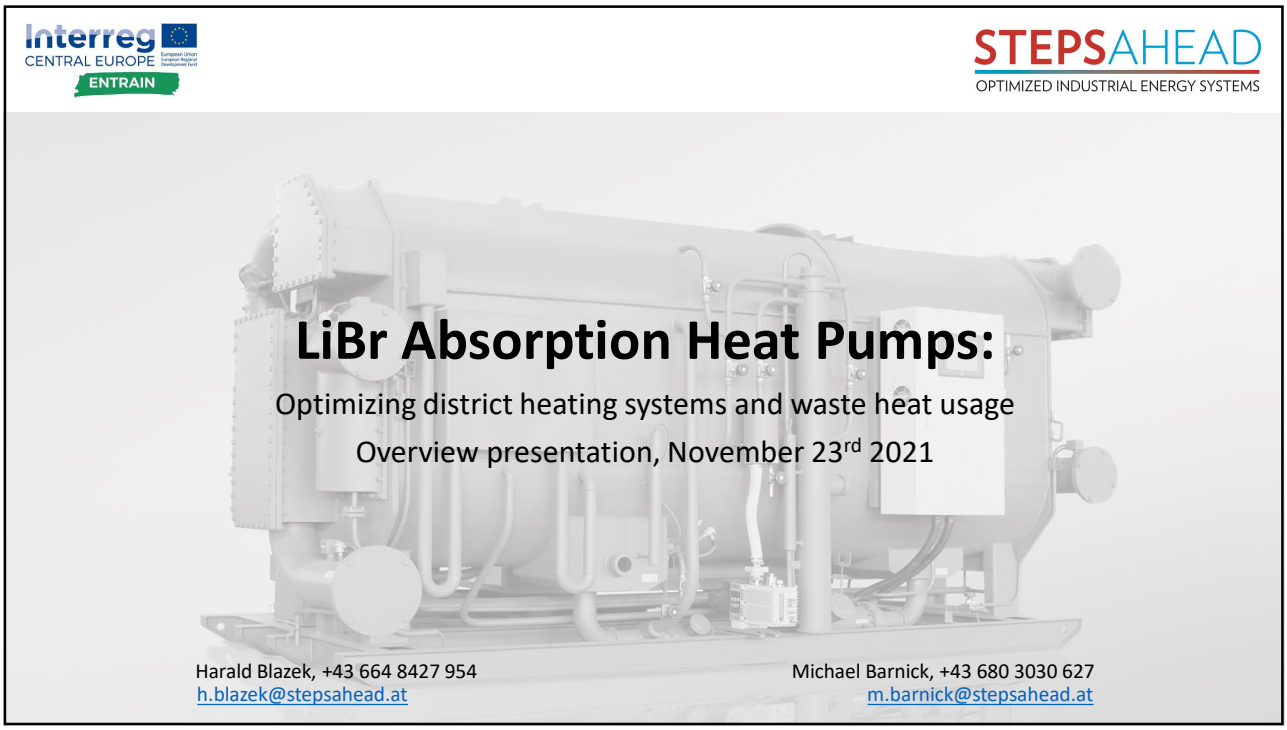


LiBr Absorption Heat Pumps:

Optimizing district heating systems and waste heat usage

Overview presentation, November 23rd 2021

Harald Blazek, +43 664 8427 954
h.blazek@stepsahead.at

Michael Barnick, +43 680 3030 627
m.barnick@stepsahead.at

Overview:

- Introduction StepsAhead 1 slide
- Working priniciple Abs.HP 3 slides
- Project Examples 15 slides
- Different machine types 4 slides
- Benchmarks 3 slides
- How to develop successful projects? 2 slides

StepsAhead Energiesysteme GmbH was founded in October 2016 in Graz, Austria.

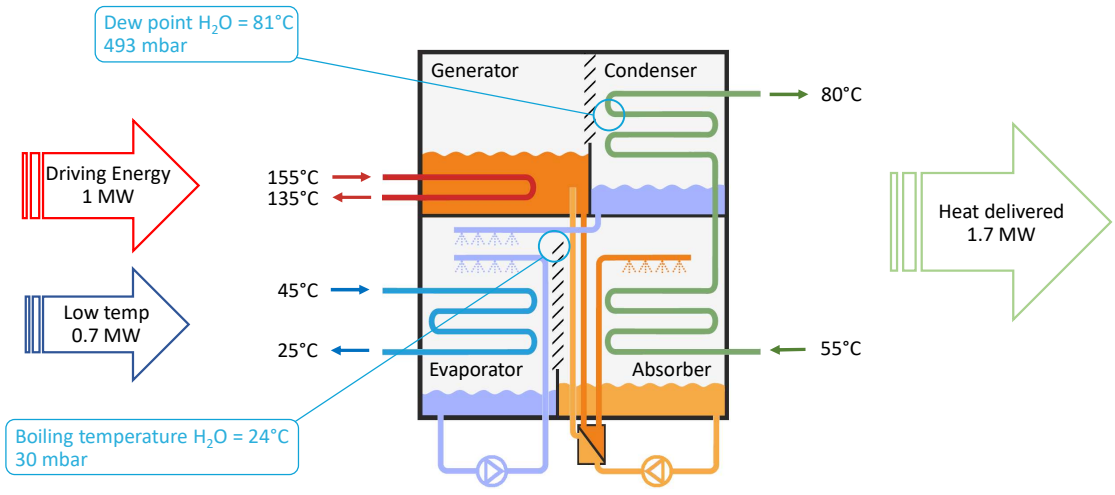
Activities:

