

 **ENOUGH**
EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050



Webinar Project „ENOUGH“

European food chain supply to reduce GHG-emissions by 2050
(Project No.: 101036588)

WP6 - Task 6.3 (Dairy): Application of a high-temperature heat pump for waste heat utilization (Demo3)

Philipp Wagner, Manuel Verdnik, René Rieberer

Graz University of Technology (TU Graz)
Institute of Thermal Engineering (IWT)
Inffeldgasse 25/B
8010 Graz
Austria

Contact: rene.rieberer@tugraz.at, www.iwt.tugraz.at
“ENOUGH”: Webinar | December 1st, 2022 | MS Teams

MS Teams, December 1st, 2022

Identified dairy demonstrators

- **Optimization of energy flows at Rørosmeieriet AS (SO, NTNU, RM) - Demo2**

The energy flows within several key heating and cooling devices will be monitored and applied for further optimization, to improve the specific energy efficiency. Innovative concepts for cold thermal storage are implemented and support load shift measures to significantly reduce peak power operations.

- **Cold water and steam/high-temperature water heat pump at Yeo Valley Farms Production Ltd. (LSBU, YEO) – Demo4**

Integration of heating and cooling at a yoghurt producer to integrate a refrigeration ice bank (used to produce chilled water) with steam generation system (currently operated from gas). This will be tested and monitored to demonstrate the opportunities for thermal integration and also the use of high temperature heat pumps to generate steam.

- **High-temperature heat pump at Ennstal Milch KG (IWT, ENGIE) – Demo3**

A high-temperature heat pump as heat source for the cleaning-in-place (CIP) system in a diary by utilizing waste heat. Development of different operational strategies derived from measurement data (and simulations)

Source: Proposal ENOUGH, No. 101036588“ (2021)

High-temperature heat pump at Ennstal Milch KG – Demo3

- Key facts Ennstal Milch
 - Founded in 1902
 - Dairy and cheese factory
 - Classic dairy products (e.g. whole milk, desserts, spreads, moulded cheese, ...)
 - Flexible co-manufacturer for numerous national and international companies
- Technical facts demonstrator
 - Chiller
 - Refrigerant: NH₃
 - Supply of “ice-water” at 1 °C
 - Max. cooling capacity 900 kW
 - HTHP
 - Directly integrated into the chiller (Refrigerant: NH₃)
 - Supply water temperature of up to 90 °C (CIP-System)
 - Max. heating capacity 550 kW

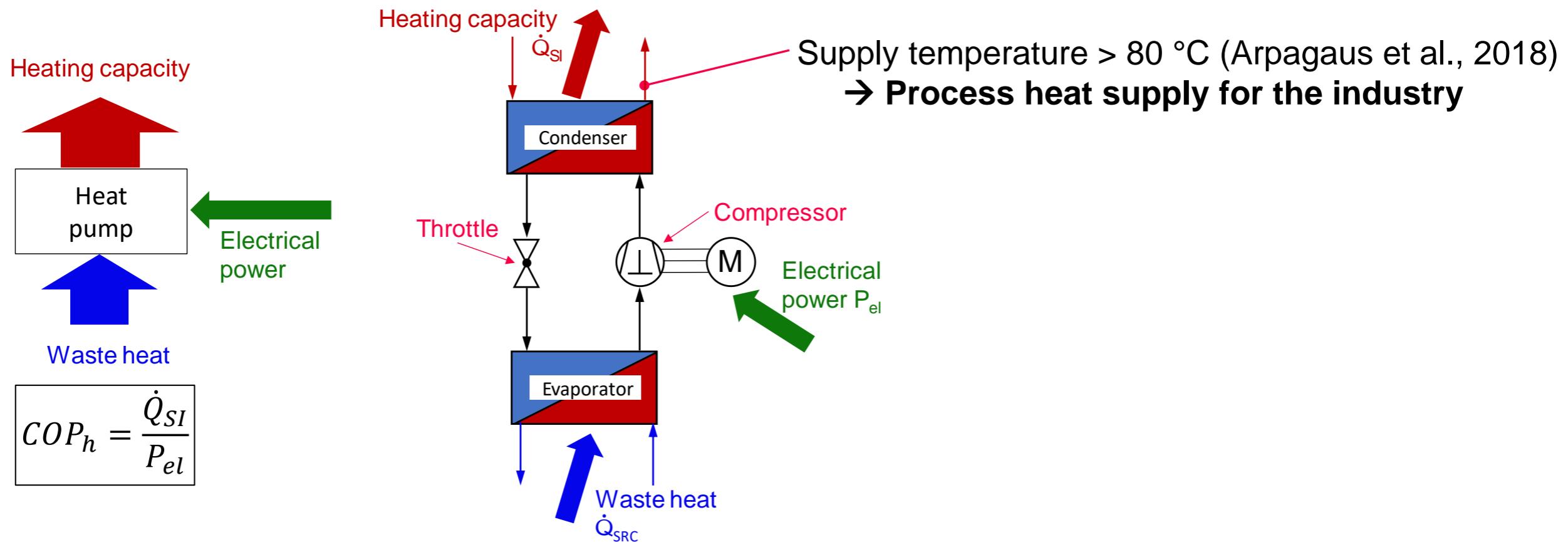


 EQUANS



High-temperature heat pump (HTHP)

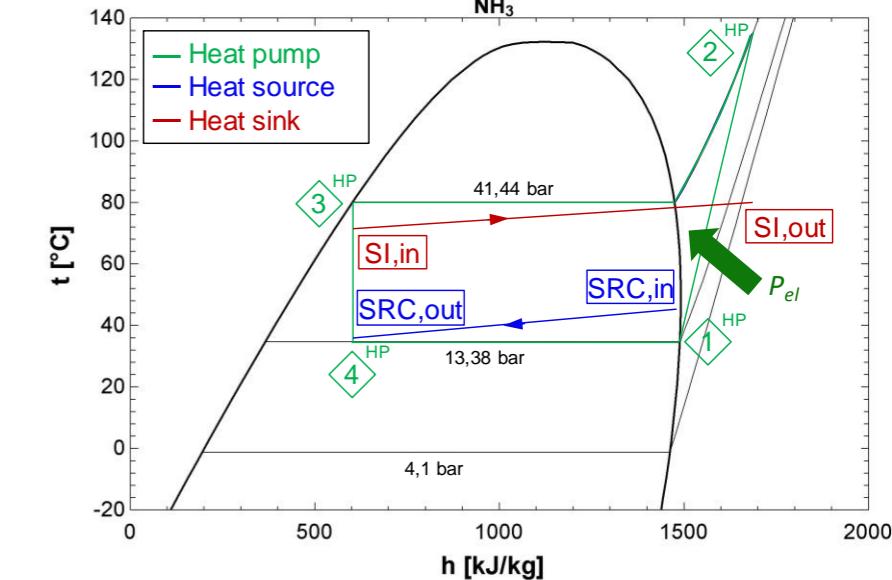
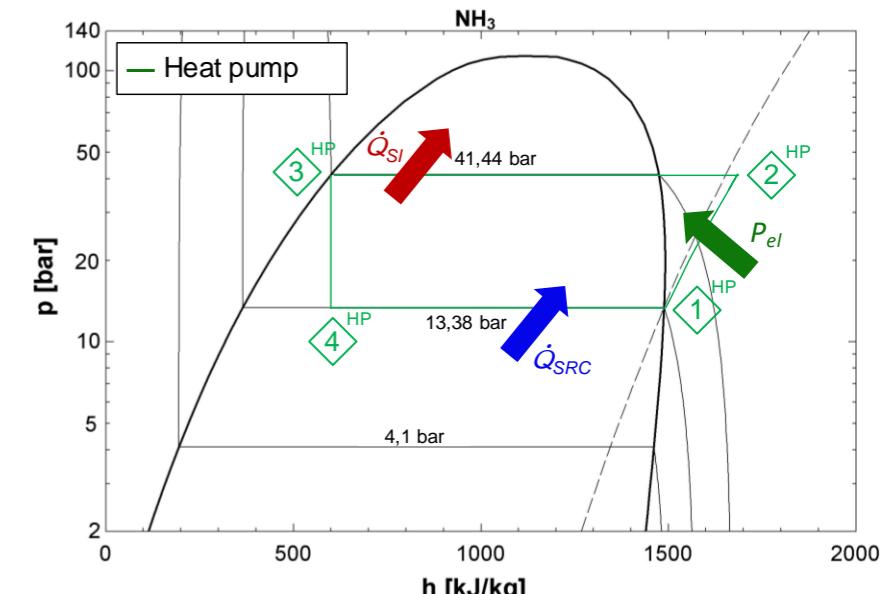
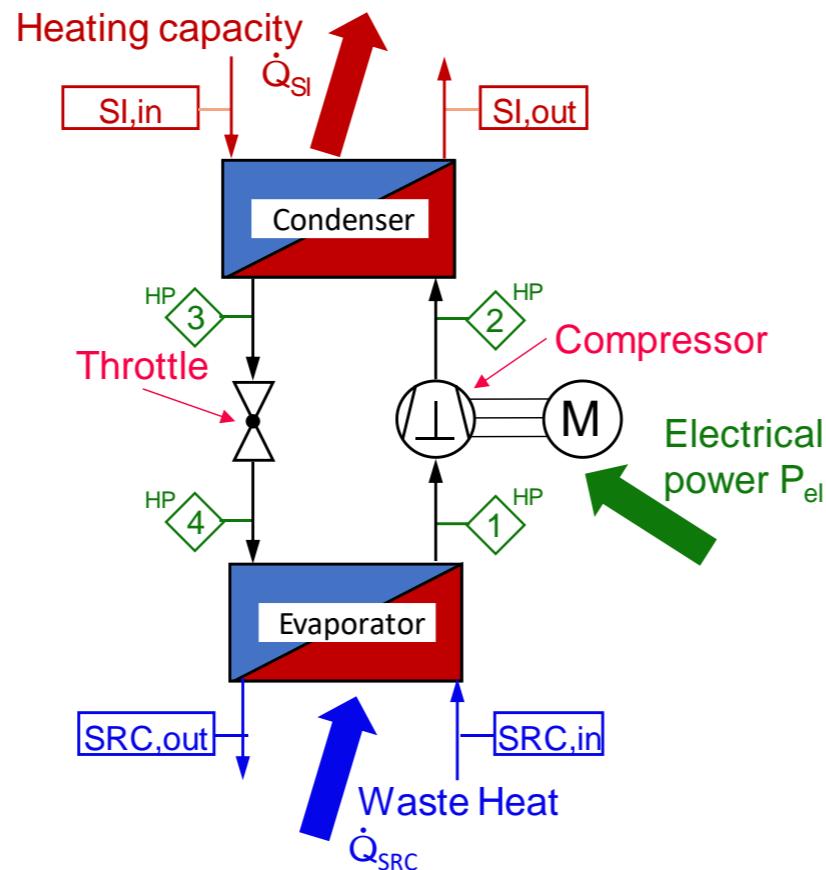
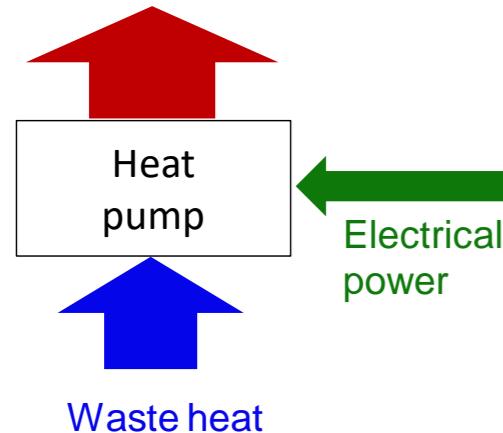
- Introduction to the heat pump process



High-temperature heat pump (HTHP)

