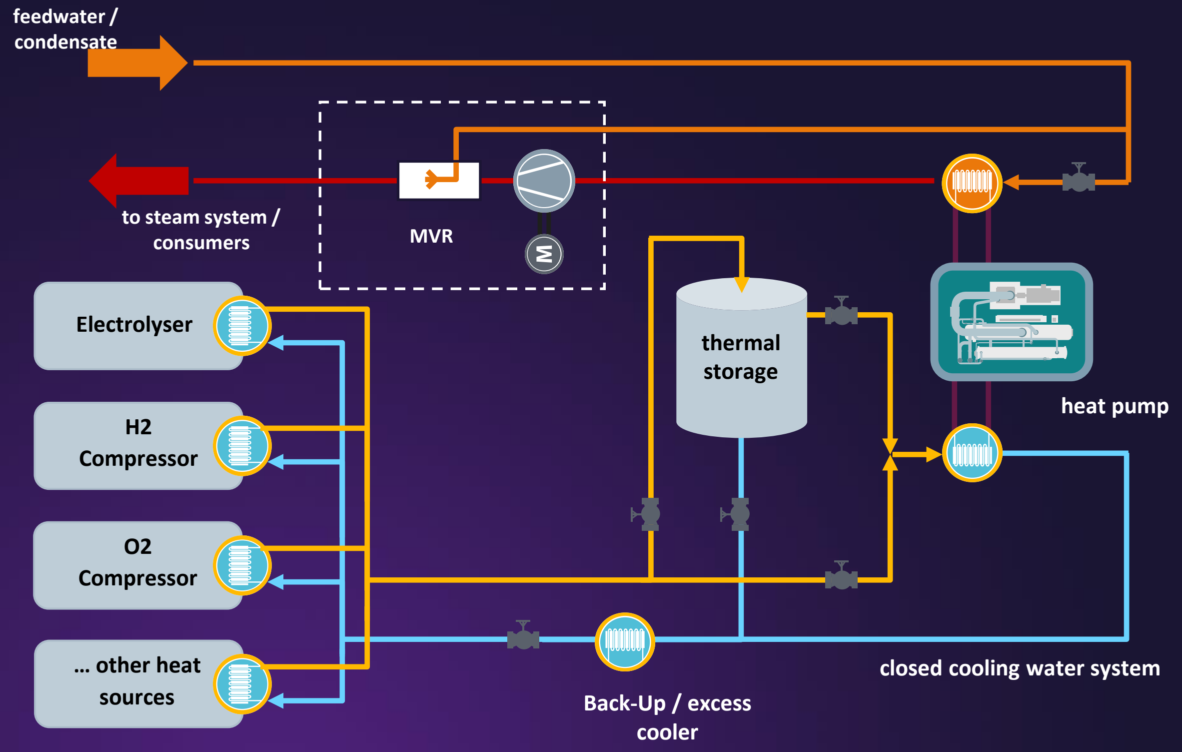
- Heat Pump absorbs the heat from the H2 production and lifts it to higher temperature level e.g. for process heating (steam)
- Heat Pump produces low pressure steam (up to 3.7 bara)
- Steam compressor with attemporation is used to produce demanded steam parameters

Challenges:

- Heat demand and waste heat from H_2 production may timewise not be congruent
- Fluctuating heat from H_2 production (esp. when driven be renewable electricity)

Concept:

- Optimized design and sizing of heat pump system by integrative measures e.g.:
  - integrating a thermal waste heat storage for electrolyzer
  - integrating a back-up / excess cooler to account for ageing of electrolyzer etc.



EXEMPLARY PROCESS DATA

Heat Source:

- approx. 8.5 MWth from H2 production (1 x electrolyzer only)
- required cooling from 48 ˚C → 35 ˚C