- We deliver turnkey solutions for heating and cooling > 1 MW, using Lithium Bromide Absorption Technology
- Including design and physical simulation of:
  - absorption machines
  - complete energy supply systems
- Including manufacturer-independent optimization of complete heating and/or cooling systems
- Including maintenance, optimisation on site & „Sale of Energy“ contracts

Michael Barnick, Founder and CTO / Harald Blazek, Founder and CEO
(and 4 absorption heat pumps, heating capacity 152 MW)

LiBr Absorption Heat Pump

(single stage, typical COP 1.70 – 1.75)

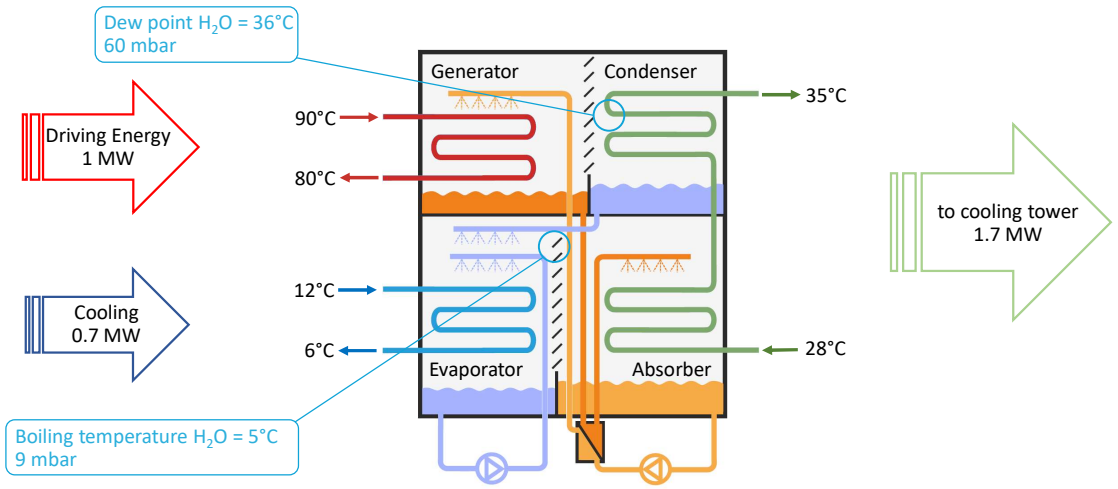


Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

LiBr Absorption Chiller

(single stage, typical COP 0.70 – 0.75)



Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

What's the economic benefit?:

Heat Pump (single stage):

Driving heat:	1.0 MW
Waste heat:	0.7 MW
Benefit:	1.7 MW

Alternative heat production from boiler:
Fuel needed approx. 1.9 MW (@ η 0,9)

Heat Pump has approx.
10 times higher benefit in EUR !

Heat pumps in projects > 1 MW are typically always profitable.

Chiller (single stage):

Driving heat :	1.0 MW
Cooling = Benefit:	0.7 MW

Alternative cold production from electric chiller:
Electricity needed approx. 0.14 MW (@ COP 5)

Remark: Cooling tower size = 200% compared to electric chillers. (= higher CAPEX)

Chiller:
Driving heat should not cost more than 15 €/MWh.
Otherwise usually not profitable.

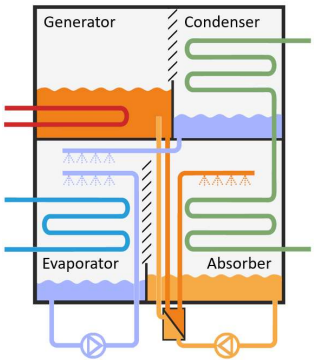
Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Working principle of a LiBr-Absorption-Heat Pump or Chiller:

Step 1, Evaporator & Absorber:
- In order to be able to absorb heat at a low temperature level, water is evaporated in the Evaporator at low pressure.
- This vapour is absorbed in the absorber by concentrated LiBr salt solution.
- A pump brings the now diluted salt solution to the Generator.

Step 2, Generator & Condenser:
- In the Generator, at higher pressure (below 1 bar absolute), the water is evaporated from the diluted salt solution by heating the solution. The salt solution is thus concentrated and can be reused in the absorber.
- In the Condenser, the resulting steam is condensed on a heat exchanger, so that the water required in the evaporator is available again in liquid phase.



The heat released in the Absorber and Condenser is absorbed by heat exchangers and transferred to the heating system.

Environmental assessment and substances used:
The substances used are water and lithium bromide salt. This heat pump therefore uses neither ozone-depleting substances nor substances that would increase the greenhouse effect.

