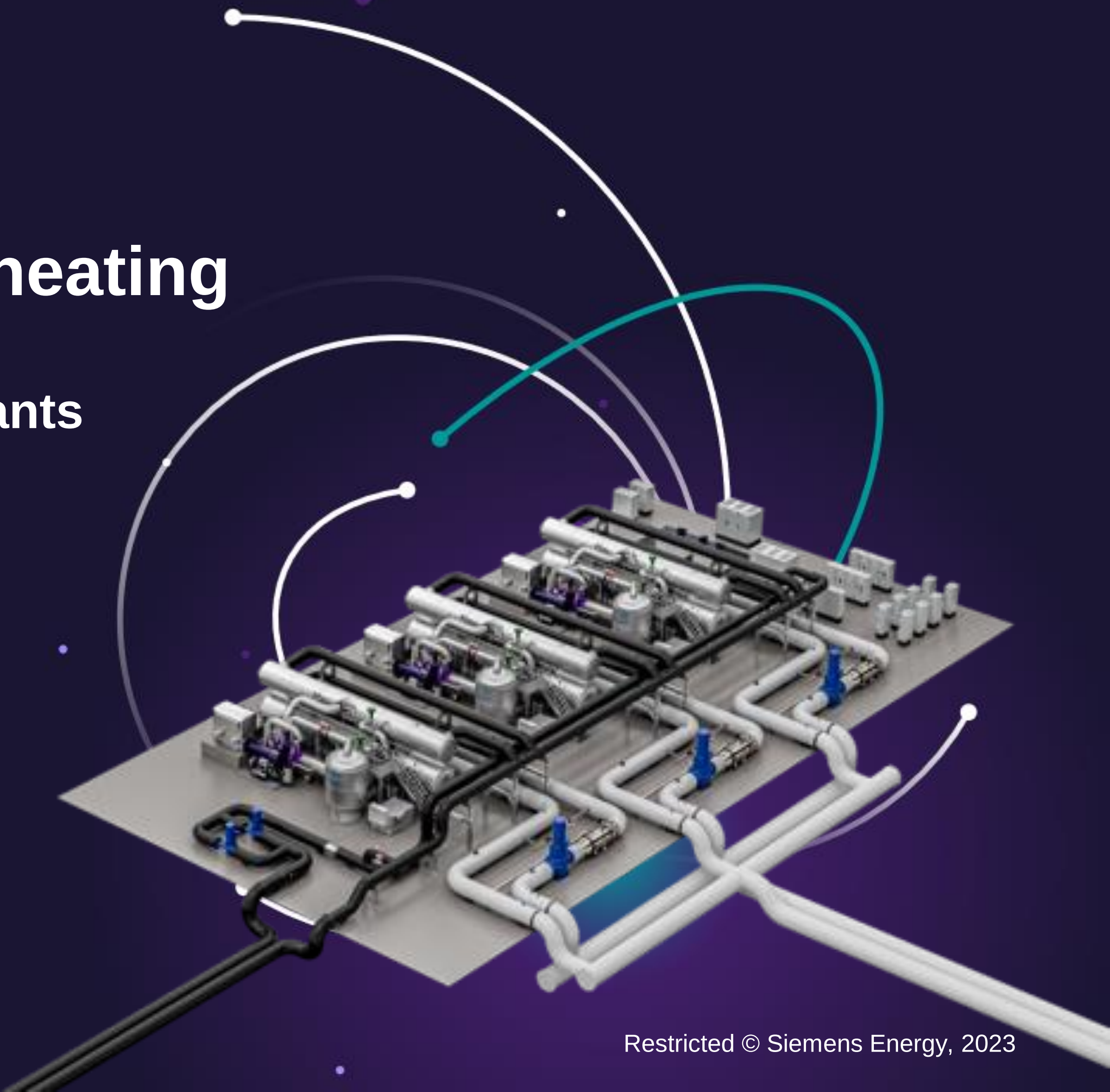
Industrial Heat Pumps
as lever for decarbonizing district heating and process steam
HSE requirements with focus on natural refrigerants



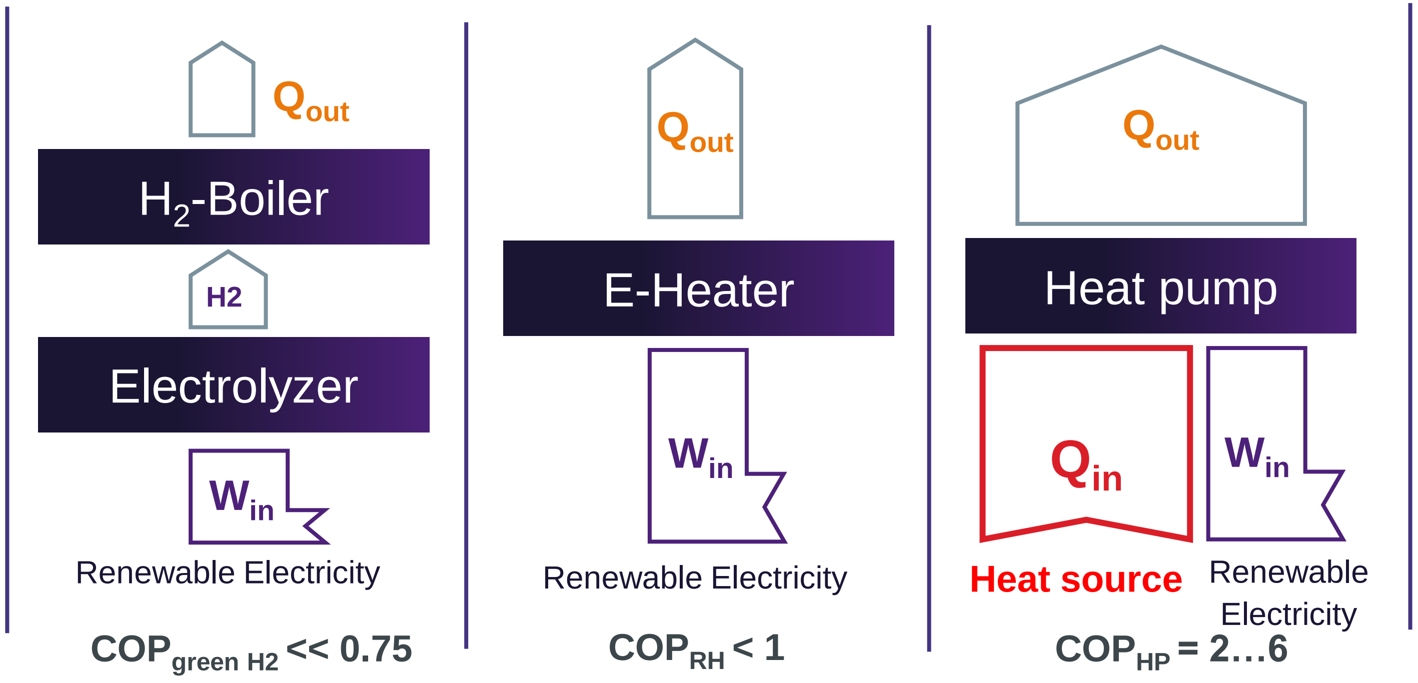
Presenter: Kevin Moritz
Siemens Energy
Norsk Energi general assembly, Oslo, 12th June 2024