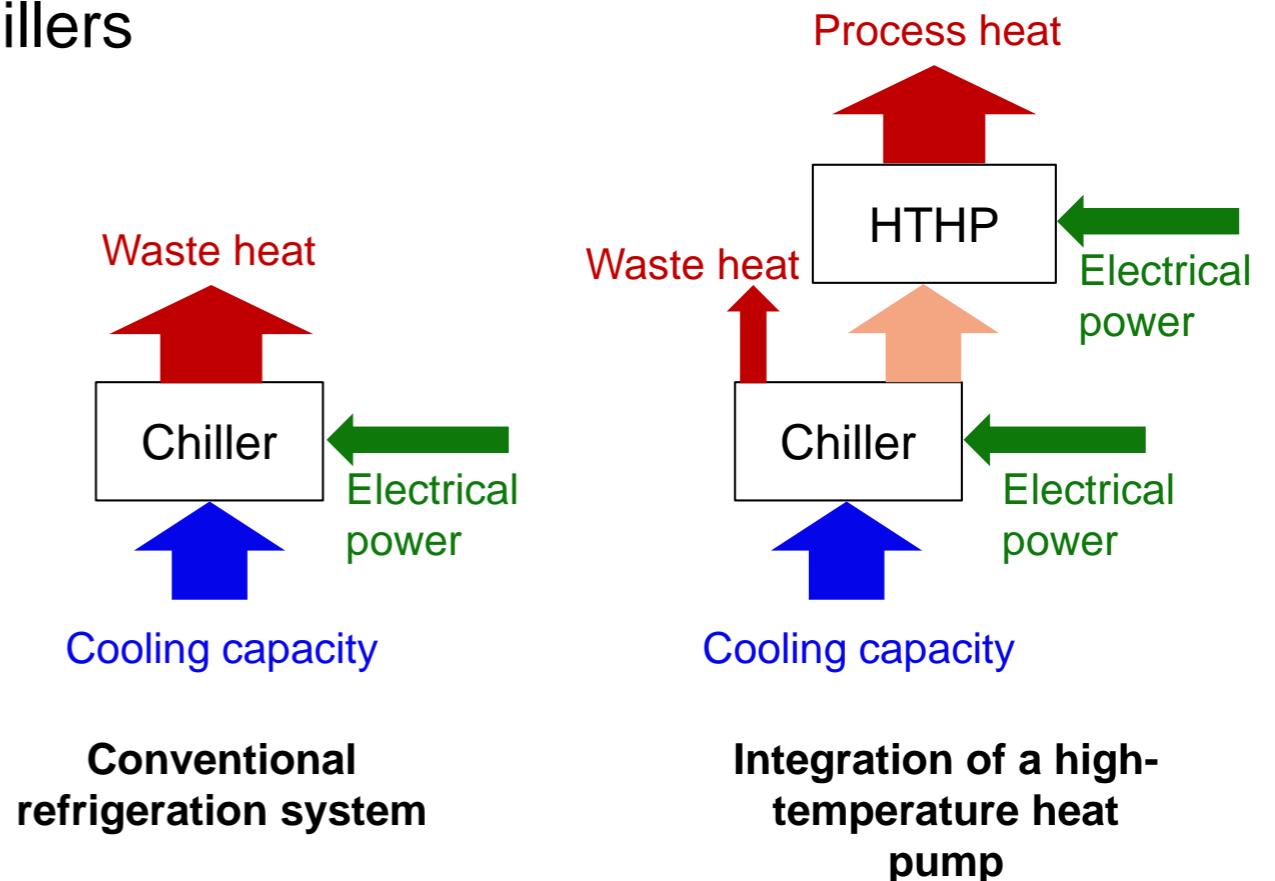
- Introduction to the heat pump process

Heating capacity

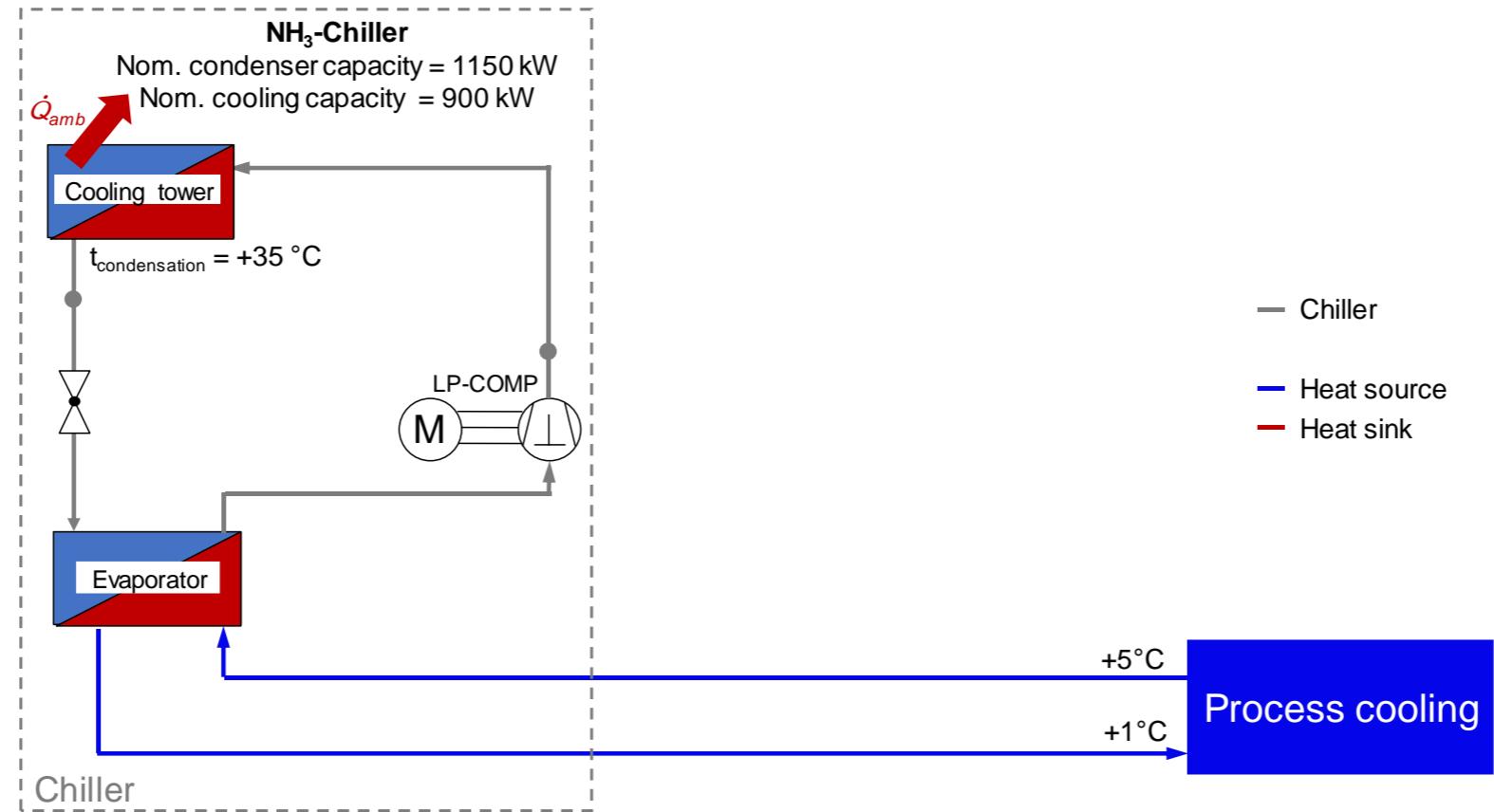


Possibility and advantages of waste heat utilization

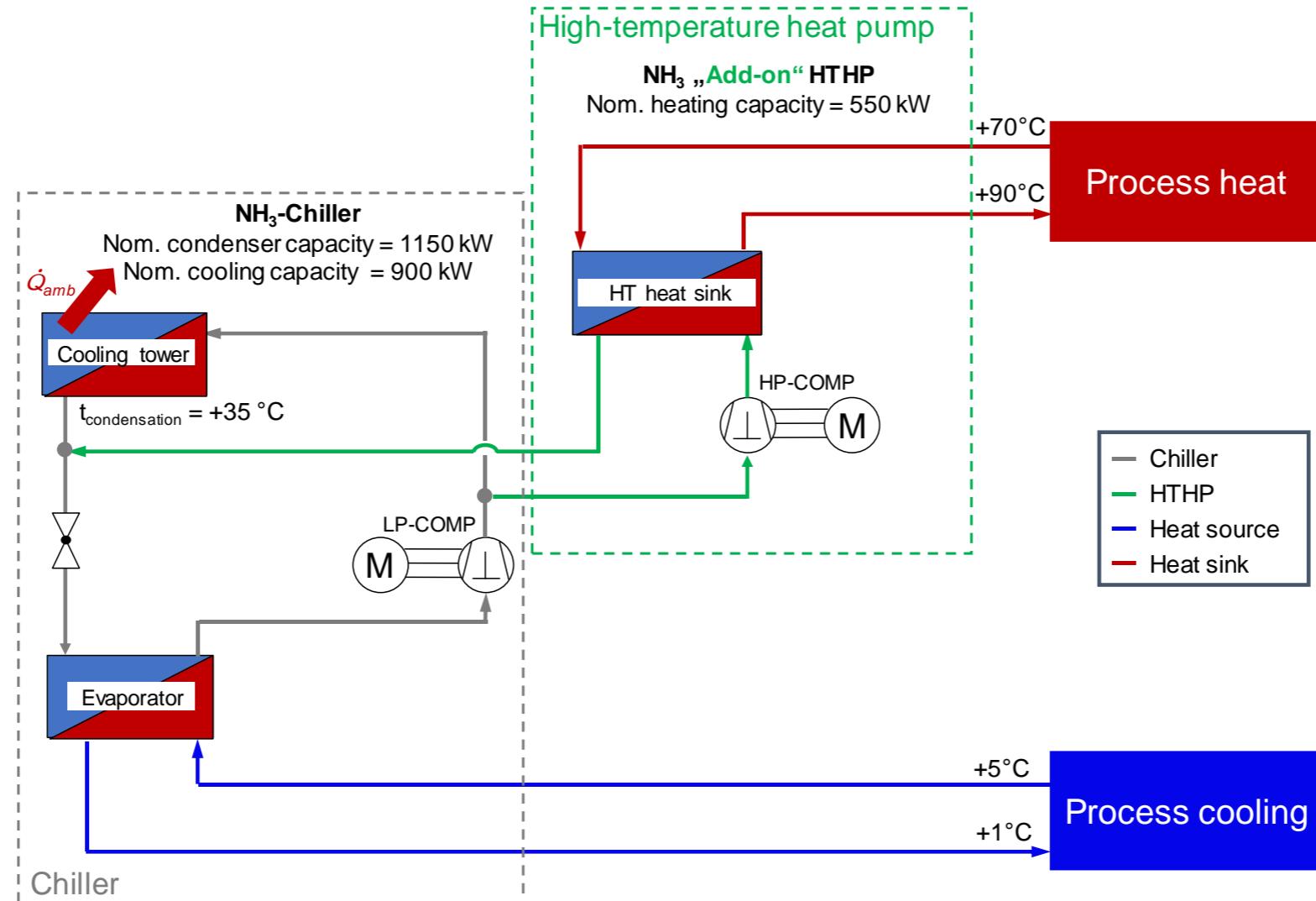
- Waste heat recovery from (existing) chillers
- High CO₂ saving potential
- Substitution of the steam system (gas)