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Is an absorption machine a complicated item? → 4 tube & shell HX, 1 plate HX, pumps, valves.

Project examples

Bioenergie Wagrain: Biomass heating plant

Flue gas condensation in a Biomass Heating plant.

Heating capacity 2 MW .

Commissioned Oct. 2020

Driving energy:
Hot water @ 150°/130°
(1.2 MW)

Low temp source:
Flue gas condensation @ 32°/22°
(0.8 MW)

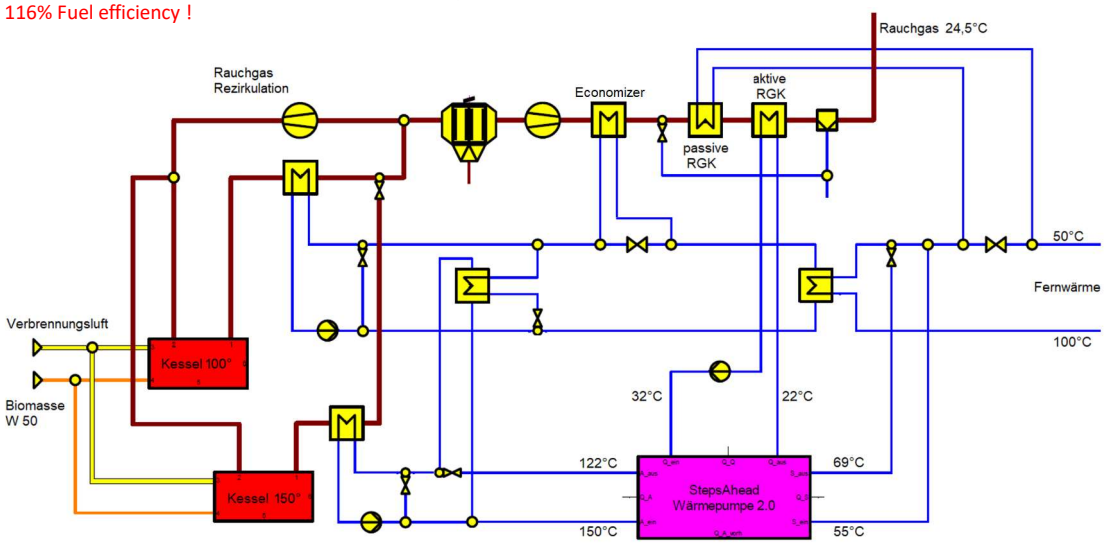
District heating:
Pre-heating from 55°/70°
(2 MW)

Update Nov. 2021: Machine number 2 and 3 are already ordered from this client, the 4th project is actually in design phase.

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Simplified schematic Bioenergie Wagrain:

Fuel water content 50% (W50), 100°C district heating
116% Fuel efficiency !



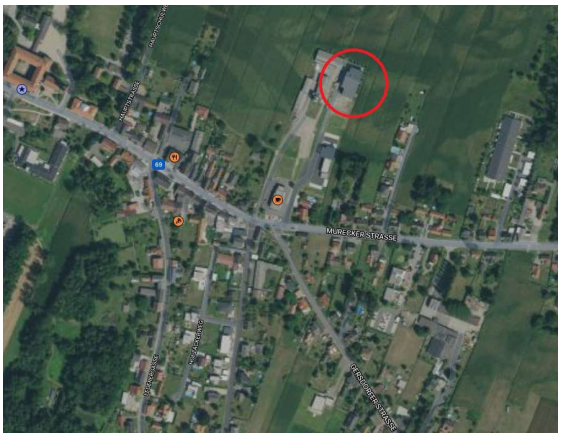
STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Project history: (Succcess factor cooperation)

The best AWPs today are produced in China. (> 100.000 Maschines in MW scale since 1990!)

Close cooperation is needed for securing first class results and avoiding misunderstandings.

Nahwaerme Strass: Biomass heating plant



Flue gas condensation in a Biomass Heating plant.

Heating capacity 1.2 MW .

Driving energy:
Hot water 150°

Low temp source:
Flue gas condensation (0.5 MW)

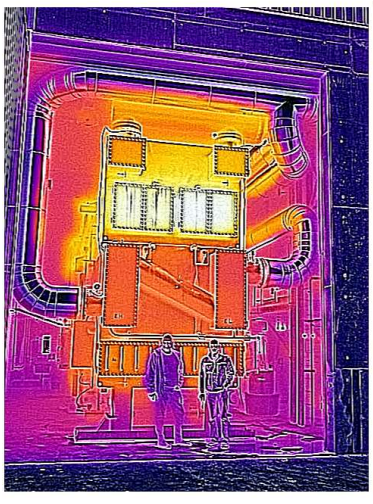
District heating:
Pre-heating district heating return: 1.2 MW

Delivery: Nov. 26th 2021 (this Friday!)