Decarbonizing Heating with Heat Pumps
energy efficient use of renewable electricity

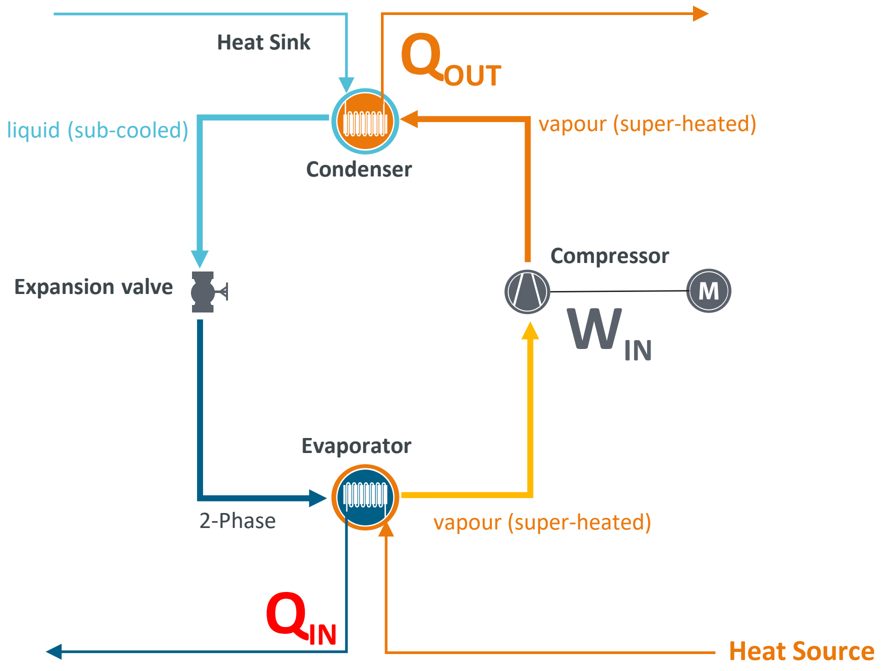
Coefficient of Performance

$$COP = \frac{\text{Thermal Energy } (Q_{OUT})}{\text{Electrical Energy } (W_{IN})}$$

Technological options



Heat Pump Process Scheme



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.

Siemens Energy's heat pump portfolio addresses both district heating and industry applications

