MHPS

Mitsubishi Hitachi Power Systems

The Future of Gas Turbine Technology
9th International Gas Turbine Conference
10-11 October 2018, Brussels, Belgium

HIGH TEMPERATURE HEAT PUMP

A NOVEL APPROACH TO INCREASE FLEXIBILITY AND EFFICIENCY OF CCGT AND CHP POWER PLANTS (PUMP-HEAT project)

Classification Level: Public

Presenter: Sven Bosser

MHPS Europe

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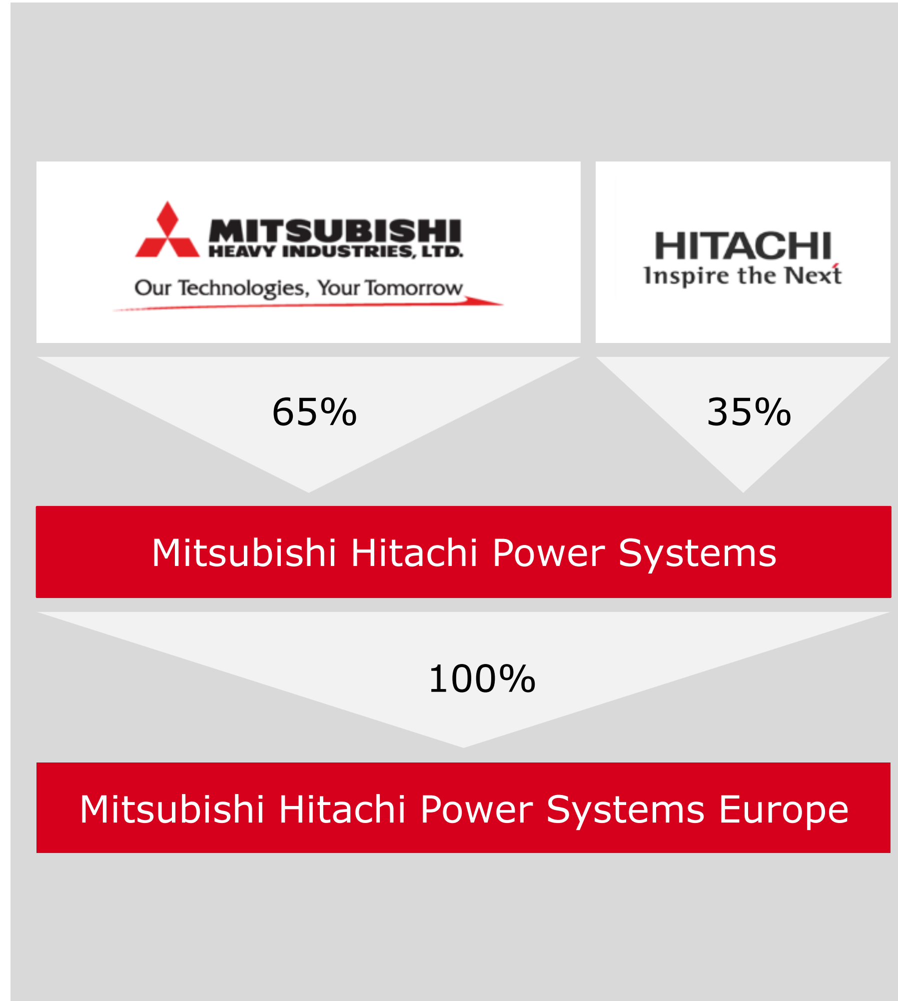
MHPS Overview

- Start of joint venture: 1 February 2014
- HQ Location: Yokohama, Japan
- Number of MHPS Group companies: 65
- Total workforce: approx. 19,500
- Major operations / businesses:
  - Thermal Power Generation Systems
  - Geothermal Power Generation Systems
  - Environmental Systems
  - Fuel Cells
- Capital: ¥100b / $892m *(USD/JPY: 112)*



MHPS Europe Overview

- HQ Location London
- Workforce 1,200
- Market Region Europe, Middle East, Africa (EMEA)

Gas fired power plants

Turnkey services and industrial plants

Coal fired power plants

Green technologies

Extensive MHPS Network in Europe, Middle East & Africa

United Kingdom

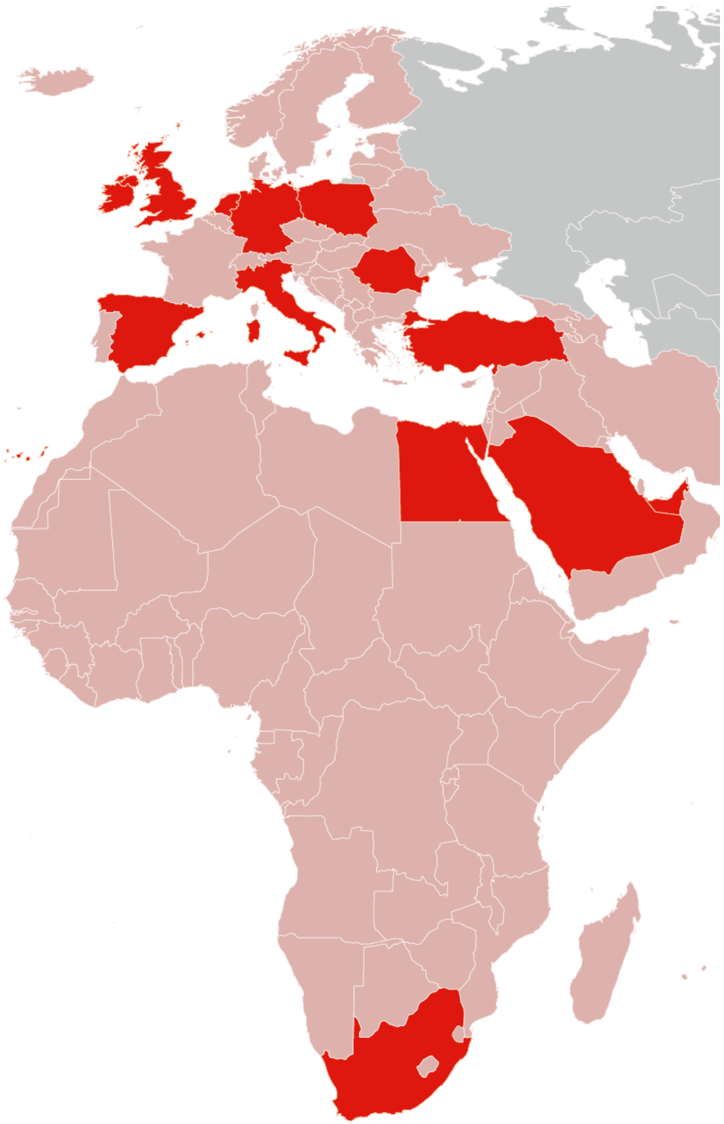
- Headquarters
- Engineering support
- Service contracts
- New plant business
- Spare parts stock and management
- LTSA program
- Field service hub