District Heating Power Plant:

Biomass cogen power plant „Klagenfurt East“

Austria‘s largest Absorption Heat Pump: 23,4 MW.
(2 Evaporators, 2 Absorbers, 2 Generators, 2 Condensers)



Driving energy:
Hot Water 130°/120°

Low temperature source:
Flue gas condensation 35°/45°

District Heating:
pre-heating return flow 60°/75°

From flue gas:
36000 MWh/yr

Savings approx.:
1 Mio EUR/yr

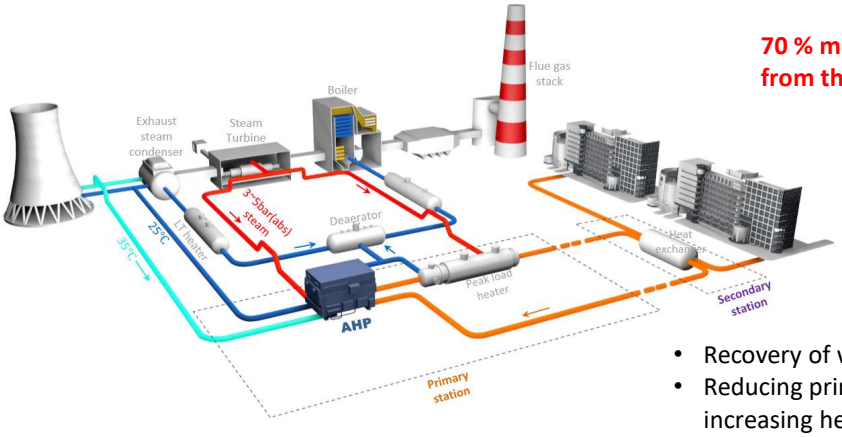
2 machines on 2 sites in operation since 2017

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

District Heating from conventional Cogen Power Plants:

Integrating low temp heat from the cooling tower circuit



70 % more district heating output from the same driving energy !

- Recovery of waste heat from the cooling tower
- Reducing primary energy usage and/or increasing heating capacity
- Reducing cooling water consumption

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

District Heating from conventional Cogen Power Plants:

Integrating low temp heat from the cooling tower circuit

HYPERBOLIC COOLING TOWER SYSTEM

Project name	AHP capacity/unit	Qty.	Total heating capacity	Delivery year
Huo Zhou power station (China Guodian)	40MW	6	240MW	2012
Tianjin Northeast Suburb thermal power station (China Guodian)	38.8MW	8	310.4MW	2012
Hebi thermal power station	40MW	5	200MW	2012
Harbin No.1 thermal power station(Datang Group)	38.8MW	8	310.4MW	2013
Ji Xi Themal Power station	23MW	2	46MW	2014

2010-2020:

More than 200 large scale Absorption Heat Pumps in Chinese Cogen Power Plants!

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

District Heating from conventional Cogen Power Plants:

8 * 38,8 MW = 310 MW Heating capacity

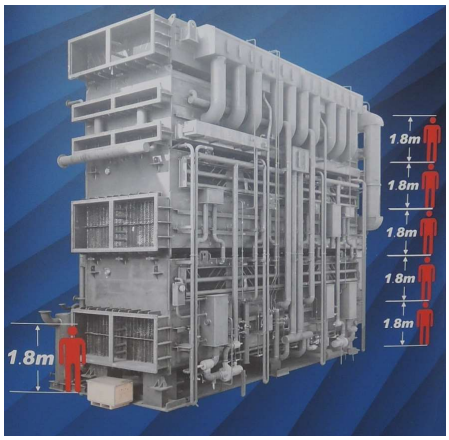
© Ebara

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

District Heating Baotou, China:

Biggest Absorption Heat Pump worldwide / 2 * 73 MW / Commissioned 2018/2019

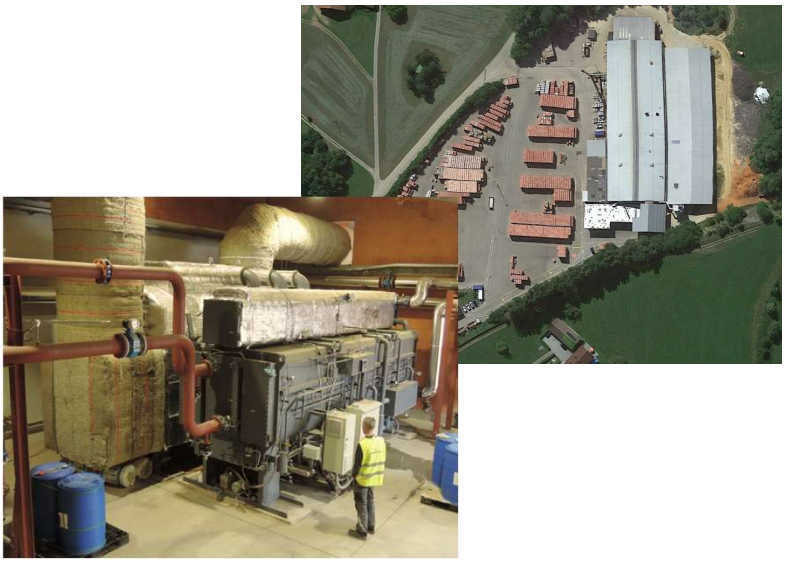


Data per machine:

- operating weight: 288 to
- driving energy: steam 3 bar_a / 98 K superheated / 42,9 MW
- district heating: 55°/82°C / 73,2 MW
- low temp source: saturated steam @ 51°C / 30,3 MW
- COP: > 1,7

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS



Industrial process optimization:

Brick production, Austria

Absorption Heat Pump: 3,8 MW
Commissioned 2017/2018.