Two complementary product lines …

SHP-C600 / C750

Based on proven design since 1982
15 – 45 MW, up to 100 °C hot water

Reference: GKM

- 20 MW thermal output
- Customer: GKM Mannheim

Latest reference: Reuter West

- 80 MW thermal output
- Customer: Vattenfall Wärme Berlin

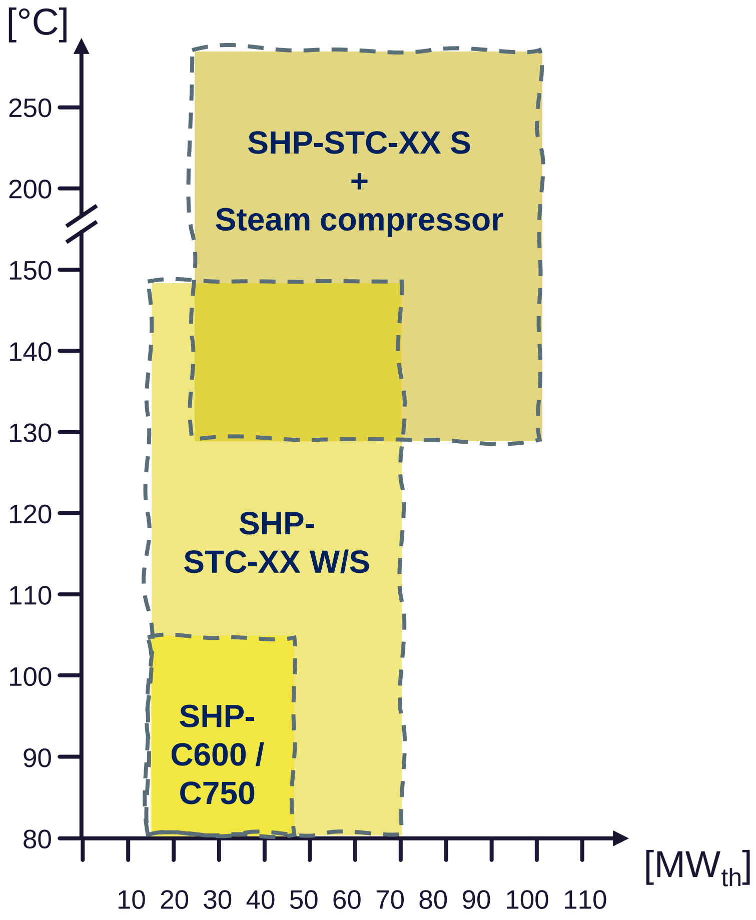
SHP-STC-XX W/S

High Temperature Heat Pump
15 – 70 MW, up to 150 °C
hot water OR steam

1st reference: Potsdamer Platz

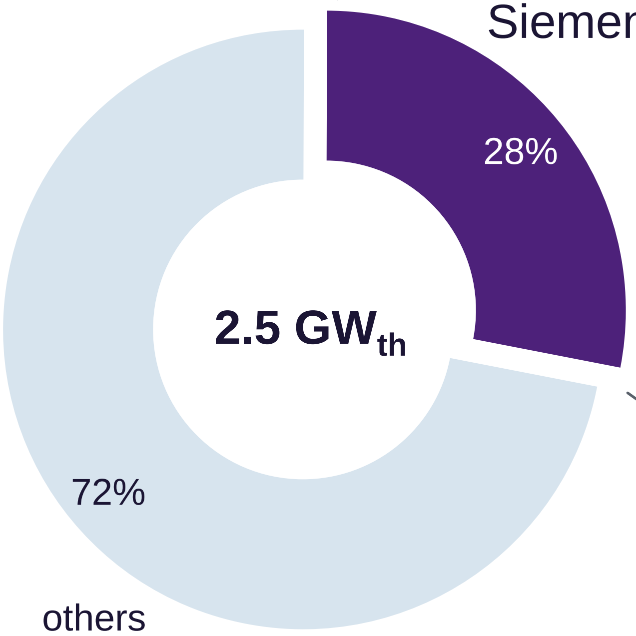
- 8.5 MW thermal output, up to 120°C D-HTG
- Customer: Vattenfall Wärme Berlin

… covering a unique outputrange



Approximately a quarter of the installed large scale heat pump capacity in European district heating is from Finspång

Large heat pumps in European DH, 2021



50
units installed since 1980

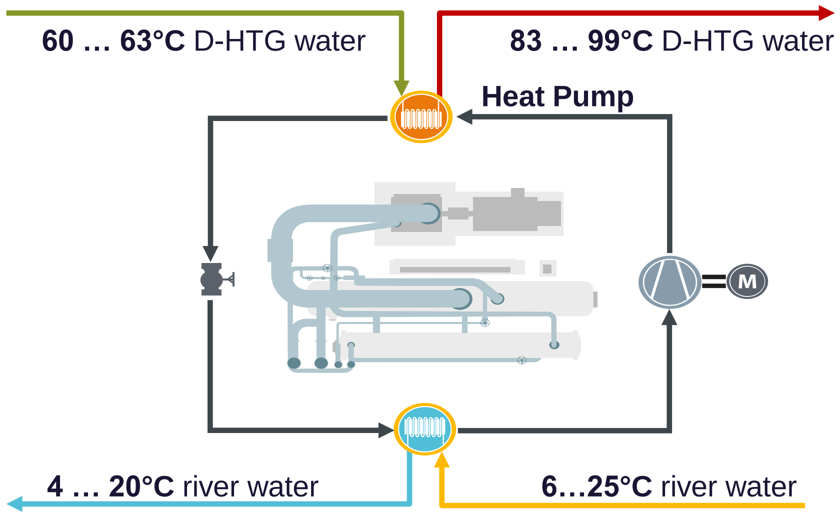
35
units still operating

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 2	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

Source: own figures and „Large heat pumps in district heating – state of the play“, Euroheat and power 2022

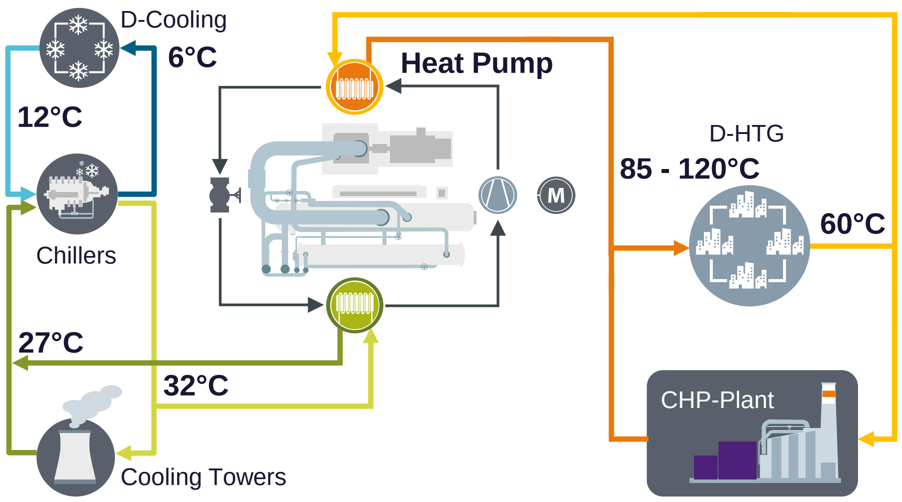
Recent examples for large scale heat pumps (1)

District heating system, MVV / GKM Mannheim, Germany



Thermal capacity	max. 20 MW_{th}	**COP** (overall)	2.7 (average)
Refrigerant	**Class A2L R1234ze(E)**		
Customer benefits	• Up to 99°C warm district heating water • Use of environmental heat river Rhein • District heat for 3500 households • CO2 savings: ~ 10 000 t/a		

District heating system, Vattenfall Wärme Berlin, Germany



Thermal capacity	max. 8.5 MW_{th}	**COP** (overall)	3.0 (average)
Refrigerant	**Class A1 R1233zd(E)**		
Customer benefits	• 85°C to 120°C hot district heating water • District heat production: ~ 55 GWh/a • CO2 savings: ~ 6500 t/a • Cooling water savings:~ 120 000 m³/a		

Recent examples for large scale heat pumps (2)

District heating system, MVV / GKM Mannheim, Germany

Thermal capacity	max. 20 MW_{th}	**COP** (overall)	2.7 (average)
Refrigerant	**Class A2L R1234ze(E)**		
Customer benefits	• Up to 99°C warm district heating water • Use of environmental heat river Rhein • District heat for 3500 households • CO_2 savings: ~ 10 000 t/a		

www.mvv.de/ueber-uns/unternehmensgruppe/mvv-umwelt/aktuelle-projekte/mvv-flusswaermepumpe