Germany

- New plant business
- Boiler manufacturing
- Delivery of key equipment and components
- Service
- Pressure parts manufacturing

MHPS Africa

- Plant Engineering
- Service



EMEA Market Region
MHPS Presences

Front offices with engineering and commercial support

- Netherlands
- Spain
- Italy
- Turkey
- Ireland
- Poland
- Egypt
- Romania

Sister companies

ATLA (Italy)

MHPS Saudi Arabia

MHPS Middle East (UAE)

- Rotating equipment repair
- GT hot parts inspection and repair
- Field service

Product Line Up

Combined Cycle Gas Turbine Plants

Boilers

Integrated Coal Gasification Combined Cycle (IGCC)

Environmental Plants SCR (DeNOX) Systems / Flue Gas Desulfurization

Gas Turbines

Generators

Coal Power Plants

Geothermal Power Plants

Steam Turbines

Peripheral Equipment

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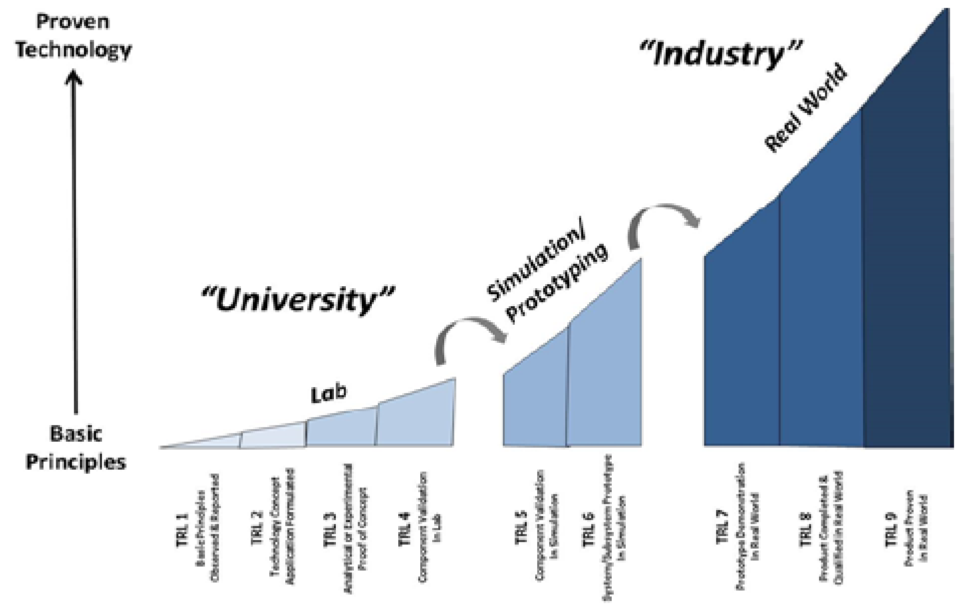
Definition of High Temperature for Industrial Heat Pumps

1. What is a high temperature for an industrial heat pump ?



Non-representative questionnaires:

- Condensation at 80°C → TRL 8 – 9
- Condensation at 100°C → TRL 6 – 8
- Condensation at 120°C → TRL 6 – 7
- Condensation at 150°C → TRL 4 – 6

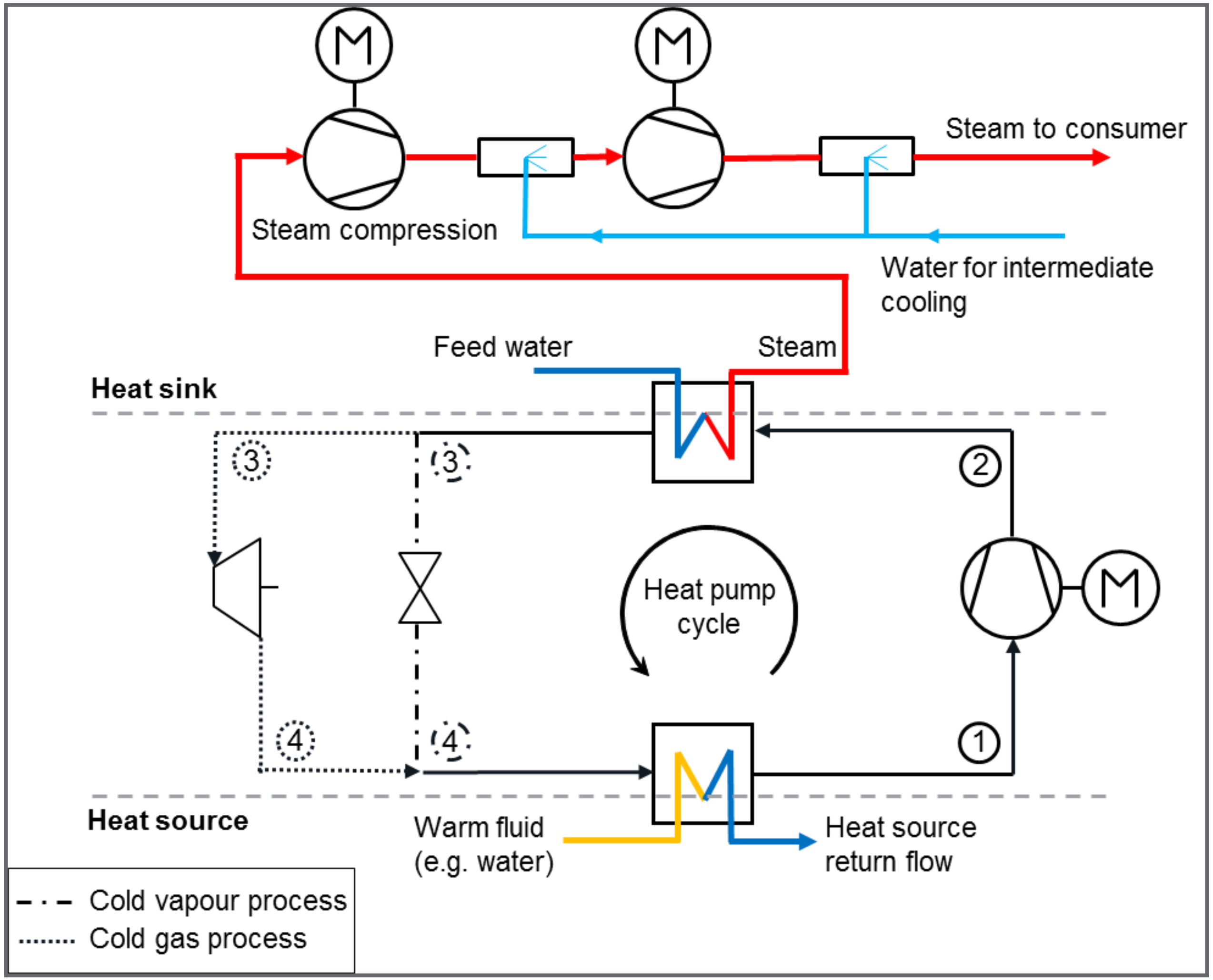
Conclusion (for today): heat sink temperature above 100°C can be considered as high temperature heat pumps (higher as industrial standard)