Driving energy:
Hot air: 400°/180°

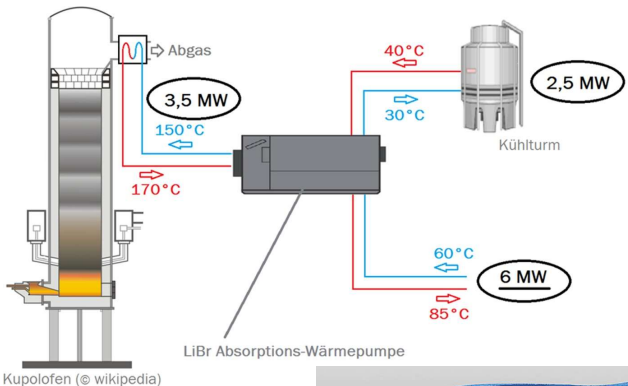
Low Temp Heat Source:
Condensing humid exhaust air: 36°/26°

Heat delivered:
Hot Water 60°/90°

Further projects are actully in design phase

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS



Industrial waste heat usage :

Smart Waste Heat usage
TIGAS / Tiroler Rohre, Austria

Waste Heat from hot flue gas was used for producing hot water for Innsbruck's district heating grid.
The heating capacity was 3,5 MW.

The installation of a LiBr Absorption Heat Pump increased the capacity to 6 MW.

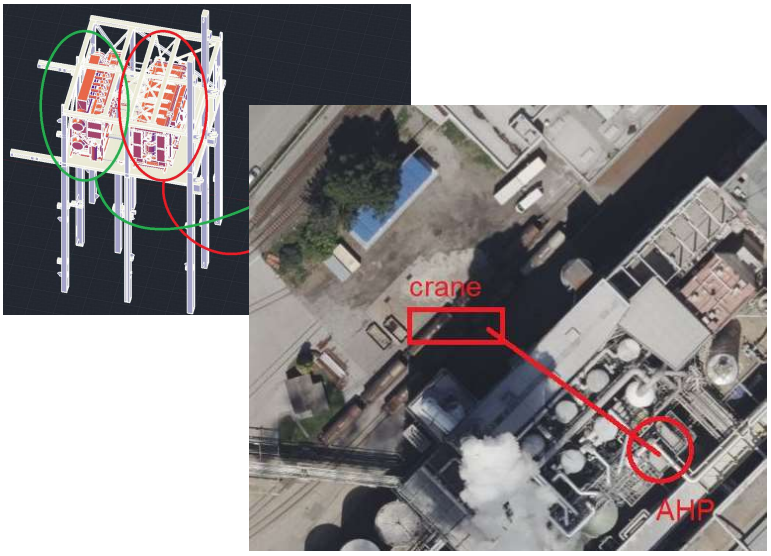
A capacity increase to 170%, without additional driving energy !

Commissioned 2016

Project: SOLID, BROAD

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS



Industrial waste heat usage:
Paper Mill, Austria

Absorption Heat Pump: 7 MW
Commissioning Jan. 2022

Driving energy:
3,5 bar steam

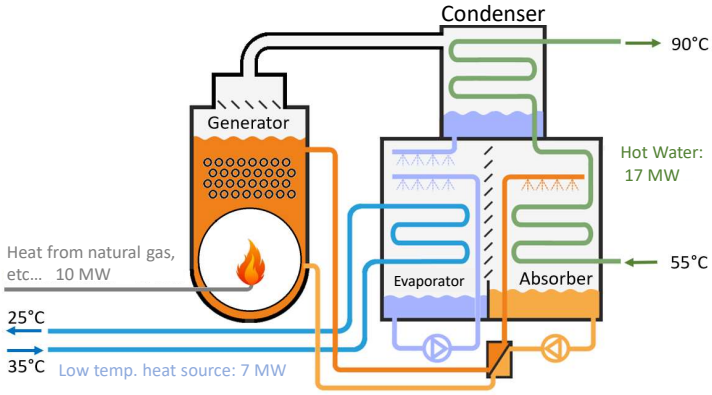
Waste heat source:
Warm waste water

Consumer:
District heating

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

The „155% efficiency“ boiler: Do you have any waste heat source available?