District heating system, Vattenfall Wärme Berlin, Germany

Thermal capacity	max. 8.5 MW_{th}	**COP** (overall)	3.0 (average)
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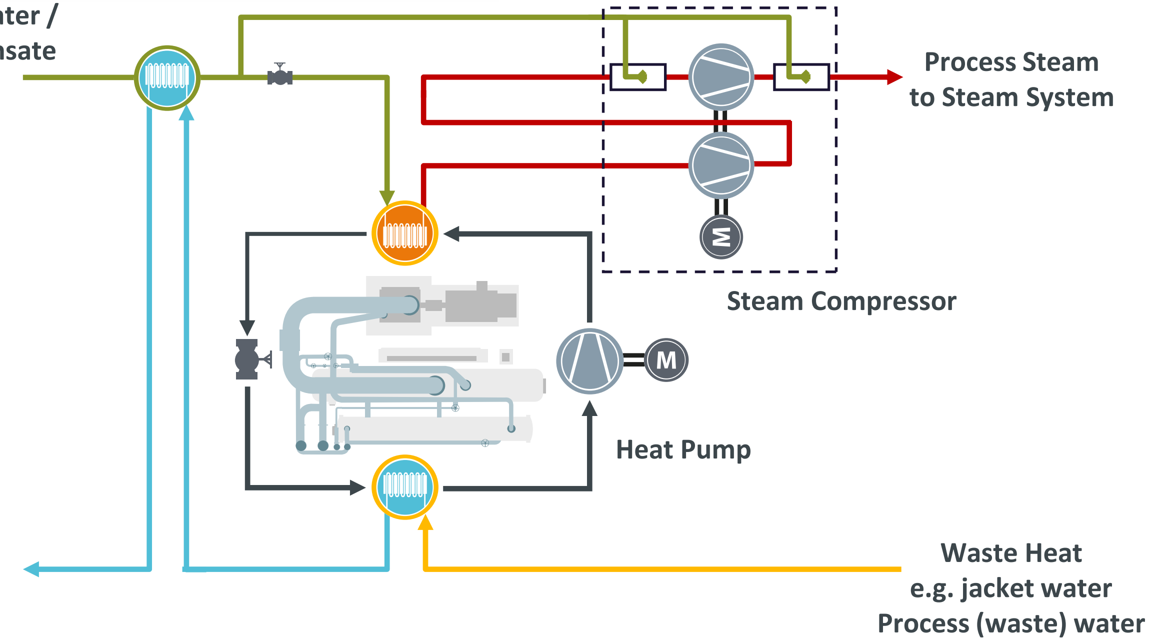
https://www.bew.berlin/fernwaermesystem/waermewende/abwaerme-und-grosswaermepumpen/

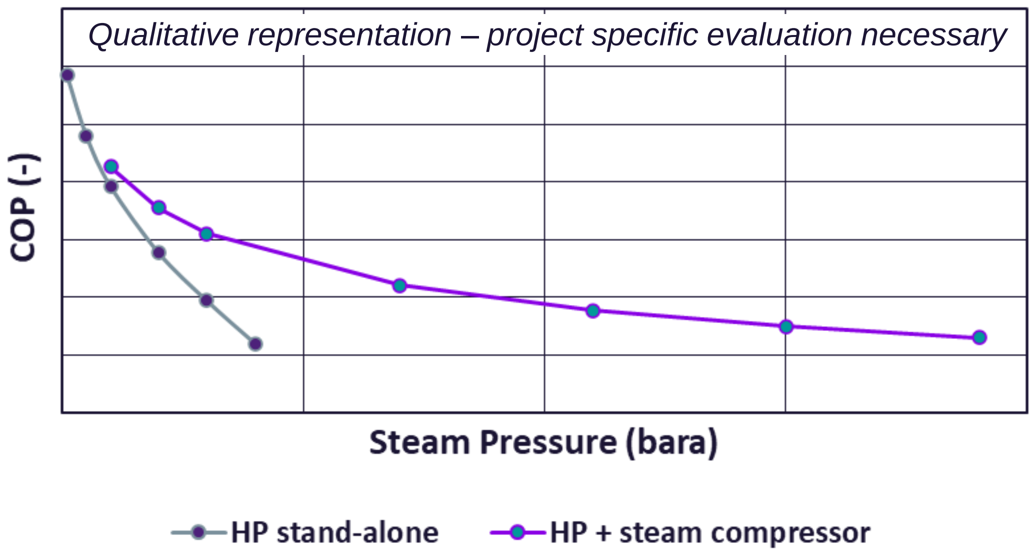
High Temperature Heat Pumps w/ Steam Compressor
Use Case – MP steam from closed cooling water

Heat pump for stream production – Utilization of waste heat

MP Steam from Waste Heat



Impact of steam compressor



Benefits of steam compressor

- New option for steam supply up to 60 barg and 300°C
- Enhanced COP at typical "low pressure" steam levels