SINTEF

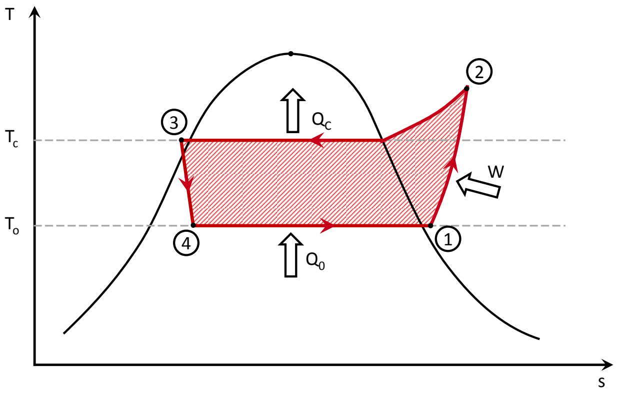
Source: Book of presentations of the International Workshop on High Temperature Heat Pumps. / Elmegaard, Brian (Editor); Zühlsdorf, Benjamin (Editor); Reinholdt, Lars (Editor); Bantle, Michael (Editor). Kgs. Lyngby : Technical University of Denmark (DTU), 2017. 176 p. (Link)

Basic Principle of High Temperature Heat Pump (HTHP)

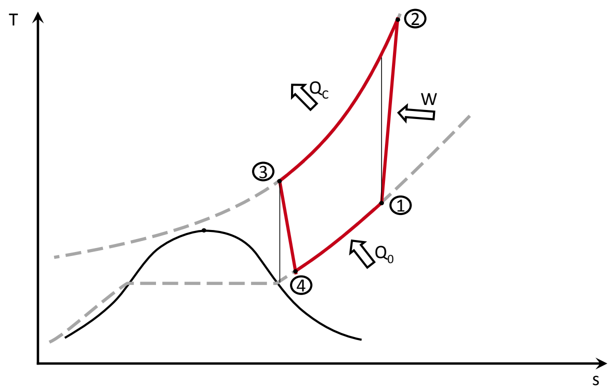
Schematic process flow diagram of the HTHP:



Cold vapour process:



Cold gas process:



Motivation for Development of HTHP for Steam Production

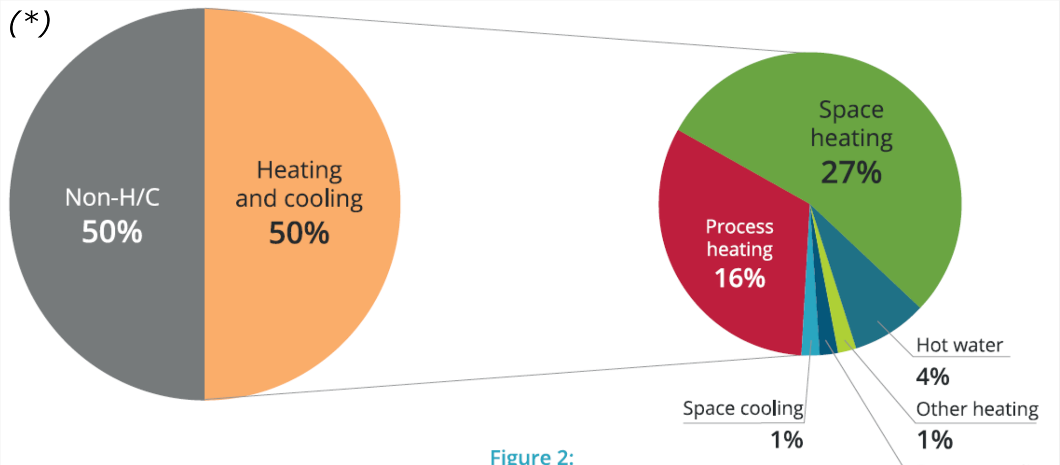


Figure 1:
Total final energy in 2015 (EU28)

Figure 2:
H&C final energy by
end-use in 2015 (EU28)

Europe consumes **half of its energy** for heating and cooling purposes. **16%** is for process heating.

Within industry, **process heating is most relevant**, as well as most challenging to decarbonise. **More than 21%** of the thermal energy is in the appropriate temperature range for a HTHP of **100–350°C**.