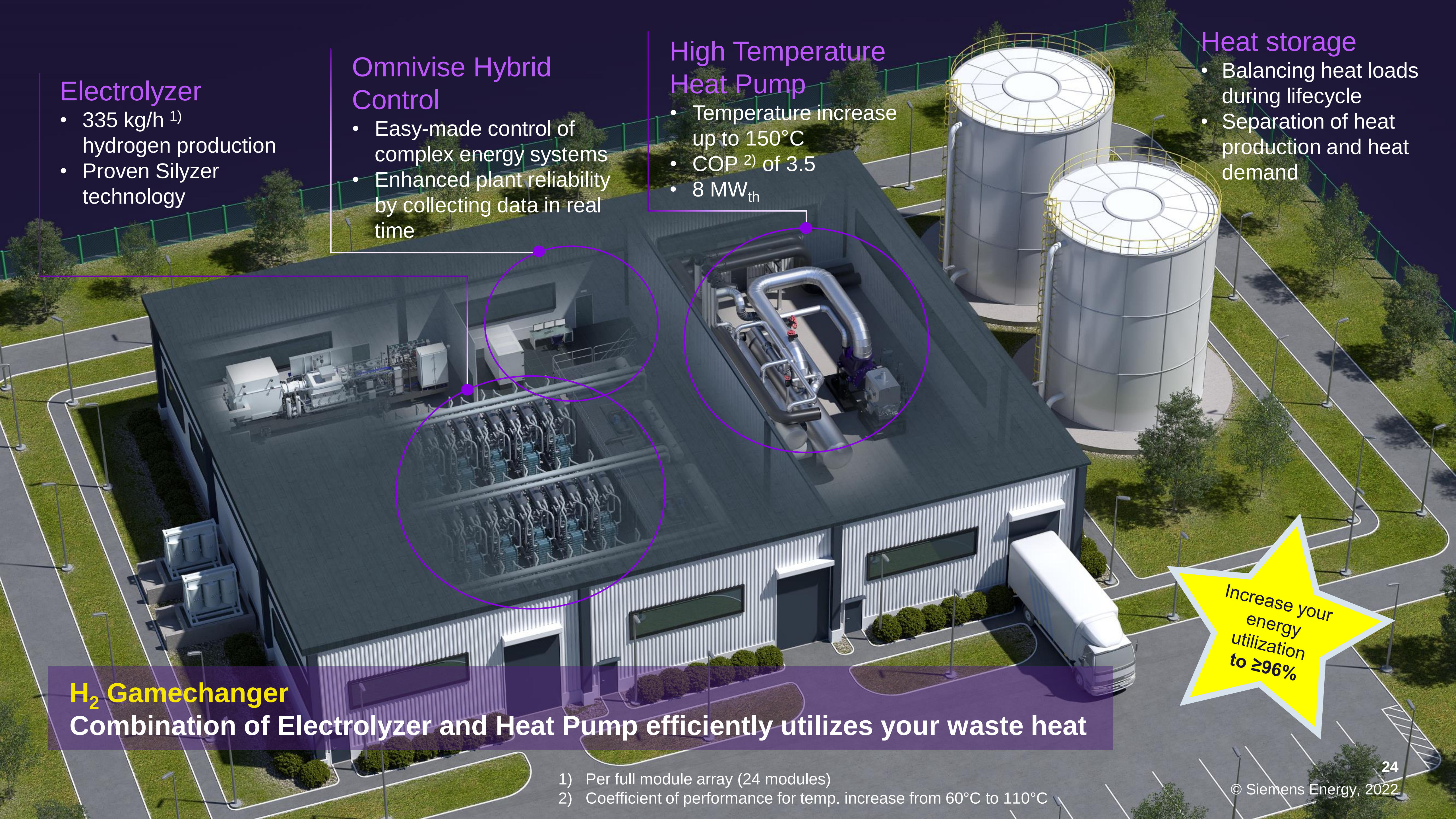
Heat Sink:

- approx. 15.1 MW_{th} process steam @ 8 bara, 190 ˚C

Heat Pump:

- COP ~ 2.1 (overall) → ~ 6.9 MW electrical power demand
- Footprint ~ 20m x 15m (heat pump) + 15m x 10m (steam compressor)

- combination of several H2 production lines onto one heat pump possible



Electrolyzer
- 335 kg/h [1)] hydrogen production
- Proven Silyzer technology

Omnivise Hybrid Control
- Easy-made control of complex energy systems
- Enhanced plant reliability by collecting data in real time

High Temperature Heat Pump
- Temperature increase up to 150°C
- COP [2)] of 3.5
- 8 MW_{th}

Heat storage
- Balancing heat loads during lifecycle
- Separation of heat production and heat demand

Increase your energy utilization to ≥96%

H_2 Gamechanger
Combination of Electrolyzer and Heat Pump efficiently utilizes your waste heat

1) Per full module array (24 modules)
2) Coefficient of performance for temp. increase from 60°C to 110°C

Industrial heat pumps
References | since 1980

Since 1980

50 Large-scale Heat Pumps from Siemens Energy

(35 still in operation)