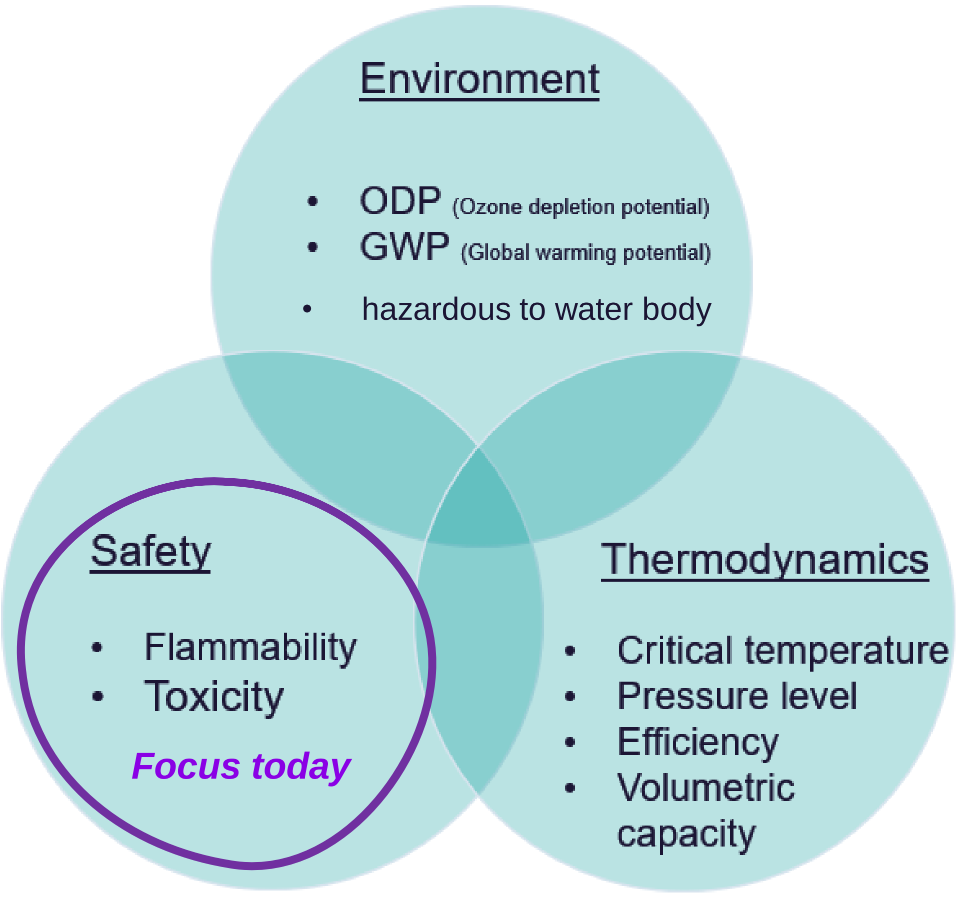
The selection of the refrigerant for heat pumps is a puzzle put together from many pieces …

SIEMENS energy

Industrial Heat pumps

Refrigerants

- Synthetic H(C)FOs: **A2L R1234ze(E),**
  A1 R1233zd(E), …
- Natural: R717 (NH_3), R718 (H_2O), R744 (CO_2)
- Hydrocarbons **A3**: **R600 Butane 3.5, R600a iso-Butane 3.5**, R290 Propane, etc.



Others …
- Price
- Availability
- Material compatibility
- Oil compatibility
- Accumulation of degradation products (TFA, PFAS)

- Temperatures in Heat Source and Heat Sink

Refrigerant selection is a multi-objective optimization process

Extract from technical note to paper industry CEPI for LP STEAM generation use case:

	Natural refrigerants					Synthetic refrigerants	
Criteria	R717 Ammonia	R744 CO_2	R600a Isobutane	**R600 Butane**	R601 Pentane	**R1233zd(E)**	R1336mzz(Z)
Flammability	Yes	No	Yes	Yes	Yes	No	No
Toxicity	Yes	No	No	No	No	No	No
Safety class	B2L	A1	A3	A3	A3	A1	A1
ODP	0	0	0	0	0	~0	0
GWP (old) new F-gas EU 2024/573	0	1	(3) 0	(4) 0.006	(5) 0	(1) 3.88	1 (2.08)
Critical temperature [° C]	132	31	135	152	197	166	171
Compressor suction volume flow for given operation point [%]	15%	7%	55%	70%	200%	100%	165%
Real achievable COP [%]	90%	80%	85%	90%	95%	100%	95%

CEPI = Confederation of European Paper Industries
GWP = Global Warming Potential means the climatic warming potential of a greenhouse gas relative to that of CO_2 in 100-years
ODP = Ozone Depletion Potential of a substance is the relative amount of degradation to the ozone layer it can cause, with R-11 being fixed at an ODP of 1.0

Interesting refrigerant options for steam supply. We offer synthetic and natural parallel.

We support our customers in their decision with specific performance evaluations, safety and environmental recommendations, engineering at early project phases, with FEED studies, basic & detail design.

SAFETY FIRST @ SE – for HP use cases with R600 & R600a

Flames, sparks, Hot surfaces: AIT-100K

- ✓ **HAZID, HARA, HAZOP, SIL-classification**
- ✓ **Fire- and Ex-protection concepts**

Primary explosion protection:

- Arrangement and separation of equipment
- **Design of equipment** → **TWO DESIGN topics to prevent formation of explosive atmosphere:**
- Testing for leak tightness
- Natural and forced ventilation
- Gas detection and alarm systems

1) ENHANCED TIGHTNESS

2) Protection of secondary systems

Secondary explosion protection:

- Classification of hazardous area **(ZONING)**
- Prevention of ignition sources

Engineering explosion protection:

The purpose of these is to limit the impact of an explosion and/or to reduce it to a non-hazardous level. The most common measures to limit the hazardous effects of explosion are as follows:

- flameproof or pressure-surge-resistant design
- pressure relief and pressure compensation equipment
- explosion suppression with extinguishing devices

<u>Topic 1</u>: Enhanced tightness (1) Definitions

Definition of **enhanced tightness** can be found in EN 1127-1 3.2 / B.1:

“absence of leakage when due to the design and measures of maintenance any of the tightness tests or tightness monitorings appropriate for the application does not reveal any hazardous leaks during normal operations and expected malfunctions…
*— equipment with enhanced tightness from which a flammable/combustible substance is not expected to be released into the atmosphere or, if it is released, **<u>will not cause any hazardous area</u>**.” …*

TRGS 722 (extract): 4.5.2 Permanently technically tight plant components

(1) In the case of parts of the plant which are **permanently technically tight**, no releases shall be expect. …

(4) Parts of the plant shall be deemed to be **permanently technically tight** if:

1. they are designed in such a way that they **remain technically tight due to their design** or
2. their technical tightness is *constantly guaranteed by maintenance and monitoring*.