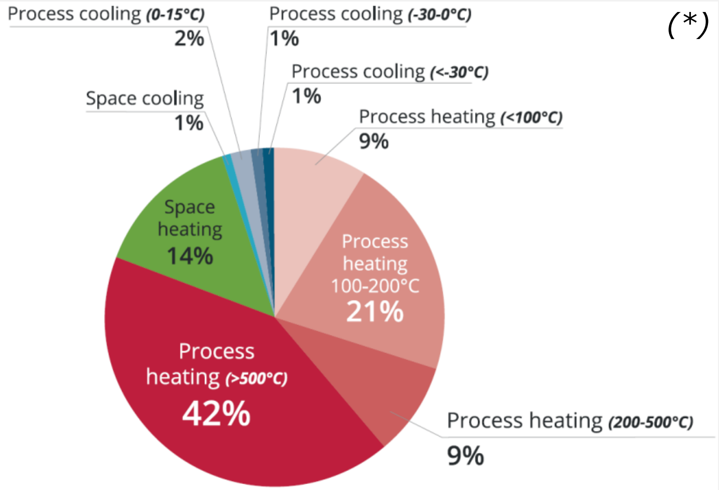


Figure 6: Industry final energy demand end-use (EU28, 2015)

(*) Source: Heating and Cooling – facts and figures, Heat Roadmap Europe 2050 – A low-carbon heating and cooling strategy; last update June 2017 (Link)

Motivation for Development of HTHP for Steam Production

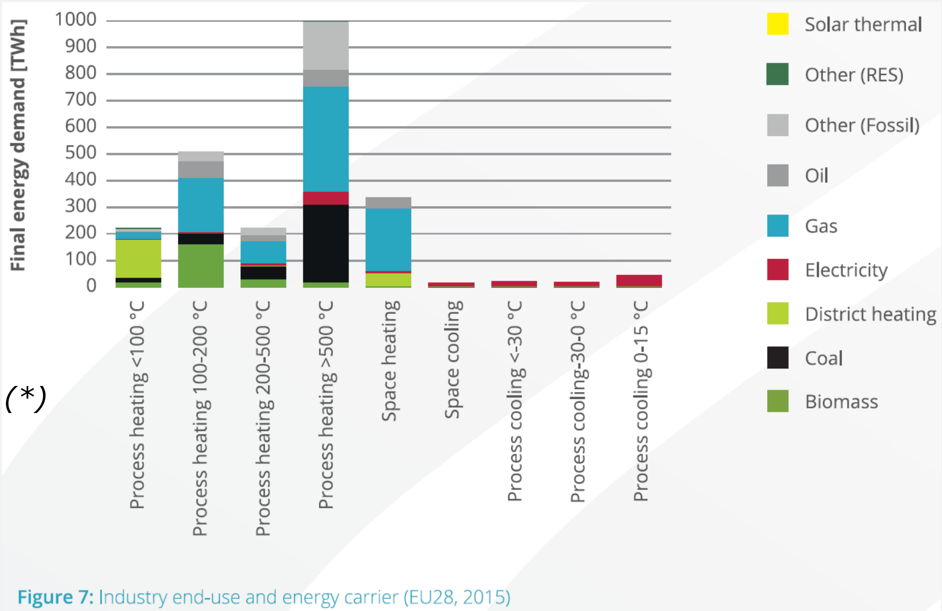
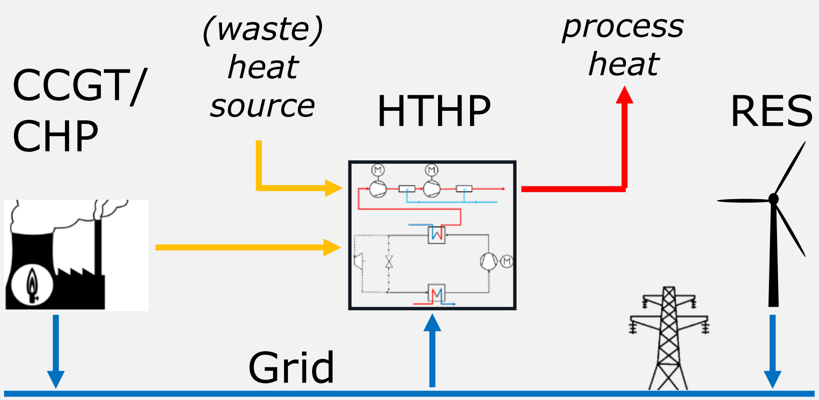


Figure 7: Industry end-use and energy carrier (EU28, 2015)

Most of the thermal energy in the temperature range of 100-350°C is produced with **fossil fuels**. The **HTHP** can use electricity from renewable energies and waste heat for **low-carbon heat production**.

In addition, HTHP can be coupled with **CCGT/CHP** power plants for a more efficient energy system **for electricity and heat production**.



(*) Source: Heating and Cooling – facts and figures, Heat Roadmap Europe 2050 – A low-carbon heating and cooling strategy; last update June 2017 (Link)