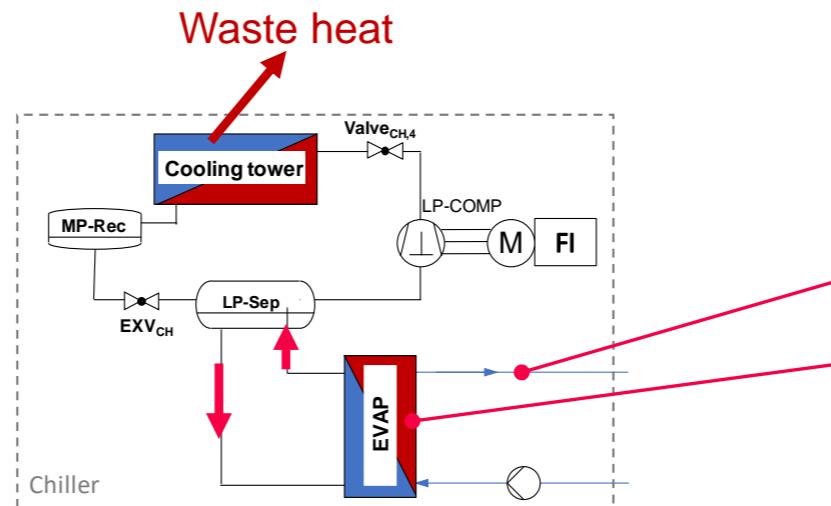
Integration concept: Principle



Integration concept: Principle



System description: Chiller

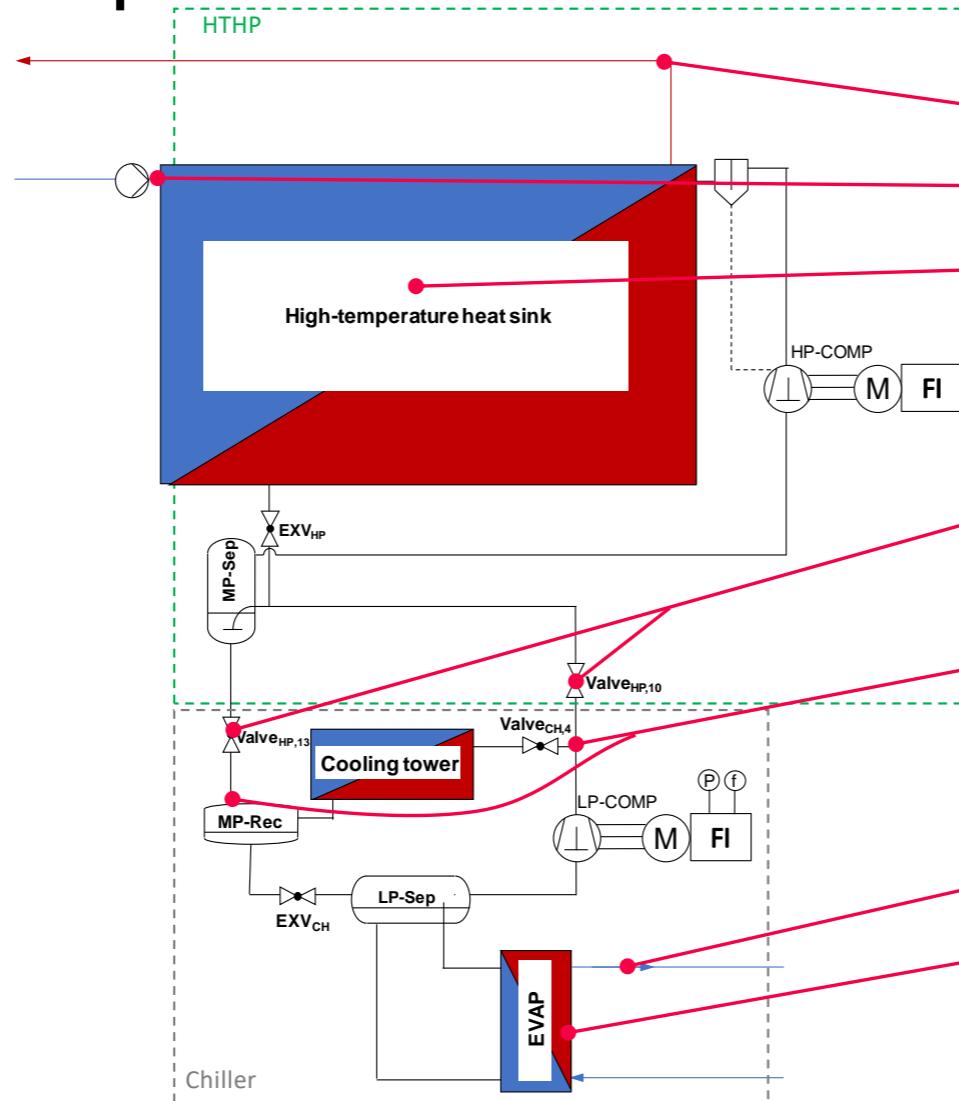


- Conventional refrigeration cycle with NH_3 as refrigerant
- Heat dissipation by means of a cooling tower
- Flooded evaporator with natural circulation
- Supply of “ice-water” at 1 °C
- Max. cooling capacity 900 kW

System description: Chiller

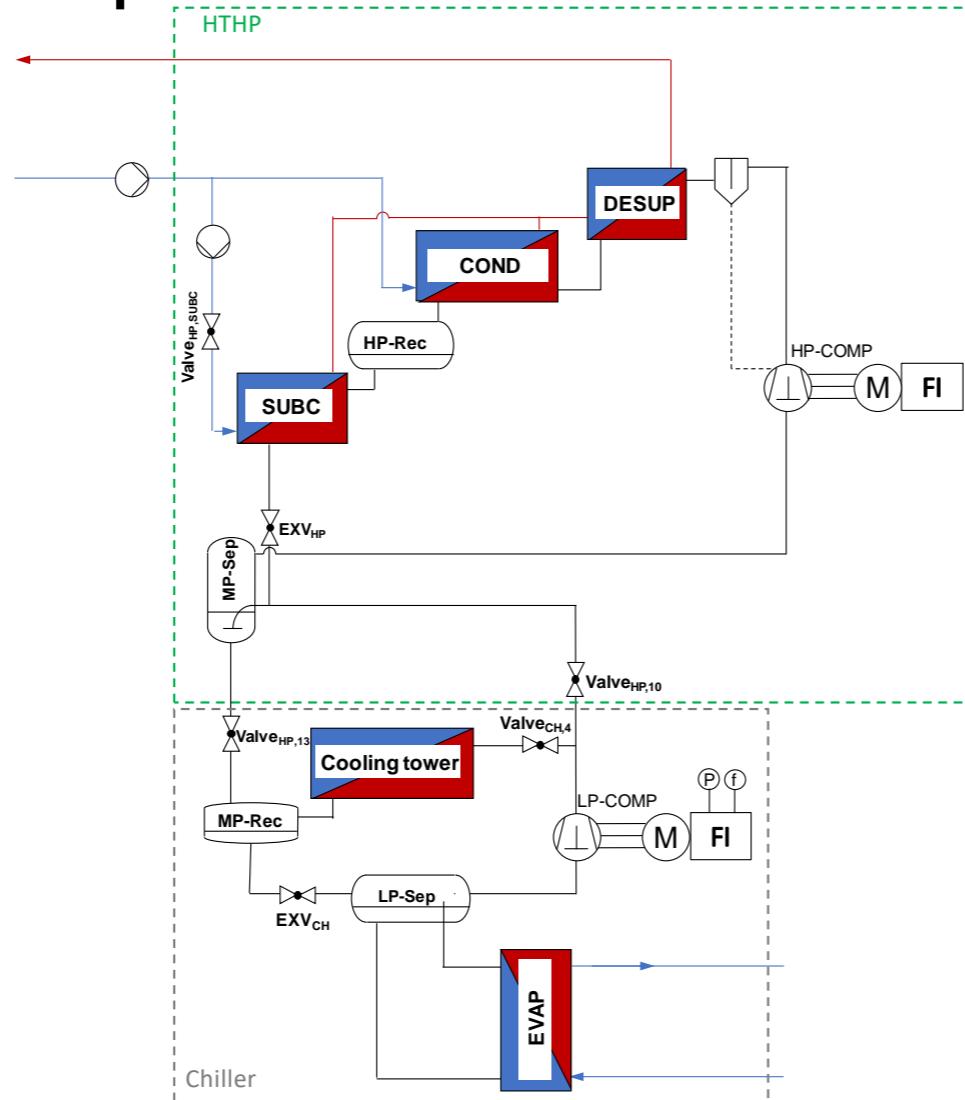


System description: HTHP



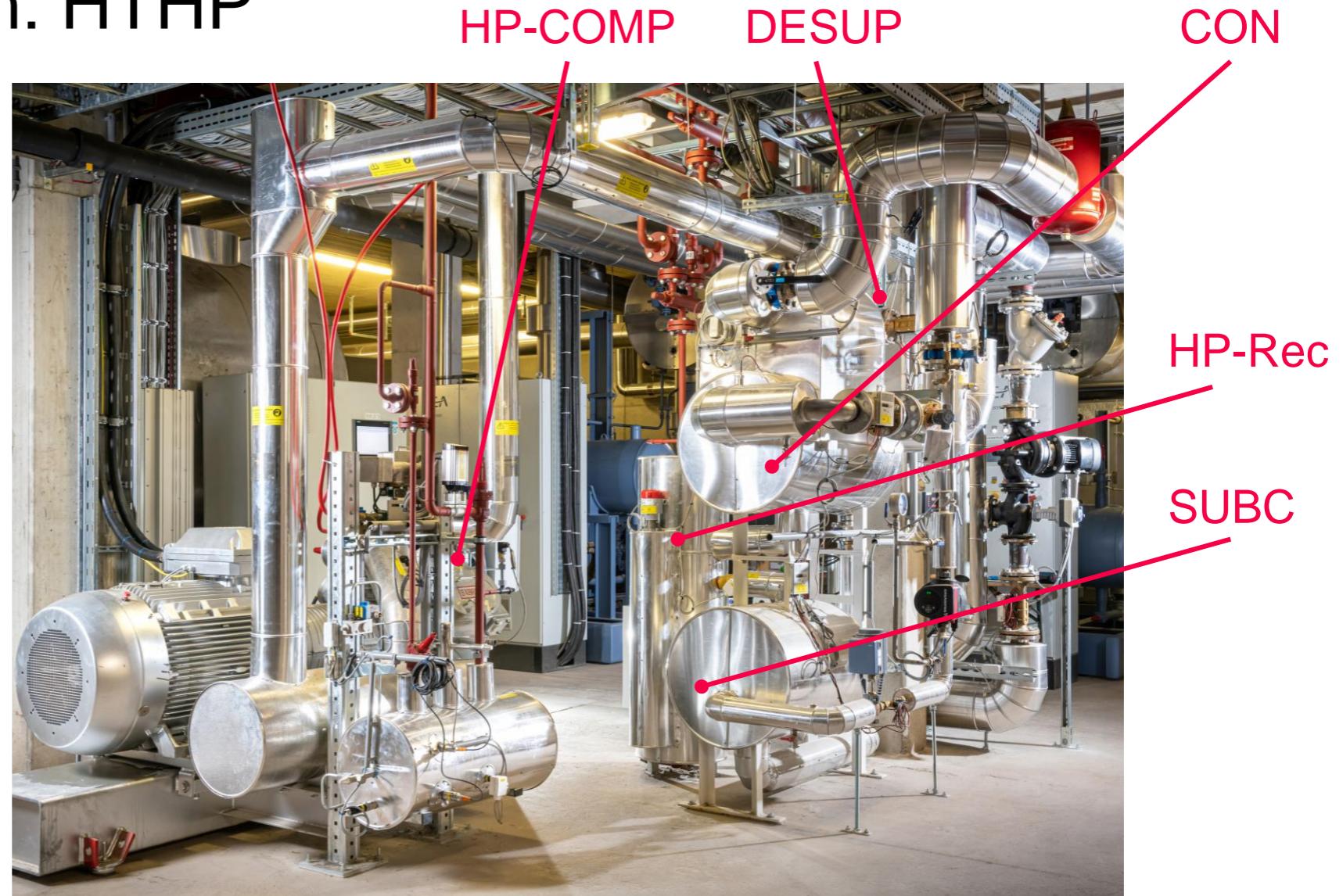
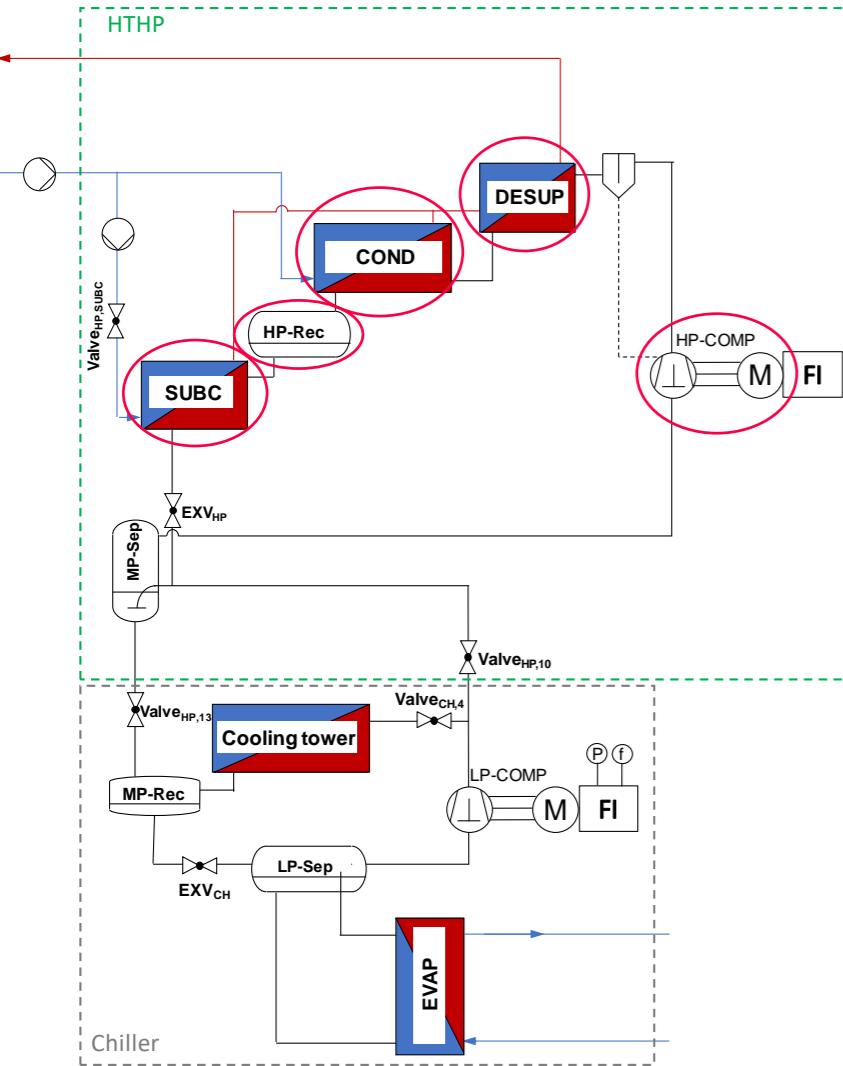
- Water outlet temperature: 75...90 °C
- Water inlet temperature: 60...80 °C
- Max. heating capacity 550 kW
- Independent operation of the chiller guaranteed
- Direct integration of the HTHP into the chiller
- Supply of “ice-water” at 1 °C
- Max. cooling capacity 900 kW