(5) **Due to their design, system components that are permanently technically tight <u>do not cause any hazardous area when unopened</u>.**

→ In theory, no (entire) Ex-Zone 2 needed according both codes

→ local ZONING on top

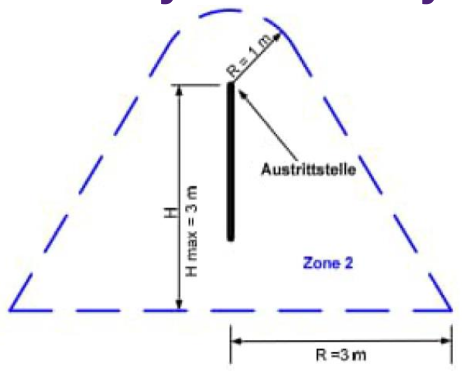


Illustration of hazardous area around possible leakage sources for heavier than air gases

<u>Topic 1</u>: Enhanced tightness (2) Selection of Components

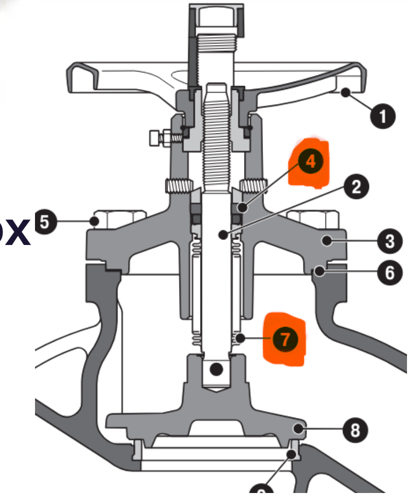
(7) Permanently technically tight parts of the plant and equipment … are e.g.

1. **Welded plant components** with
   (a) detachable components, the detachable joints required for this purpose, operationally **only rarely loosened** …
   (b) detachable connections to pipes, fittings or blind covers, whereby the separable connections required for this purpose are **rarely loosened,** and are designed in accordance with the following requirements in this section

2. for gases, vapours, liquids: parts of the system which also contain sealing elements, like
   a) shaft bushings with **double-acting mechanical seals**,
   e.g. on pumps; Agitators,
   b) canned motor pumps;
   c) **magnetically coupled pumps;**
   d) diaphragm pumps with double diaphragm and interstitial monitori

   e) **Valves sealing the spindle bushing** by means of **bellows and safety stuffing box**

   f) **gas-lubricated seals with monitoring of gas flow or pressure;**
   g) Stuffing-boxless valves with permanent magnet drive.
   ….



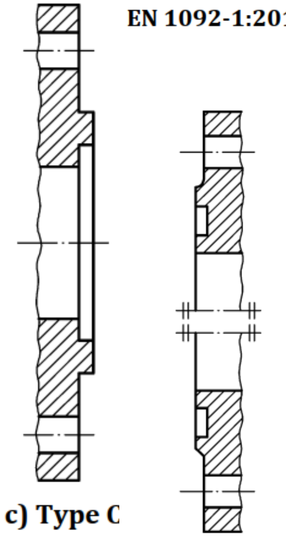
<u>Topic 1</u>: Enhanced tightness (3) Selection of Connections

(8) Permanently technically tight connections for valves or pipeline connections and, for example:

1. **Non-detachable connections, e.g. welded, brazed**,

2. detachable connections that are **rarely loosened during operation**; this is the case for combinations of flange connection with soft material gaskets, if

   a) **The flange and gasket are selected and installed acc. the manufacturer's specifications**
   b) the combination is suitable for the application;
   c) the soft material of the seal does not becomes brittle nor flows inadmissibly;
   d) **the seal is safe against blow-out,** and
   e) the surface pressure of the seal is sufficiently above the req. min. compression.



Examples of seals that meet these criteria include:

   a) flanges with welded lip seals;
   b) tongue and groove flanges;
   c) flanges with protrusion and recess;
   d) flanges with V-grooves / V-groove seals;
   e) **Flanges with smooth sealing strip and special gaskets,** e.g. soft material gaskets up to PN 25 bar, gaskets with metal inner edge, comb-profiled gaskets, ….

   f) **metal-to-metal sealing compounds (cupper ring)**
   g) cutting and clamping ring connections ≤ DN32,
   h) <u>*NPT thread*</u> **or other conical pipe threads** with tapered pipe threads *with sealing in the thread* up to DN50, **(e.g. Swagelock)**

Topic 2: Protection of secondary systems acc. EN 378-2 6.2.6.8

6.2.6.8 Protection of the secondary cooling and heating system

For a refrigerating system with a refrigerant charge of more than 500 kg, measures shall be taken to detect (e.g. by refrigerant detectors) and report (e.g. by a warning detector) the presence of refrigerant in any associated circuit containing water or other liquids.

When B1, A2L, A2, B2, B2L, A3 or B3 refrigerant of more than 500 kg is used in an indirect system (refer to EN 378-1:2016, 5.4) the heat exchanger shall not allow the release of the refrigerant into the areas served by the secondary heat-transfer fluid due to a failure of the wall of the evaporator or condenser.

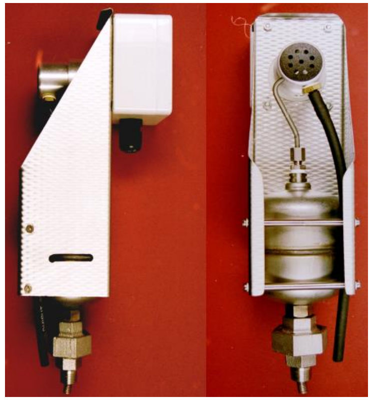
EN 378-2 6.2.6.8 mentions three EXAMPLES
→ Basically, these three solutions are possible (with adaptions):

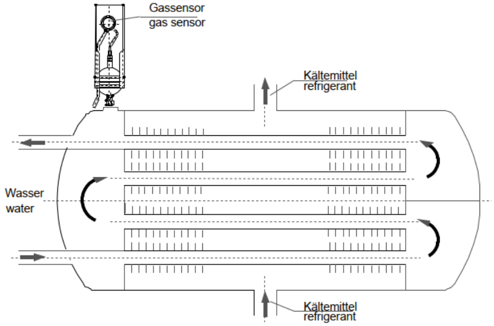
EXAMPLE 3:
The **pressure of the secondary circuit is always greater than the pressure of the primary circuit** in the area of contact.

→ You can be lucky if secondary system has a higher pressure.
→ But, is the higher pressure in the secondary system assured under all conditions?

T2 Example 1: Protection of secondary systems - acc. EN 378-2:

An automatic air/refrigerant separator, mounted on the secondary circuit on the outlet pipe from the evaporator or the condenser and at a higher level than the heat exchanger. …
The air separator shall discharge the refrigerant into the vented unit housing or the outside.