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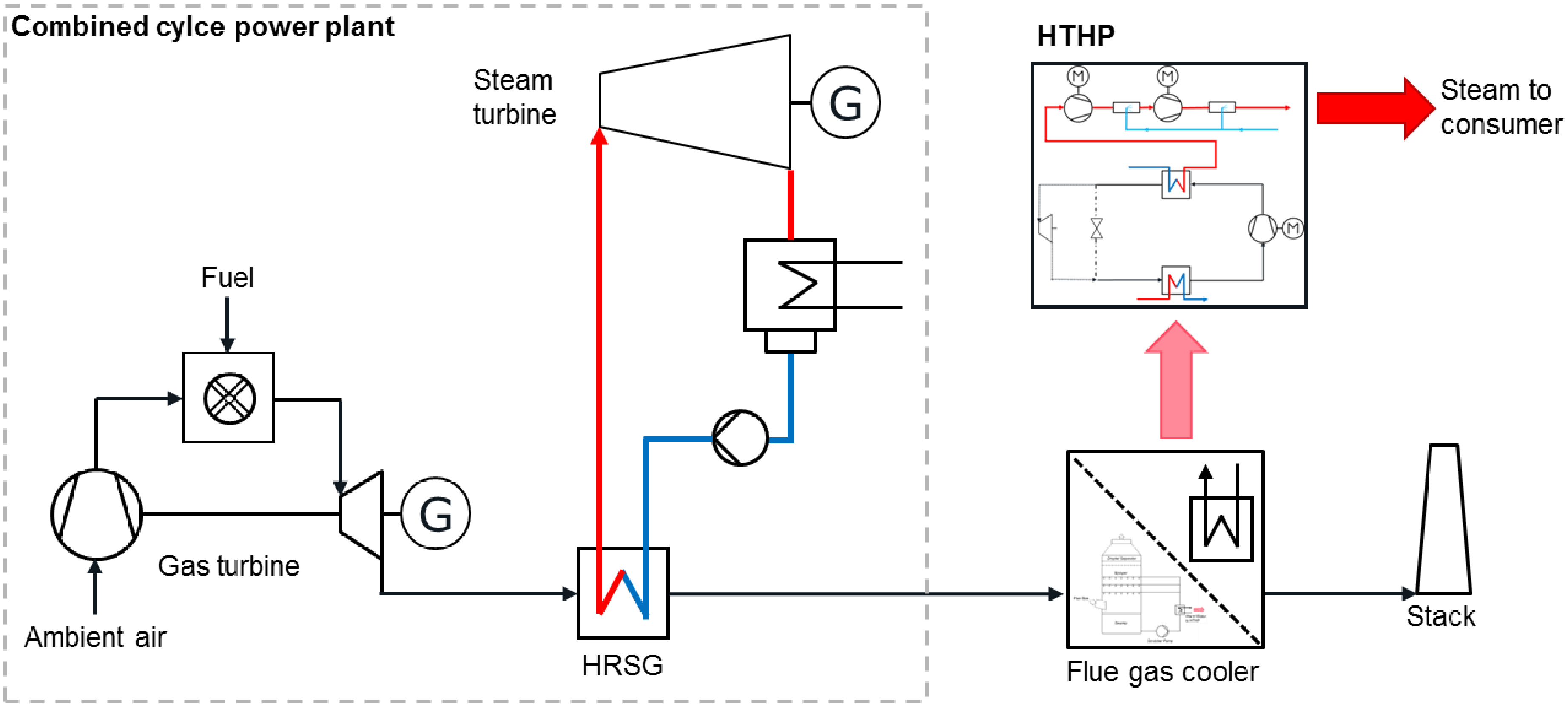
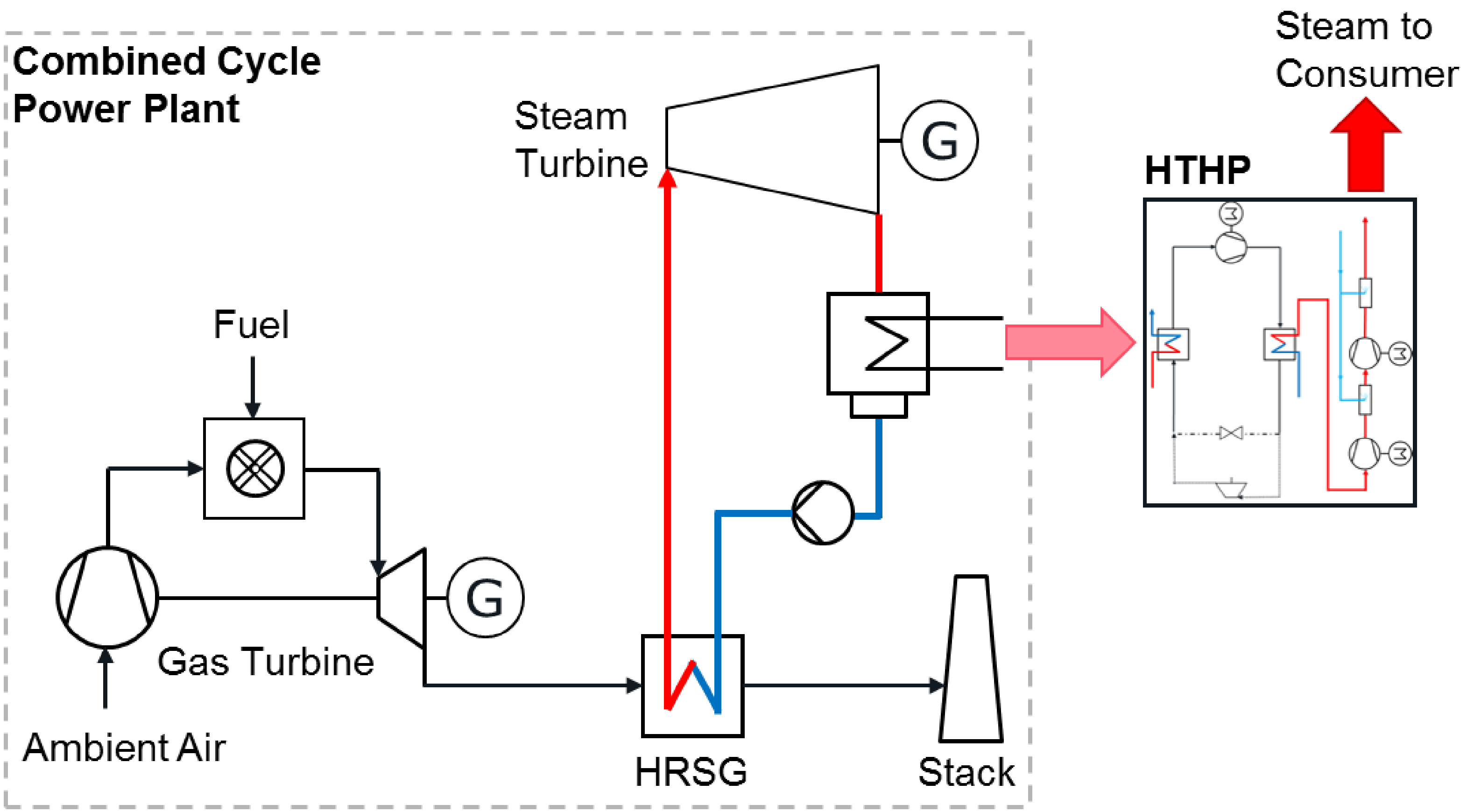
Layout Option HTHP 1 – Heat Recovery from Flue Gas

- Recovery of sensible and latent heat from the hot flue gases after the heat recovery steam generator (HRSG) of the CCGT power plant.
- Flue gas cooler designed as indirect heat exchanger or as spray cooler.
- Minimum allowable flue gas temperature has to be considered.