System description: HTHP

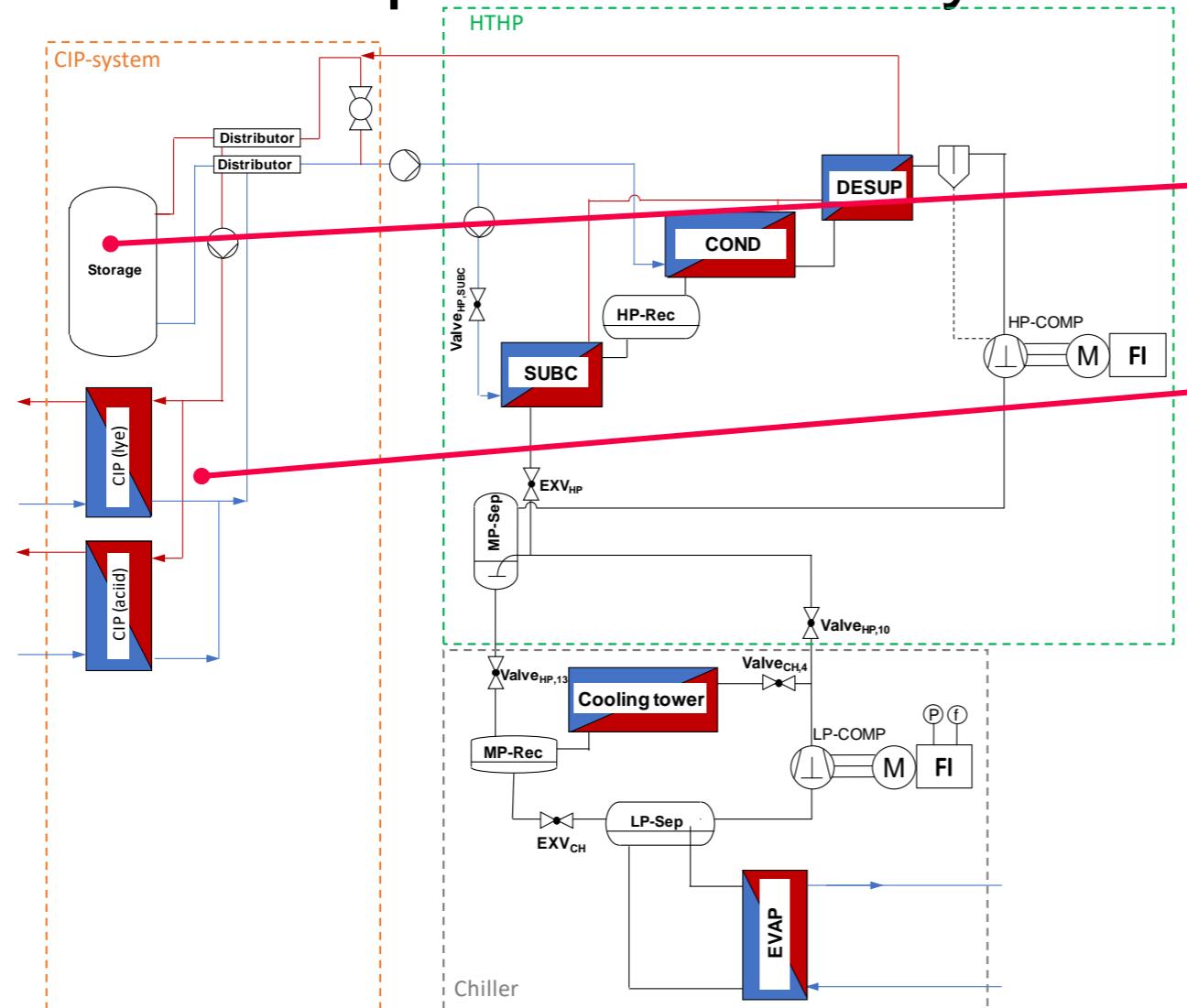


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System description: HTHP

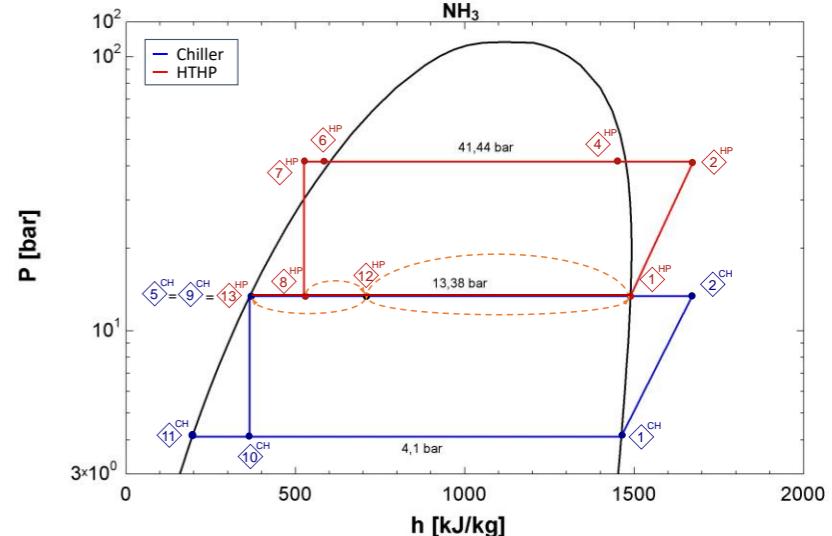
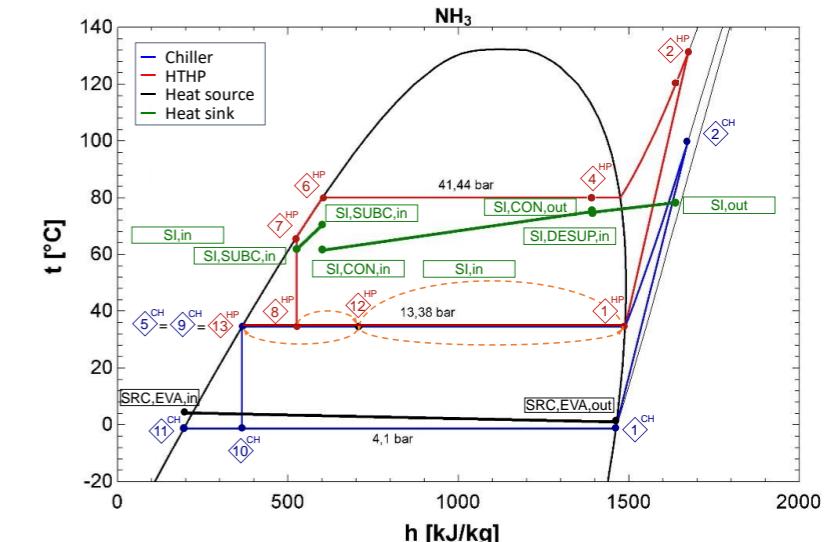
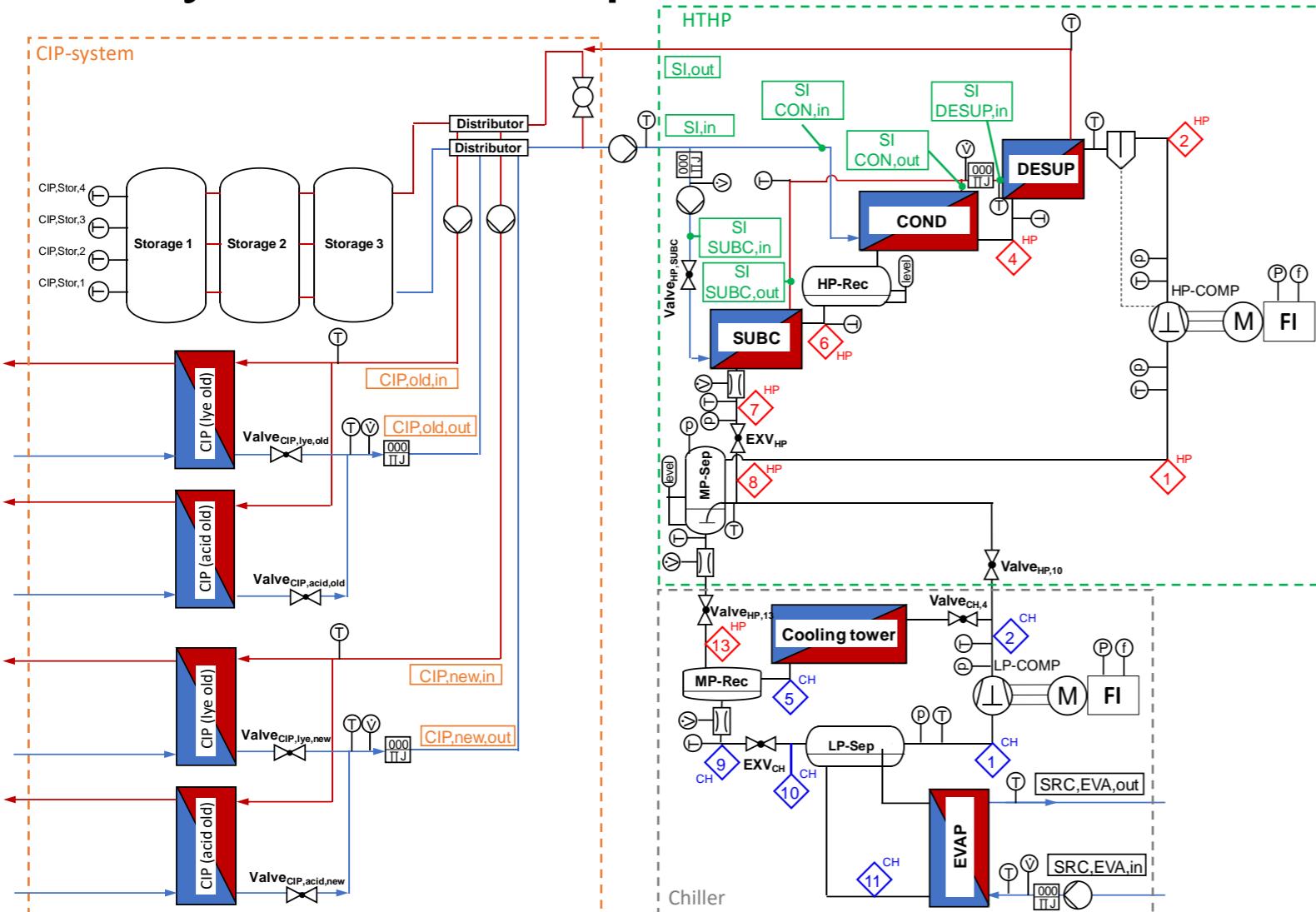