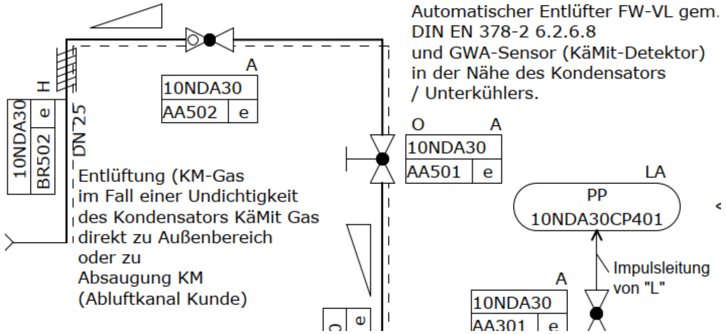




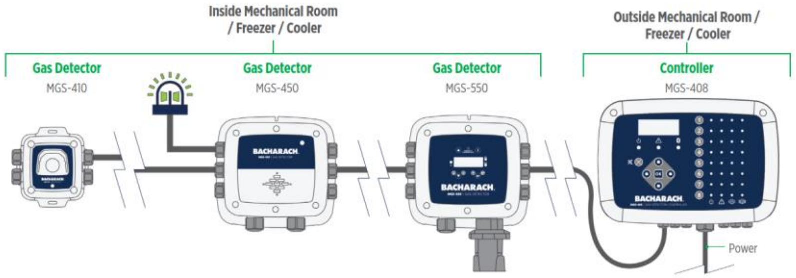
Gassensor an einem Rohrbündel-Wärmetauscher

Gas sensor on the heat exchanger

Automatic float-controlled vent valve combined with gas sensor at high point of D-HTG forward line



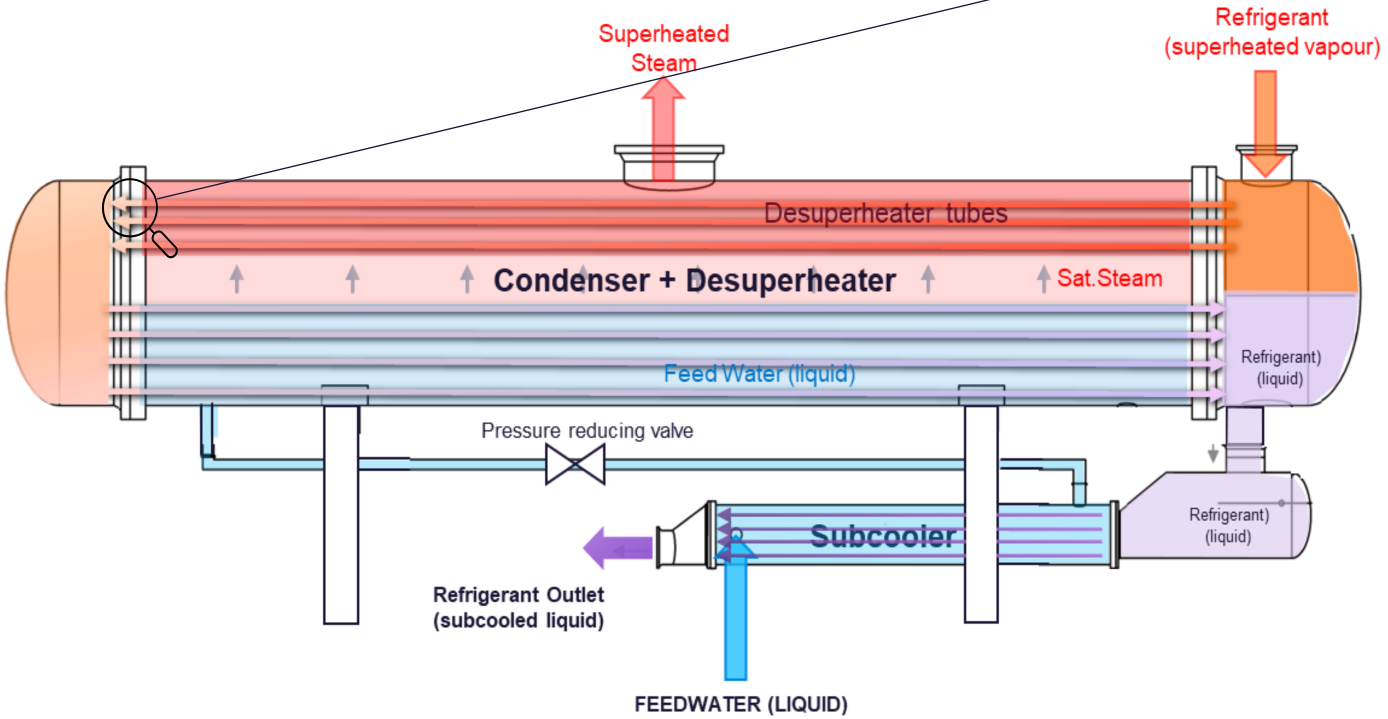
→ **Solution for District heating, heat source, (cooling water)**