1,25 MW direct fired HP

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Absorption Heat Exchanger:

Taiyun-Gujiao Project: Long distance heat transportation

Long distance heat transportation based on AHE

- Heat source: 4*600MW CHP
- Heat production: 3.2GW
- Heat transported: 3.2 GW
- Building floor area heated: 80 million m²
- Distance from CHP plant to city center: 50 km
- Tunnel for pipe: 18 km
- Pipe size: 4*1400 mm
- Temperature: 130/20 °C
- Circulated flow rate: 8 t/s

A Novel District Heating Solution Based on Absorption Heat Exchanger(AHE) for Different Types of Cogeneration Plants 11

- Lowering return temperature on the primary district heating grid
- Increasing transport capacity
- Facilitating/Increasing waste heat integration

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Absorption Heat Exchanger:

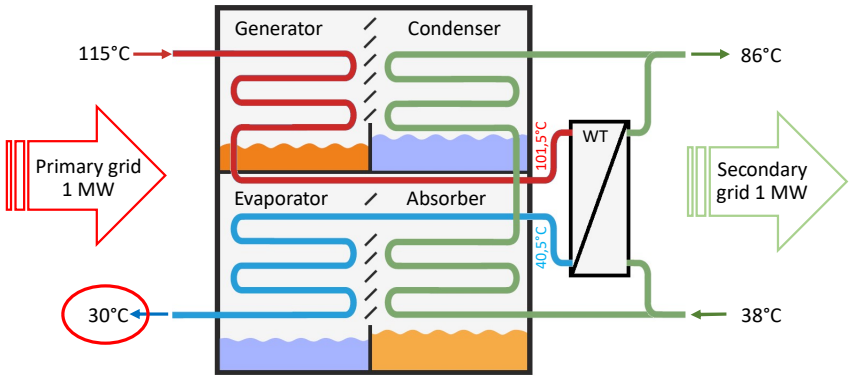
- Lowering return temperature on the primary district heating grid
- Increasing transport capacity
- Facilitating/Increasing waste heat integration

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Absorption Heat Exchanger:

- Lowering return temperature on the primary district heating grid
- Increasing transport capacity
- Facilitating/Increasing waste heat integration



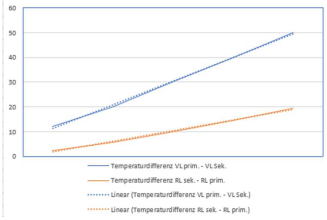
Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Absorption Heat Exchanger:

Quelle: https://docplayer.org/63264256-Drei-partner-eine-gemeinsame-vision.html

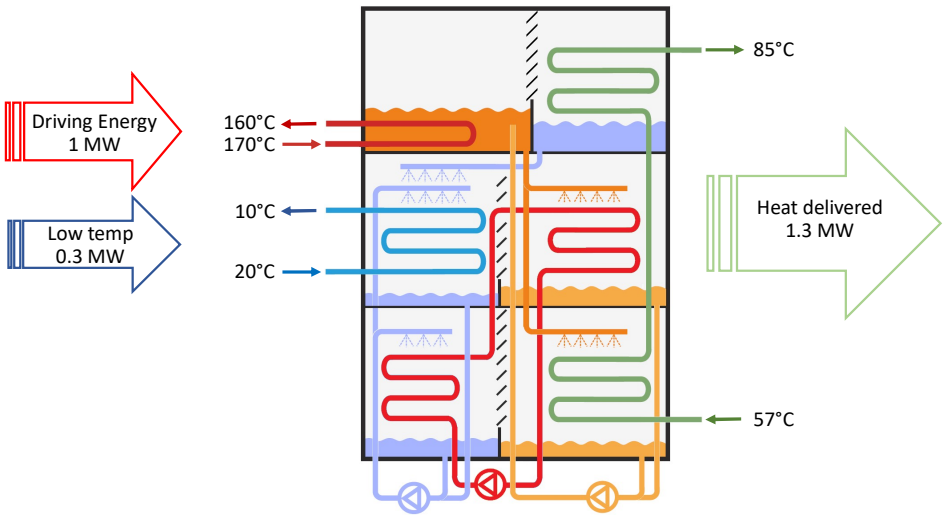
air temp.	sek. grid		prim. grid		Return no AHX	ΔT return with AHX
°C	°C	°C	°C	°C	2 K diff. HX	°C
-15	118	55	130	54,7	57	2,3
-10	110	55	130	51,3	57	5,7
0	100	55	130	46,9	57	10,1
10	90	55	130	42,3	57	14,7
20	80	55	130	37,6	57	19,4



- Lowering return temperature on the primary district heating grid
- Increasing transport capacity
- Facilitating/Increasing waste heat integration