System description: Overall system (simplified)



- 3x4 m³ storage tank to buffer demand peaks
- Supply of a cleaning-in-place (CIP)-system

System description: Measurement equipment



Current status

- Plant already in operation
- Extensive measurement data of the chiller, HTHP and the “CIP-demand” available
- Data analysis tool (stationary offline evaluation) available

- Modelling
 - Set-up of a thermo-physical model of the chiller, HTHP and storage tank(s)
 - Validation of the simulation model with measurement data

Monitoring: Evaluation / Comparison

■ Chiller

$$COP_{CH,c} = \frac{\dot{Q}_{CH,SRC,EVA}}{P_{CH,el}}$$

■ HTHP

$$COP_{HP,h} = \frac{\dot{Q}_{HP,SI}}{P_{HP,el}}$$

$$SPF_{HP,h,\tau} = \frac{\int_{t=0}^{\tau} \dot{Q}_{HP,SI} \cdot dt}{\int_{t=0}^{\tau} P_{HP,el} \cdot dt} = \frac{Q_{HP,SI,\tau}}{W_{HP,el,\tau}}$$

■ System

$$COP_{sys} = \frac{\dot{Q}_{CH,SRC,EVA} + \dot{Q}_{HP,SI}}{P_{CH,el} + P_{HP,el}}$$

■ with:

$$\dot{Q}_{CH,SRC,EVA} = \dot{m}_{CH,SRC,EVA} \cdot (h_{CH,SRC,EVA,in} - h_{CH,SRC,EVA,out})$$

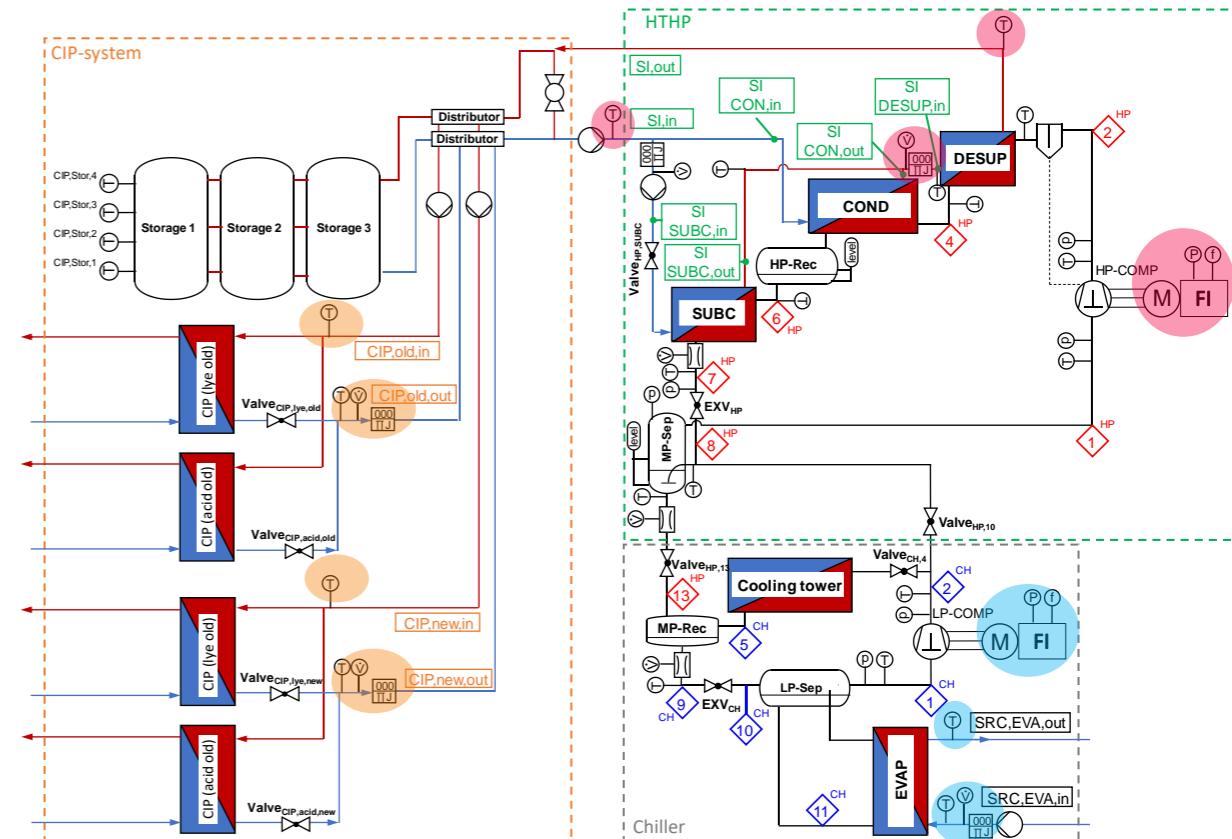
$$\dot{m}_{CH,SRC,EVA} = \dot{V}_{CH,SRC,EVA,in} \cdot \rho_{CH,SRC,EVA,in}$$

$$\dot{Q}_{HP,SI} = \dot{m}_{HP,SI} \cdot (h_{HP,SI,out} - h_{HP,SI,in})$$

$$\dot{m}_{HP,SI} = \dot{V}_{HP,SI,DESUP} \cdot \rho_{HP,SI,DESUP,in}$$

$$\dot{Q}_{CIP} = \dot{m}_{CIP,old} \cdot (h_{CIP,old,in} - h_{CIP,old,out}) + \dot{m}_{CIP,new} \cdot (h_{CIP,new,in} - h_{CIP,old,out})$$

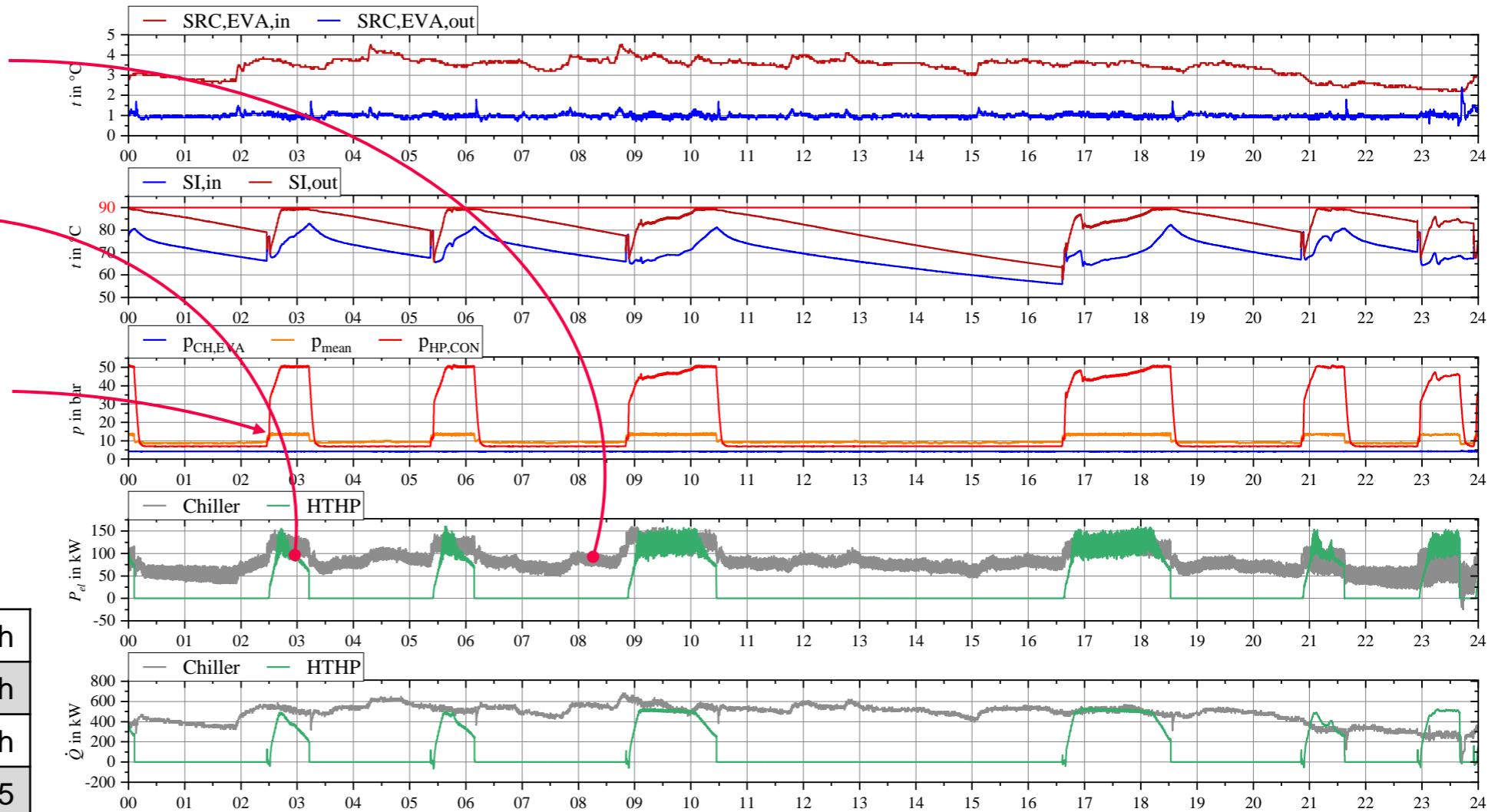
$$\dot{m}_{CIP,old} = \dot{V}_{CIP,old,out} \cdot \rho_{CIP,old,out} \quad \dot{m}_{CIP,new} = \dot{V}_{CIP,new,out} \cdot \rho_{CIP,new,out}$$



$$Q_{CIP,\tau} = \int_{t=0}^{\tau} \dot{Q}_{CIP} \cdot dt$$

„Monitoring“ - Exemplary day of operation ($t_{HP,SI,out,target} = 90^\circ\text{C}$)