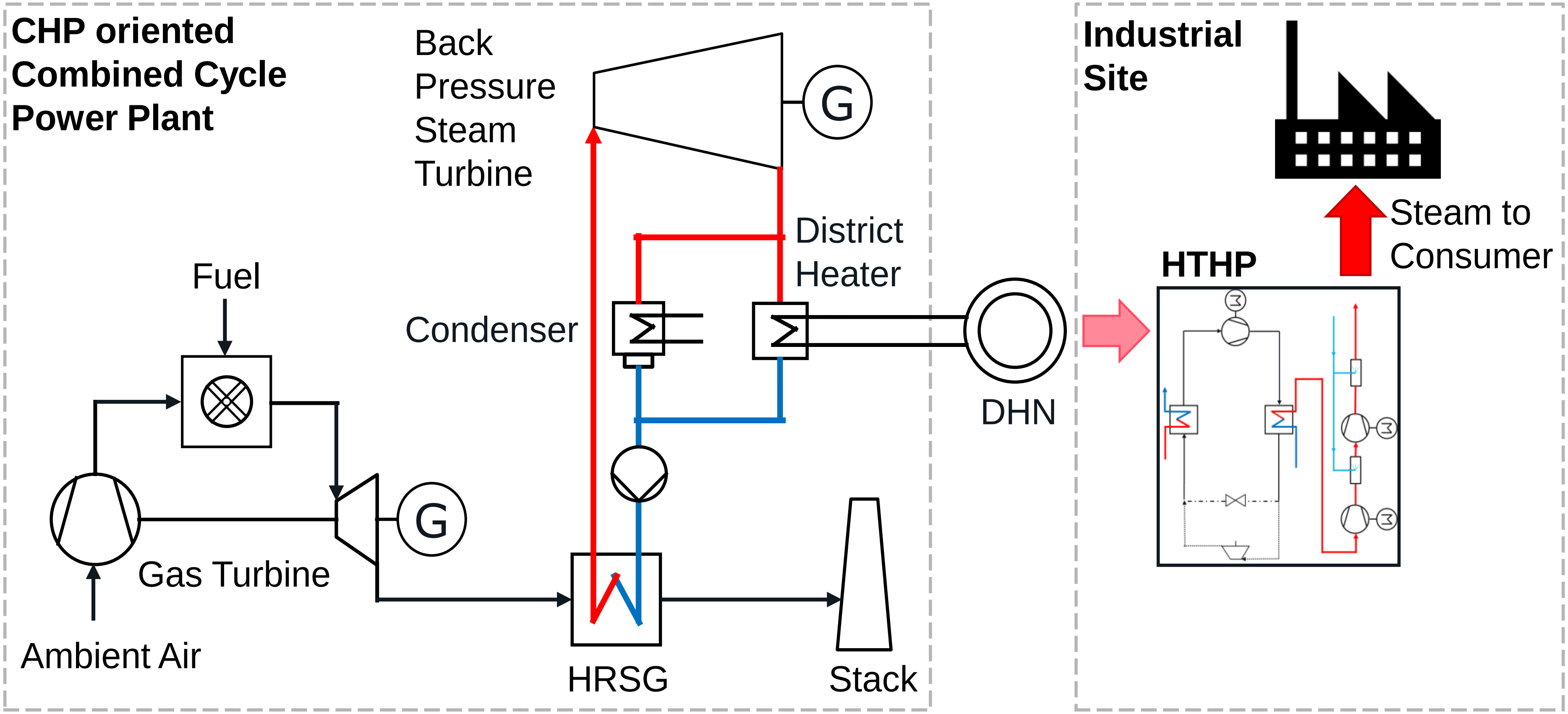
Layout Option HTHP 2 – Heat Recovery from Condenser

- Heat recovery from the steam condenser in power oriented CCGT power plants.
- Low available temperature for HTHP heat source.
- Steam demand near power oriented CCGT power plant?



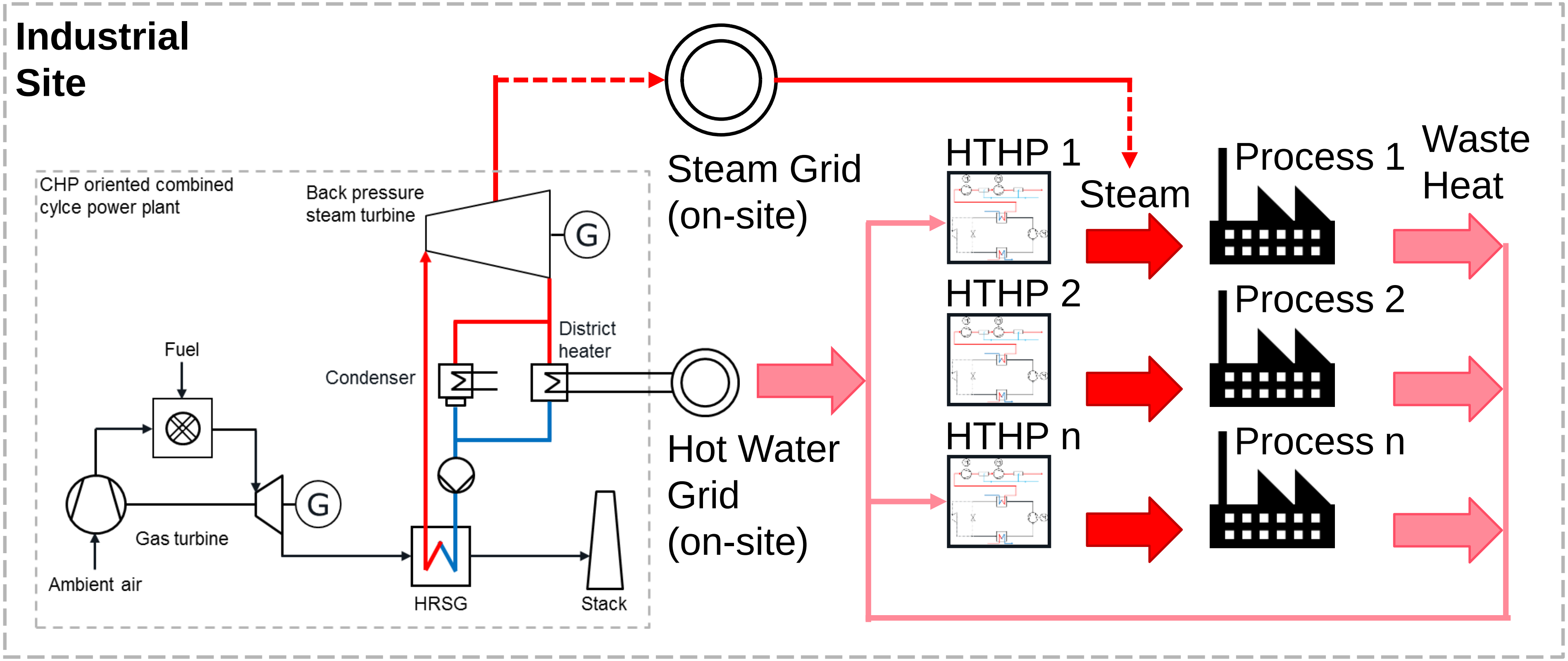
Layout Option HTHP 3 – Utilization of DHN