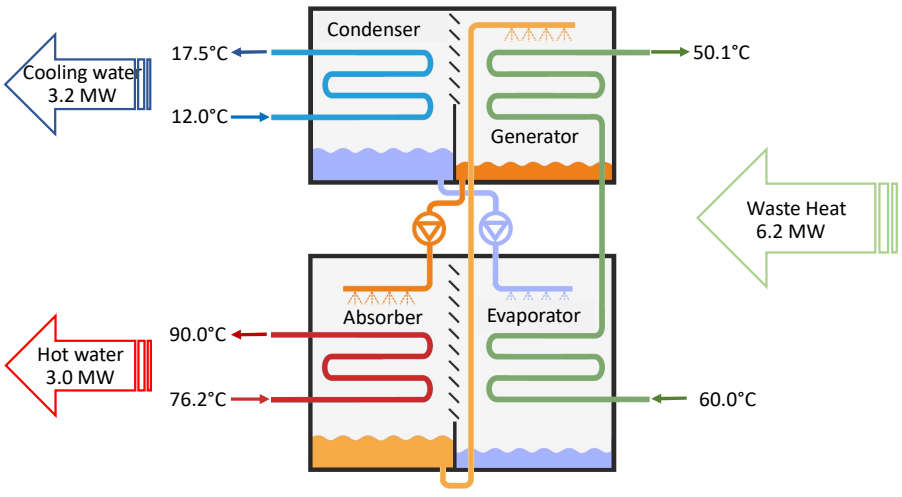
LiBr Double Lift Heat Pump

(COP 1.3)



LiBr-Heat Transformer, Category 2 Heat Pump

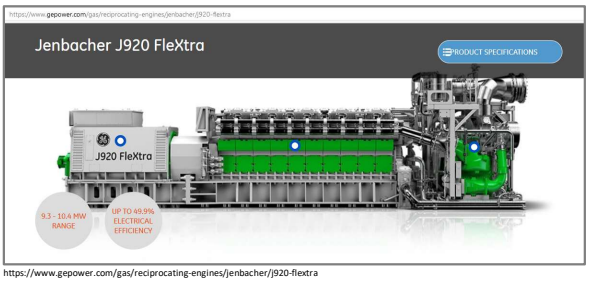
(COP approx. 0.48)



Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

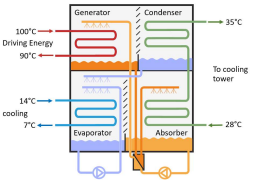
Advanced Cogeneration / Trigeneration



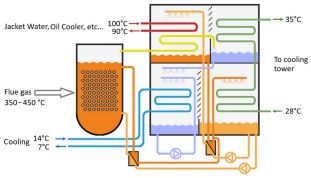
https://www.gepower.com/gas/reciprocating-engines/jenbacher/j920-flextra

Summer: Chiller usage

Standard: Single Stage chiller

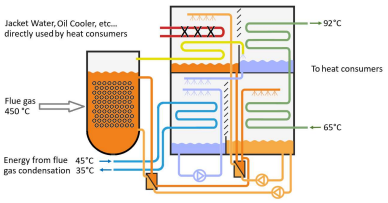


Advanced: 40% more cooling!



Winter: Heat Pump usage

Active flue gas condensation increases heat output by approx. 20 % !
Fuel efficiency > 100% can be reached.

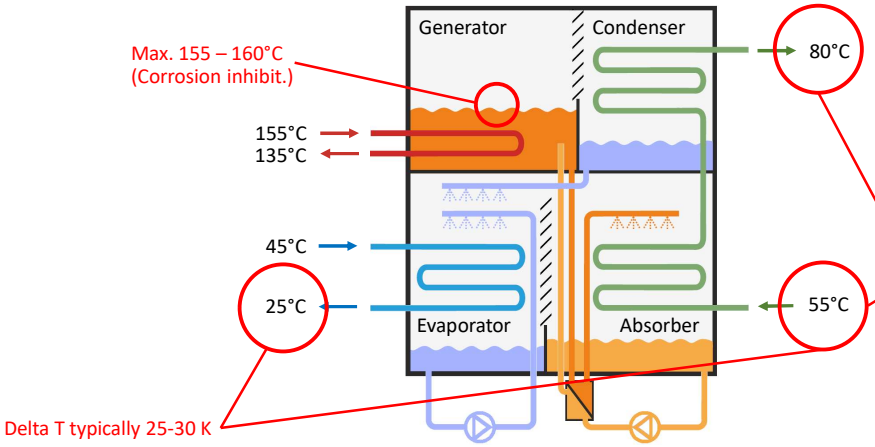


Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

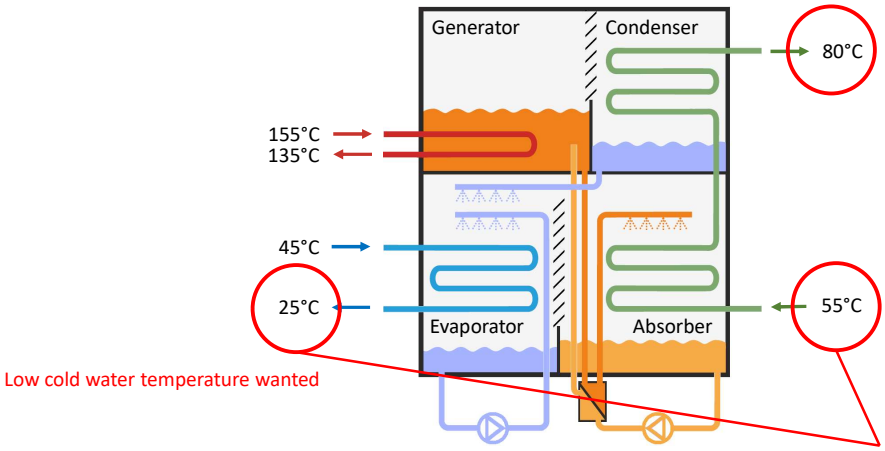
Benchmarks

LiBr Absorption Heat Pump benchmarks



- Pre-heated return flow
  Pre-Heating up to 100°C possible, when low temp input in Evaporator is approx. 50°C and driving energy is sufficiently hot.
- Heat from the boiler needed for increasing this temperature to target temperature for heating consumer.