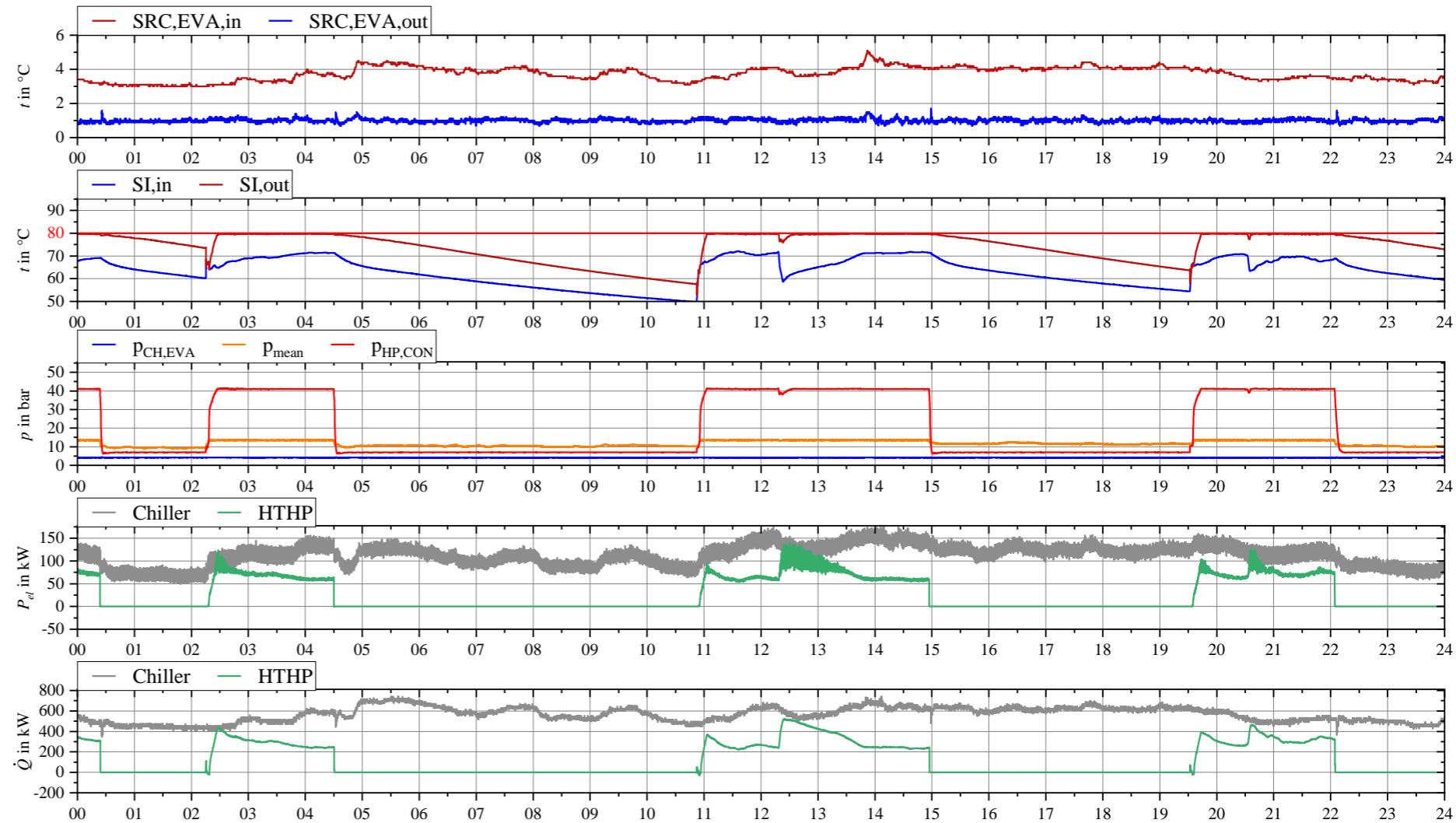
- Continuous operation of the chiller
- Operating of the HTHP on demand
- Medium-pressure level raised in HTHP operation



$\tau = 1 \text{ day}$	$Q_{CIP,\text{day}}$	2685 kWh
	$Q_{HP,SI,\text{day}}$	2733 kWh
	$W_{HP,el,\text{day}}$	659 kWh
	$SPF_{HP,h,\text{day}}$	4.15

„Monitoring“ - Exemplary day of operation ($t_{HP,SI,out,target} = 80^\circ C$)

- In comparison to $t_{HP,SI,out,target} = 90^\circ C$ at $80^\circ C$:
 - Less on/off cycles
 - Longer operating time of each “on/off” cycle
 - Higher SPF



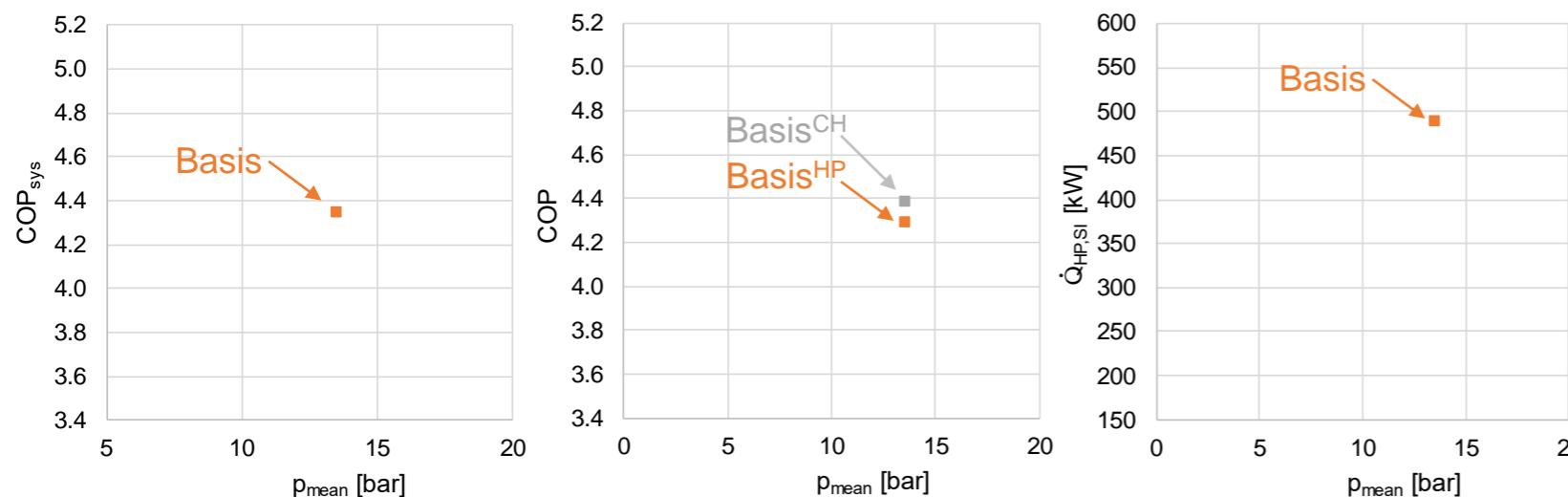
$\tau = 1 \text{ day}$	$Q_{CIP,\text{day}}$	2770 kWh
	$Q_{HP,SI,\text{day}}$	2958 kWh
	$W_{HP,\text{el},\text{day}}$	650 kWh
	$SPF_{HP,h,\text{day}}$	4.55

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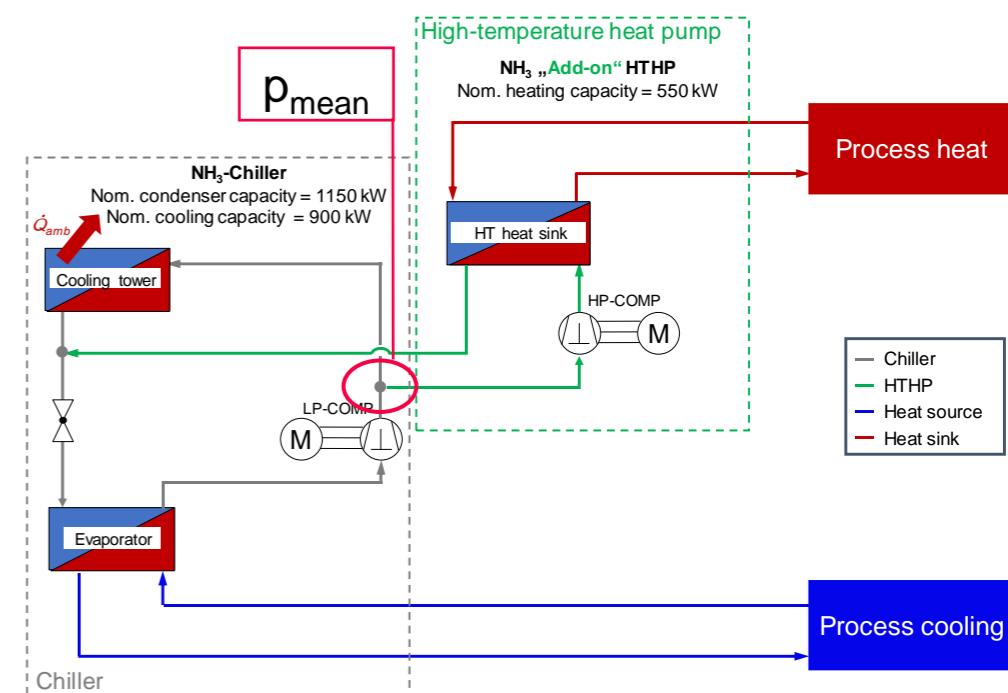
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Interaction of the chiller & HTHP - p_{mean}

- Medium pressure level (p_{mean}) influences the capacities and efficiencies of the chiller & HTHP



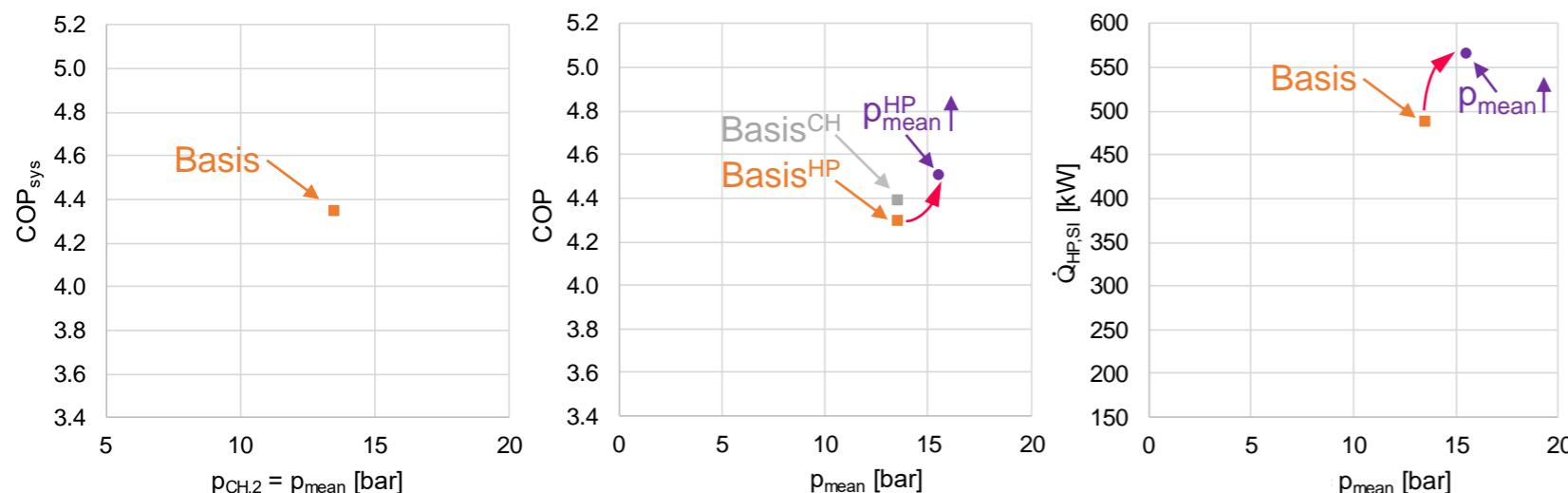
	Basis
p_{mean}	$\approx 13.5 \text{ bar}$ ($t_{\text{cond}} \approx 35^\circ\text{C}$)
$\dot{V}_{\text{HP,SI,in}}$	$\approx 25 \text{ m}^3/\text{h}$
$t_{\text{HP,SI,in/out}}$	$\approx 62 / 78^\circ\text{C}$



Source: Wagner et al. (2021)