- The district heating network (DHN) is used as a heat distribution system for the decentralised production of steam with HTHP.
- Possibility to increase the annual utilisation of CHP power plants while avoiding seasonal fluctuations in the heat demand.



Layout Option HTHP 4 – Industrial CHP

- The industrial CHP produces less steam and more hot water.
- The HTHP(s) use hot water for the decentralised production of steam.
- The amount of steam which needs to be transported over long distances in the steam grid is reduced which decreases the energy losses through pressure and heat losses.



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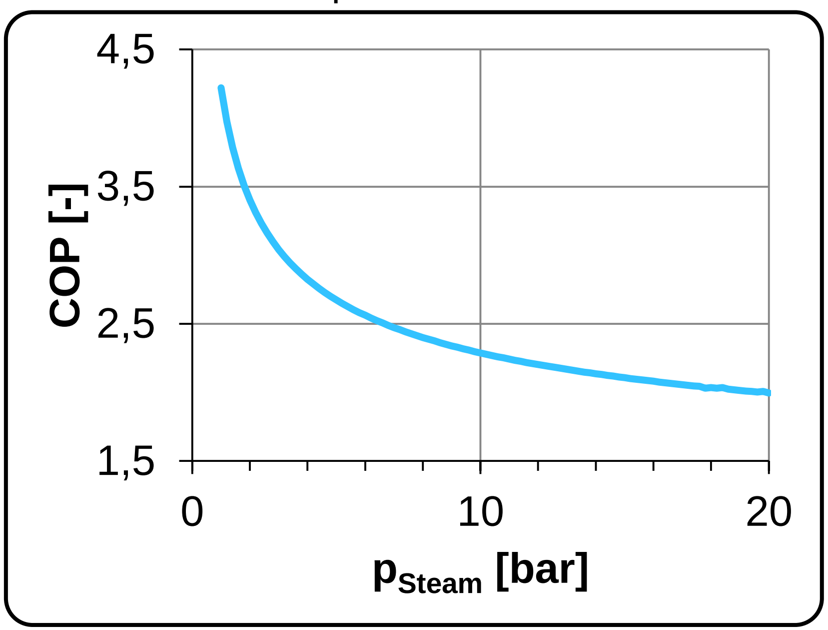
HTHP Case Studies

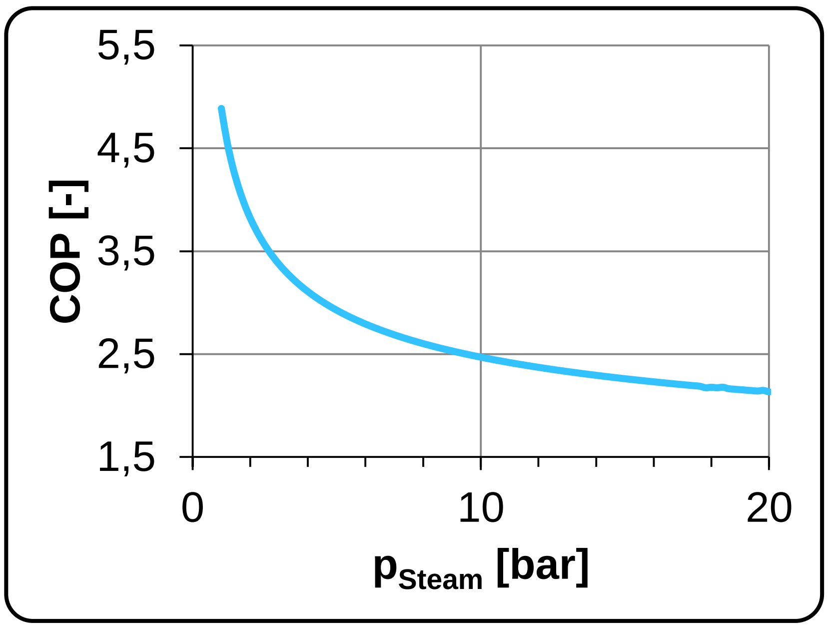
- Several case studies for different commercial applications are ongoing:
  - **Integration in thermal power plants**
  - Food sector, Chemical industry, Paper drying, etc.
- The coefficient of performance (COP) of the HTHP depends on the heat source temperature and on process steam pressure/temperature.

$$\mathrm{COP} = \frac{\dot{H}_{\mathrm{Steam}} - \dot{H}_{\mathrm{Feed\ Water}}}{P_{\mathrm{el}}}$$