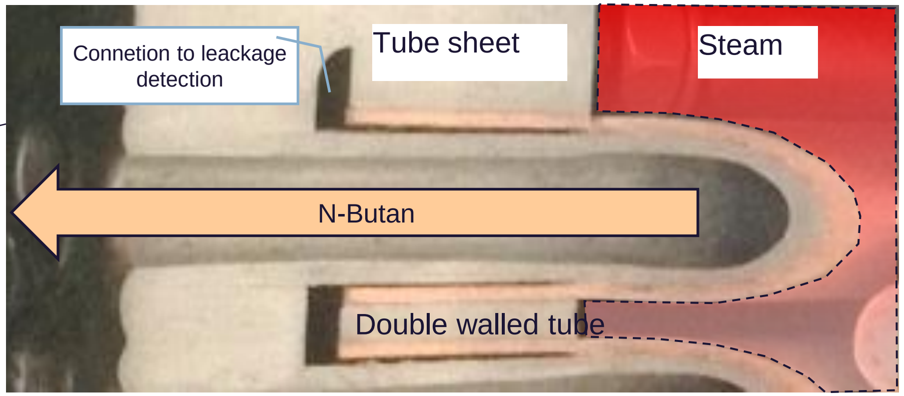


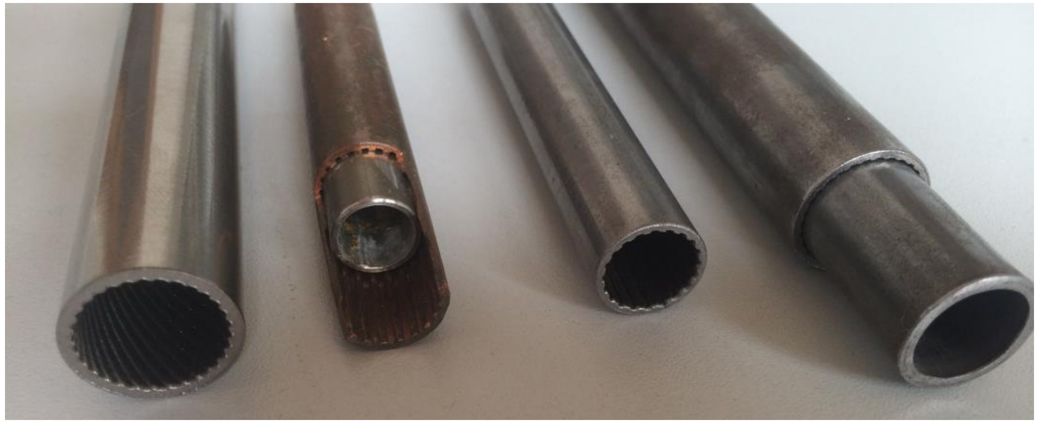
Gas Warning system
Several refrigerant sensors in machinery room,
at heat sink automatic vent valve,
and at heat source outlet via sampling funnel

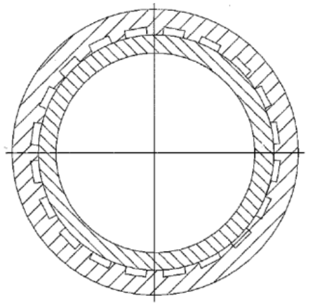
T2 Example 2: Protection of secondary systems acc. EN 378-2:

A double wall heat exchanger, between the primary and the secondary circuit, in order to avoid, in case of leakage, that the refrigerant leaks into the secondary circuit.









Special Solution for STEAM producing Heat Pump:
→ Safety tube heat exchangers

Summary

- Large scale HPs enable low carbon heat supply to district heating systems and process steam applications
- SE approaches the market by offering large scale HPs for a wide range of temperatures
- SE is a heat pump supplier with a strong track record and recent new unit references
- SE offers HPs with synthetic and natural refrigerants
- SE is well aware of the challenges and capable of handling A3 refrigerants
- For natural refrigerants we are looking for first time applications

Contact page

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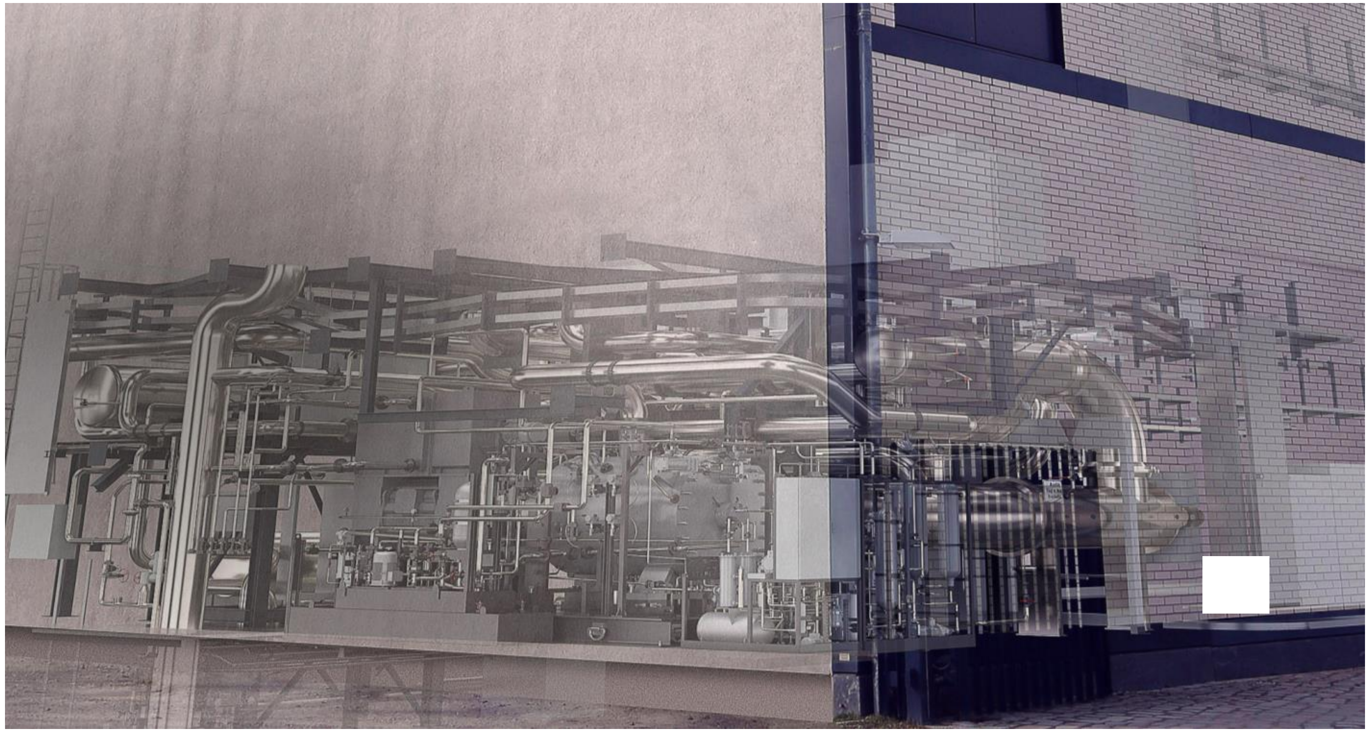

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