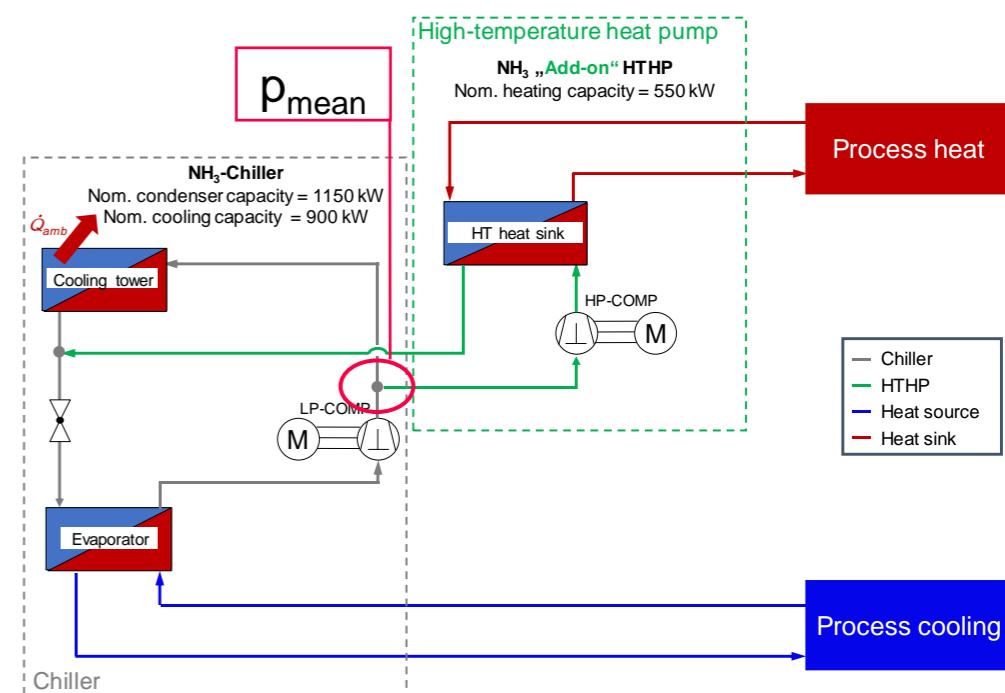
Interaction of the chiller & HTHP - p_{mean}

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■ Increase of the heating capacity and efficiency of the HTHP

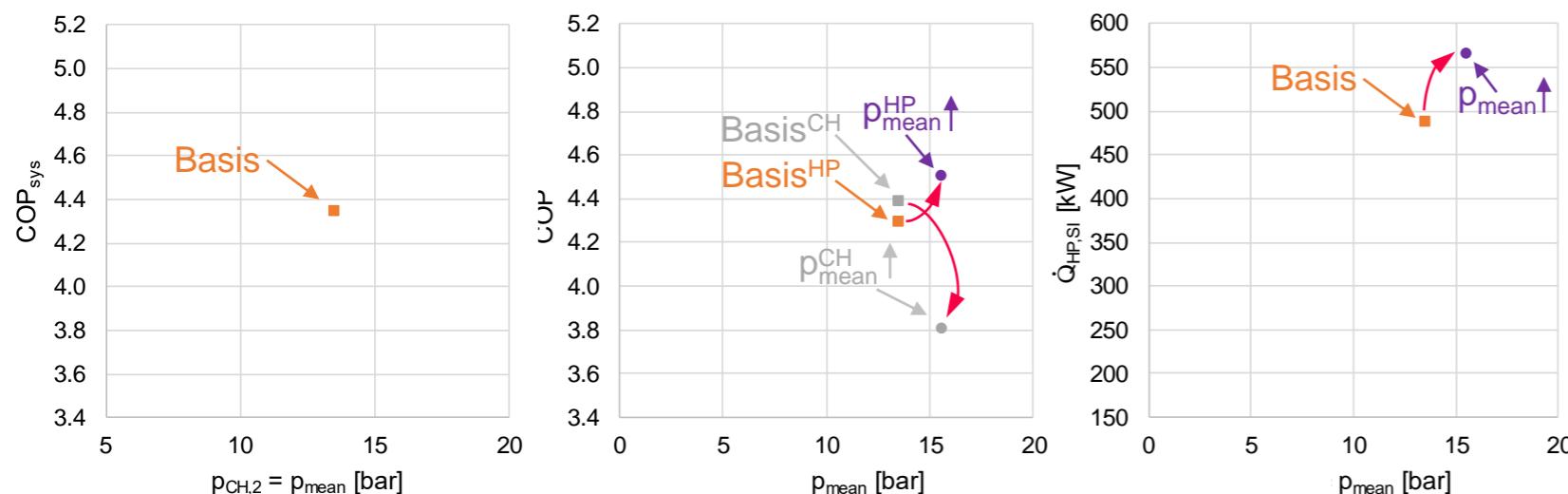
	Basis	$p_{\text{mean}} \uparrow$
p_{mean}	$\approx 13.5 \text{ bar } (t_{\text{cond}} \approx 35^\circ\text{C})$	$\approx 15.5 \text{ bar } (t_{\text{cond}} \approx 40^\circ\text{C})$
$\dot{V}_{\text{HP,SI,in}}$	$\approx 25 \text{ m}^3/\text{h}$	
$t_{\text{HP,SI,in/out}}$	$\approx 62 / 78^\circ\text{C}$	$\approx 65 / 84^\circ\text{C}$



Source: Wagner et al. (2021)

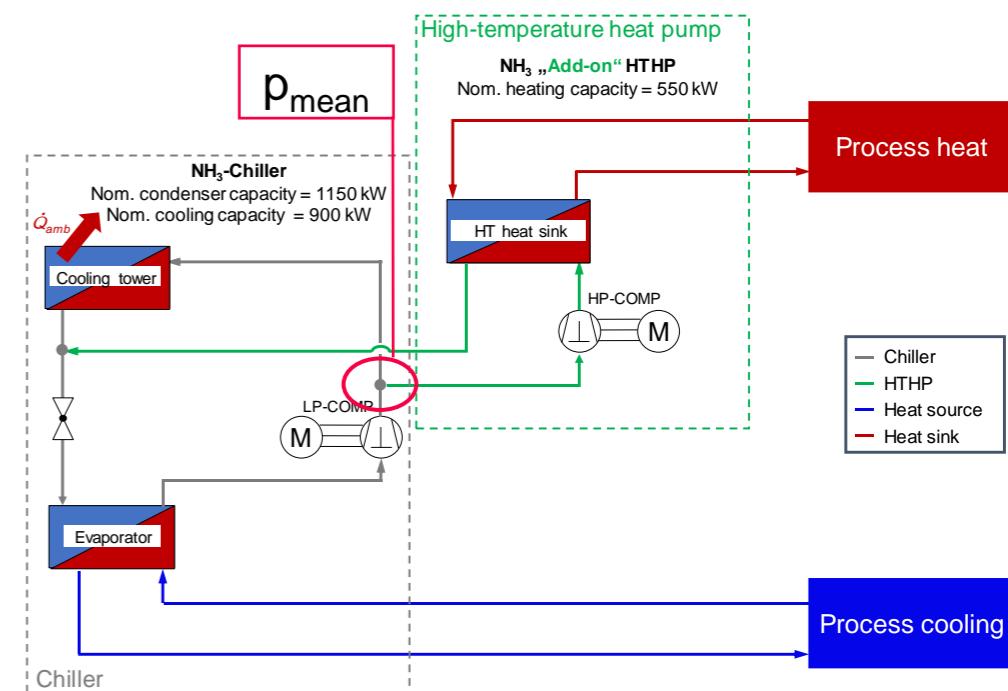
Interaction of the chiller & HTHP - p_{mean}

- Medium pressure level (p_{mean}) influences the capacities and efficiencies of the chiller & HTHP



- $p_{\text{mean}} \uparrow$
- Increase of the heating capacity and efficiency of the HTHP
 - Decrease of the efficiency of the chiller

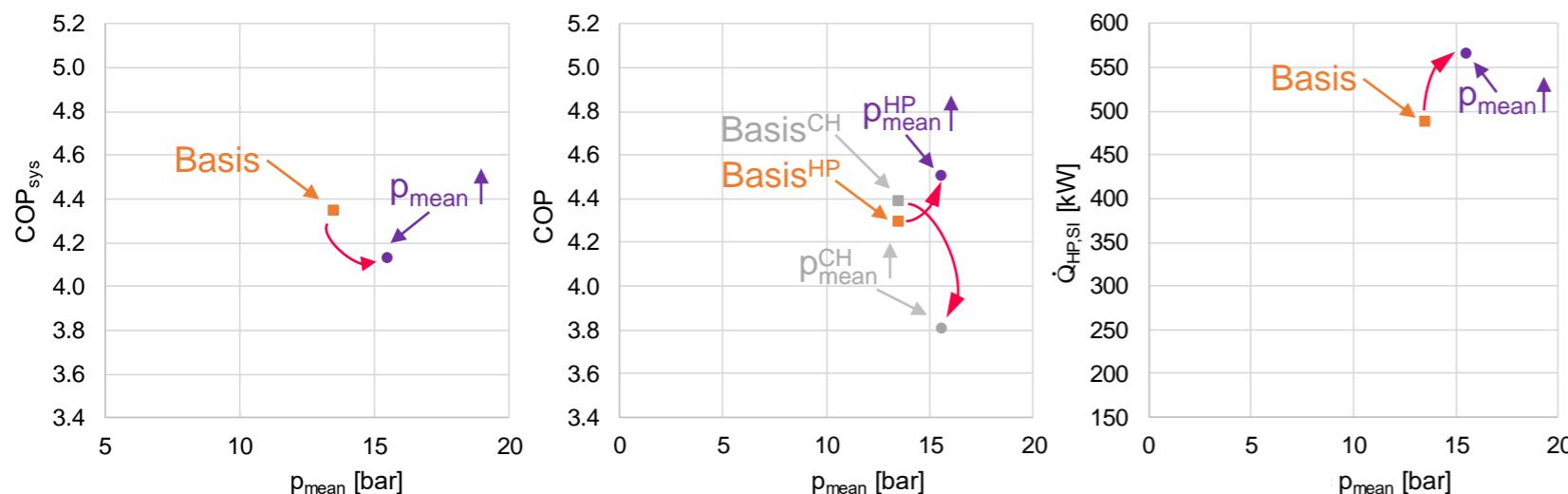
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Source: Wagner et al. (2021)

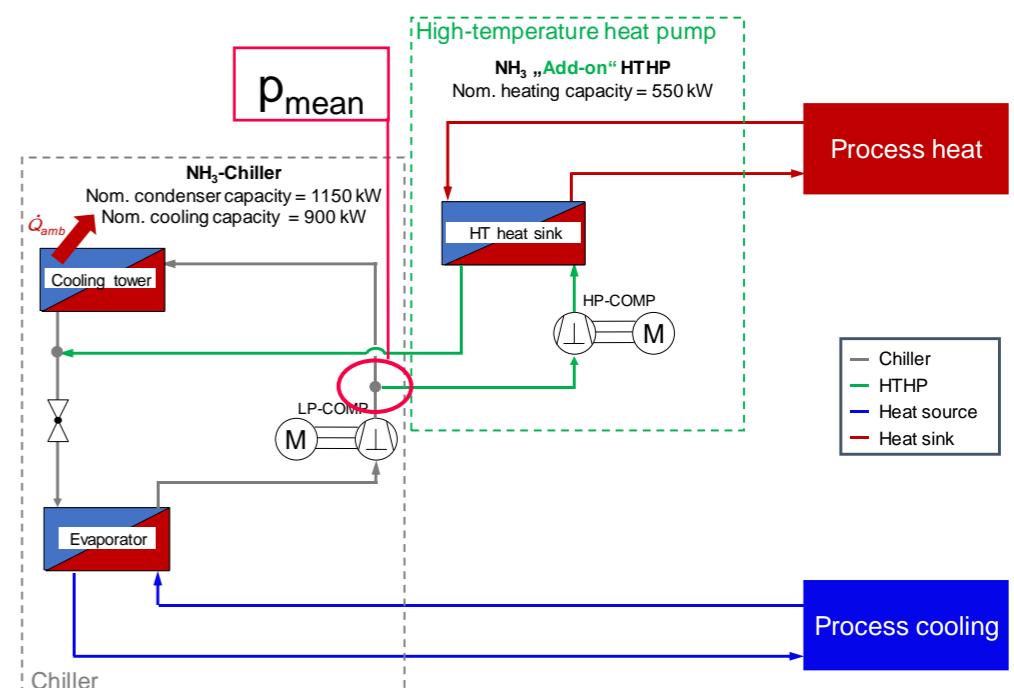
Interaction of the chiller & HTHP - p_{mean}

- Medium pressure level (p_{mean}) influences the capacities and efficiencies of the chiller & HTHP



- $p_{\text{mean}} \uparrow$
- Increase of the heating capacity and efficiency of the HTHP
 - Decrease of the efficiency of the chiller
 - Optimum of the system efficiency
 - Influence on the overall system (incl. CIP and cooling demand)?