heat source temperature 80°C



heat source temperature 140°C



CCGT with HTHP – Case Study

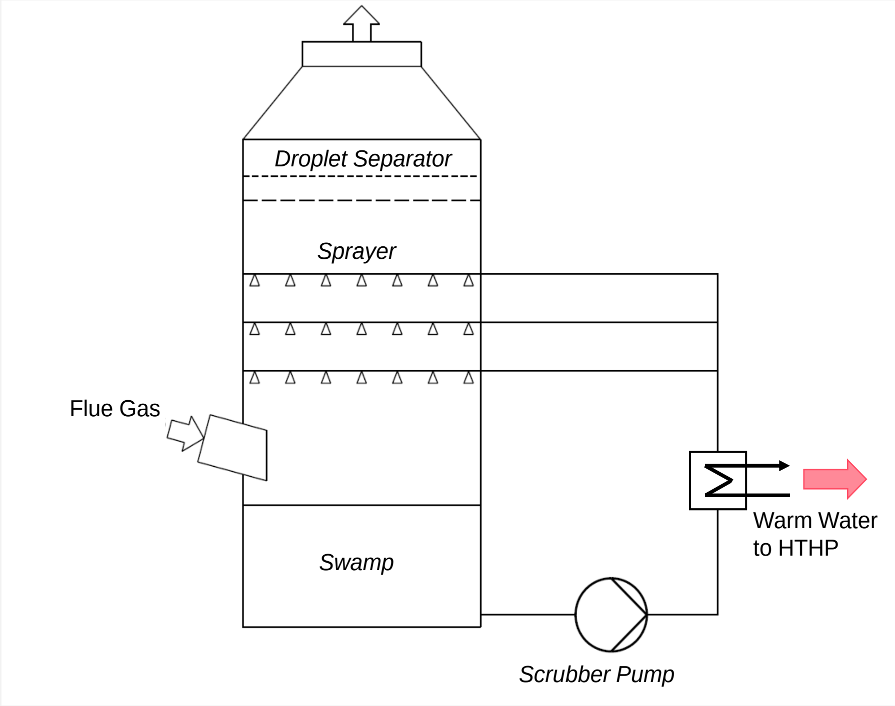
- Within the PUMP-HEAT project a case study of the integration of HTHP into an industrial CHP CCGT power plant was performed based on the before described 4 layout options.
- Thermodynamic calculations were performed to evaluate the layout options on a technical basis with regard to e.g. the net fuel utilisation factor.

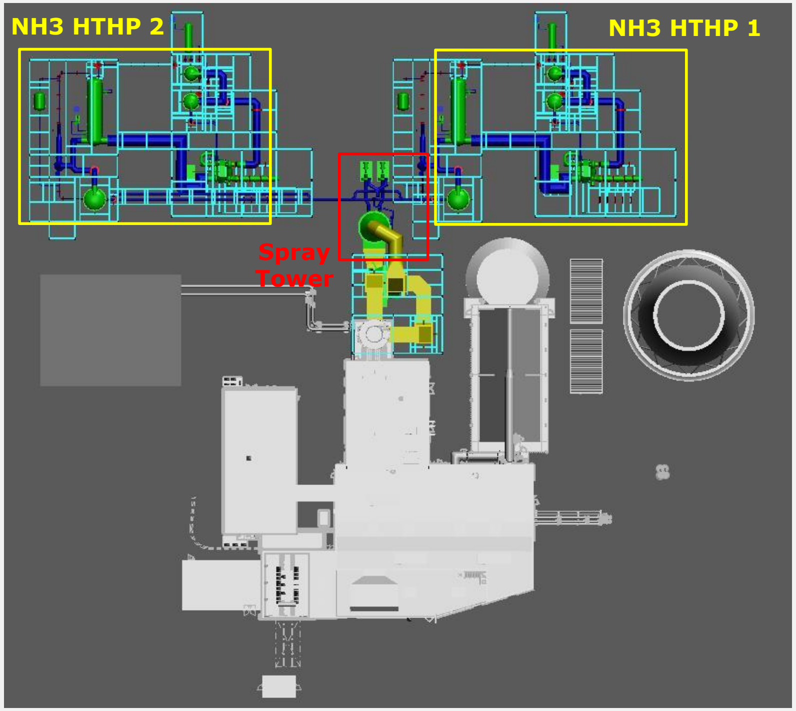
$$Net\ Fuel\ Utilisation\ Factor = \frac{\sum_{i=1}^{n} \dot{H}_i + P_{el,net}}{\dot{m}_F * LHV}$$

- The CHP power plant in its standard configuration without integrated HTHP produces approx. 65MW$_{el,net}$ of electricity, approx. 200MW$_{th}$ of process steam and approx. 20MW$_{th}$ of hot water.
- Process steam parameters are: 4.2bar and 160°C.
- The HTHP is preliminarily designed with the working fluid R717 (NH_3) with cold vapour process and 2-stage steam compression.

CCGT with HTHP – Case Study Layout Option 1

- Layout option 1 with heat recovery from flue gas is designed with a spray tower derived from a flue gas scrubber.
- This devise allows to recover the sensible as well as the latent heat from the GT exhaust gas.
- The HTHP part is devided into two separated HTHPs with an electricity consumption of approx. 15MW$_{el}$ each.
- Sketch of spray tower and arrangement planning of CCGT + 2 HTHPs:





CCGT with HTHP – Case Study Results

Layout Option	Power to Heat Ratio [MW_{el} / MW_{th}]	COP of HTHP	Net Fuel Utilisation Factor [%]	Application Case	Priority
Reference Power Plant	0.55	-	90.8	Industrial CHP Plant	-
HTHP 1 (flue gas)	0.16	1.74	101.9	Industrial CHP Plant	High
HTHP 2 (condenser)	0.19	1.85	87.2	Power oriented CC Power Plant	Low
HTHP 3 (DHN)	0.31	1.90	85.2	CHP Plant for DHN	Medium
HTHP 4 (industrial)	0.16	1.90	92.4	Industrial CHP Plant	High

- HTHP 1: highest net fuel utilisation factor; investment costs to be analysed
- HTHP 2: lower net fuel utilisation factor and limited application potential (power oriented power plant vs. production of process steam)
- HTHP 3: low net fuel utilisation factor but increased annual plant utilisation and potential for integration of electricity from renewable energy sources; limited application potential because DHN is needed
- HTHP 4: high net fuel utilisation factor; alternative option to HTHP 1

Content

Conclusions

- There are various options to combine high temperature heat pumps with CCGT power plants to increase the fuel utilisation.
- The most promising application is for industrial CHP plants.
- To increase the net fuel utilisation factor, waste heat from the exhaust gas can be used as heat source for the HTHP (layout 1).
- Alternatively, the HTHP can use hot water from the industrial hot water grid for decentralised production of process steam (layout 2).
- A detailed investigation of the HTHP process and of the HTHP components will be performed in the PUMP-HEAT project.

ACKNOWLEDGMENTS

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Power for a Brighter Future