Nr.	Project	Heat Output	Nr.	Project	Heat Output
1	Ludvika 1	11 MWth	26	Lund GEO	20 MWth
2	Västeras 1	12 MWth	27	KungsängenVP1	8 MWth
3	Uppsala 1	13 MWth	28	Örebrö VP1	20 MWth
4	Uppsala 2	13 MWth	29	Örebrö VP2	21 MWth
5	Uppsala 3	13 MWth	30	Huskvarna	7 MWth
6	Visby	12 MWth	31	Hammarby VP1	20 MWth
7	Borlänge 1	12 MWth	32	Hammarby VP2	20 MWth
8	Borlänge 2	12 MWth	33	Hammarby VP6	30 MWth
9	Västeras 1	12 MWth	34	Hammarby VP7	30 MWth
10	Lund1	13 MWth	35	Akersberga VP1	6 MWth
11	Malmö1	13 MWth	36	Järfälla VP1	20 MWth
12	Malmö2	13 MWth	37	Järfälla VP2	20 MWth
13	Malmö3	13 MWth	38	Solna VP1	30 MWth
14	Eskilstuna 1	13 MWth	39	Solna VP2	30 MWth
15	Upplands Väsby 1	11 MWth	40	Solna VP3	30 MWth
16	Upplands Väsby 2	11 MWth	41	Solna VP4	30 MWth
17	Sandviken	12 MWth	42	Lund Geo 2	27 MWth
18	Gävle 1	14 MWth	43	Ropsten VP91	25 MWth
19	Eskilstuna 2	13 MWth	44	Ropsten VP92	25 MWth
20	Borlänge 3	12 MWth	45	Ropsten VP93	25 MWth
21	Kalmar VP1	13 MWth	46	Ropsten VP94	25 MWth
22	Örnsköldsvik VP1	14 MWth	47	Lindesberg VP1	5 MWth
23	Örnsköldsvik VP2	5 MWth	48	Eslöv VP1	9 MWth
24	Umea VP1	17 MWth	49	Jönköping	25 MWth
25	Umea VP2	17 MWth	50	Hammarby VP 5	30 MWth

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2 Compression heat pumps – technology and products

3 Use cases

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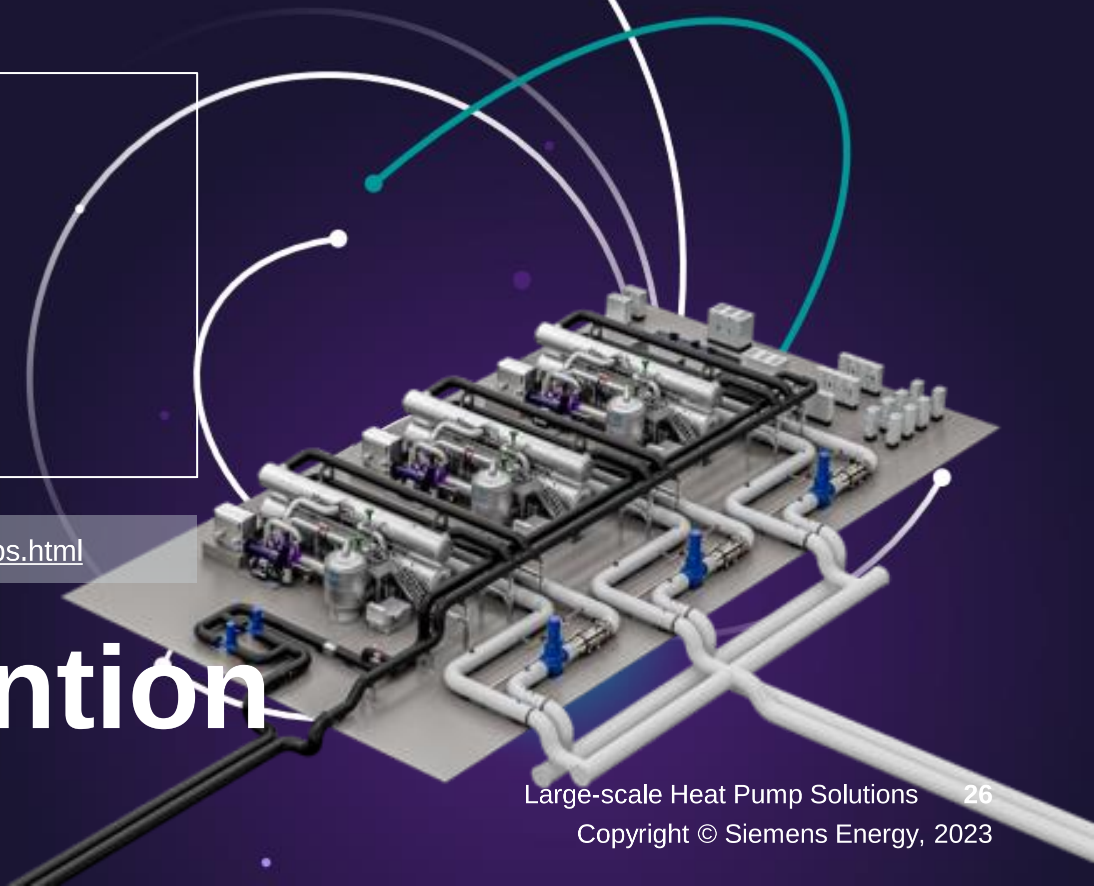
More Information: https://www.siemens-energy.com/global/en/offerings/power-generation/heat-pumps.html



Thank you for your attention