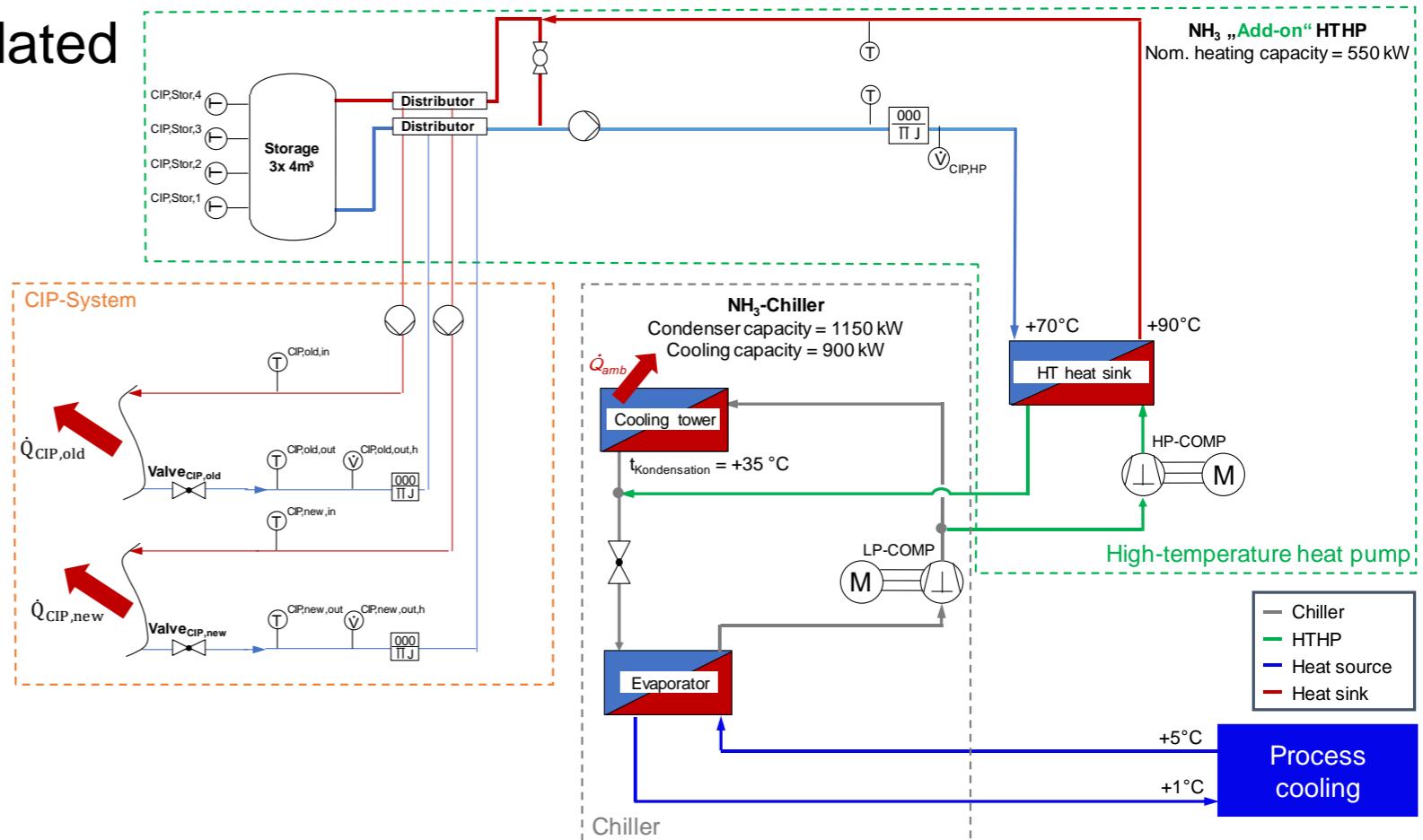
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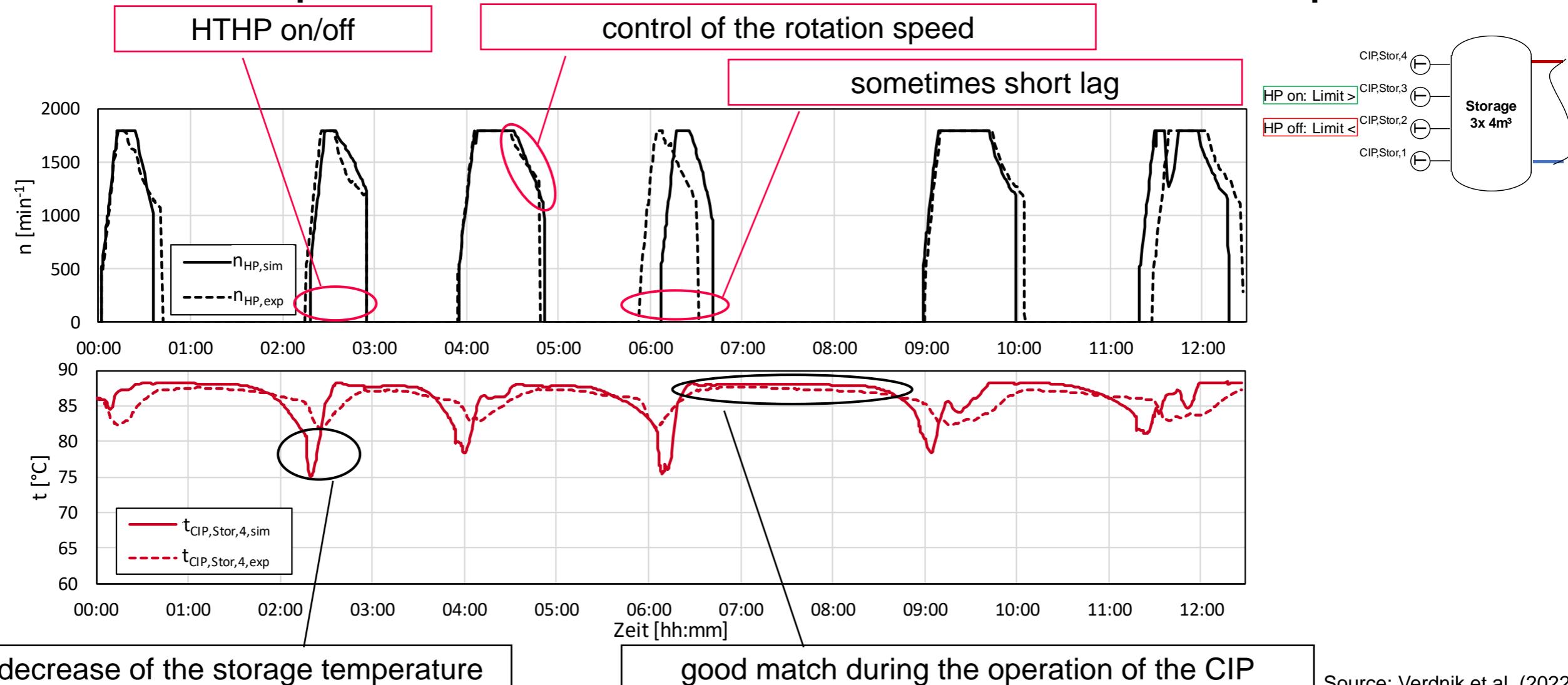
Source: Wagner et al. (2021)

Transient simulation model

- Dymola / Modelica: TIL Suite with adaptions
- Simulation studies with a validated model of the chiller, HTHP and storage tank
- Focus on:
 - Storage tank (charging / discharging)
 - Interaction of the system (chiller & HTHP)

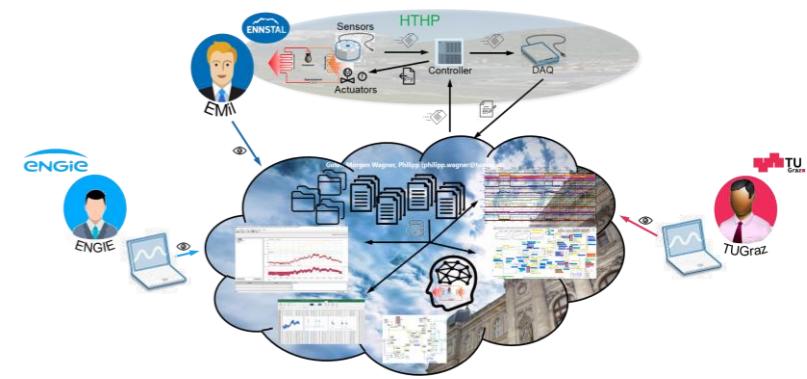


Transient operation of the HTHP – simulation vs. experiment



Outlook (incl. WP5 activities)

- Monitoring
 - Further measurement data analysis and optimization of the operation
 - Evaluation of the operation of the CIP-system
- Modelling and Simulation
 - Integration of possible further consumers (e.g. hot water, pasteurization, ...)
 - Optimisation (interaction of chiller and heat pump, shorter start-up duration, new components, ...)
 - Increasing of the plant efficiency by means of better load response / predictive control
- Smart data
 - Clear and simple visualization of the measurement data (for all involved partners)
 - Simplified and automatic data preparation for further use (e.g. measurement data evaluation (energy meter, efficiency, ...), ...)
 - Communication between the plant and the simulation model



Award winning demonstration project

- Energy Globe Styria Award
 - Winner in the category “Industry”
- Energy Globe Austria Award
 - Winner in the category “Fire”

Energy Globe Austria



Energy Globe Styria
Award ceremony



Energy Globe Austria – Award ceremony



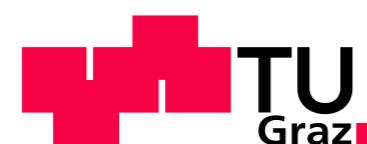
Publications

- Wagner, P., Verdnik, M., Rieberer, R., Demmerer, T., Blaser, M., 2021. High-temperature ammonia heat pump as an add-on to an existing chiller. Proc. 9th IIR Conference: Ammonia and CO₂ Refrigeration Technologies, Ohrid.
- Wagner, P., Verdnik, M., Rieberer, R., Demmerer, T., Blaser, M., 2021. Add-on NH₃-Hochtemperatur-Wärmepumpe zur Abwärmenutzung einer bestehenden Kälteanlage. Proc. Deutsche Kälte-Klima-Tagung 2021, Dresden.
- Verdnik, M., Wagner, P., Wernhart, M., Rieberer, R., 2022. Modellbasierte Analyse einer NH₃-HTWP in einem Molkereibetrieb. Proc. Deutsche Kälte-Klima-Tagung 2022, Magdeburg.

Acknowledgments / Contact



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René Rieberer

Institute of Thermal Engineering
Graz University of Technology

rene.rieberer@tugraz.at

Inffeldgasse 25/B, A-8010 Graz

www.iwt.tugraz.at



Mathias BLASER

EQUANS Kältetechnik GmbH

Mathias.BLASER@equans.com

Lange gasse 19

6923 Lauterach, Austria

www.equans.at