LiBr Absorption Heat Pump design criteria

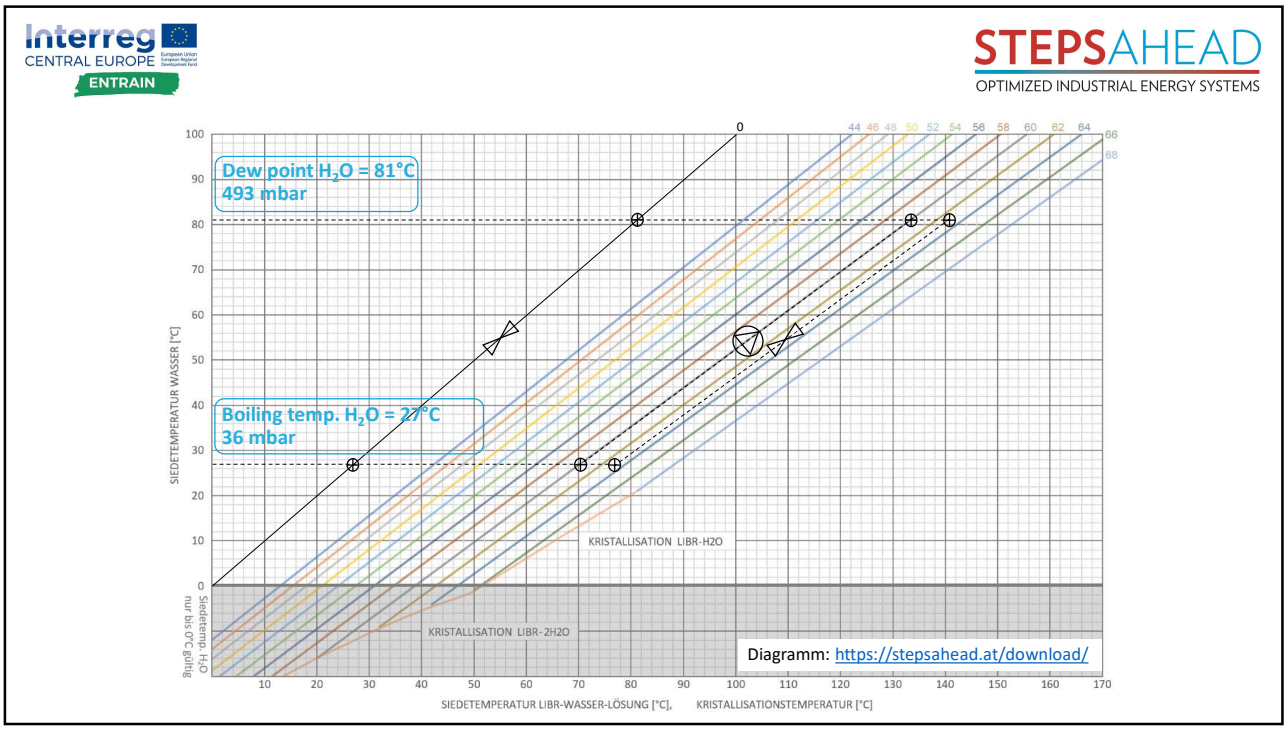


High hot water temperature can be reached with low LiBr concentration.

Defined by client.
Usually, no change possible.

High delta T → high LiBr concentration

Max. possible concentration = 63%



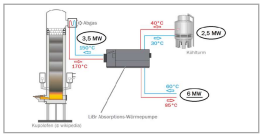
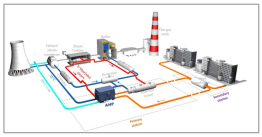
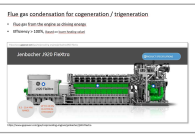
How to develop successful projects?

- Optimized machine design
- Optimized integration in local systems

Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

When is the driving heat „for free“?

	Waste Heat at 170°C available. District Heat needed at 90°C. A perfect case for using an Absorption Heat pump. 70% performance increase compared to the original project. ✓
	Steam from the turbine is used for district heating and as driving energy for the AHP. A perfect case for using an Absorption Heat pump. 70% more district heating output due to the integration of low temp heat from the cooling tower circuit. ✓
	Hot water from the boiler is used for district heating and produces the driving energy for the AHP. This project increases boiler efficiency by approx. 30% without increased wood consumption. ✓
	approx. 400°C flue gas as driving energy. Condensing the flue gas increases the heat output significantly. Overall efficiency > than 100% (based on lower heating value) is possible in many applications. ✓

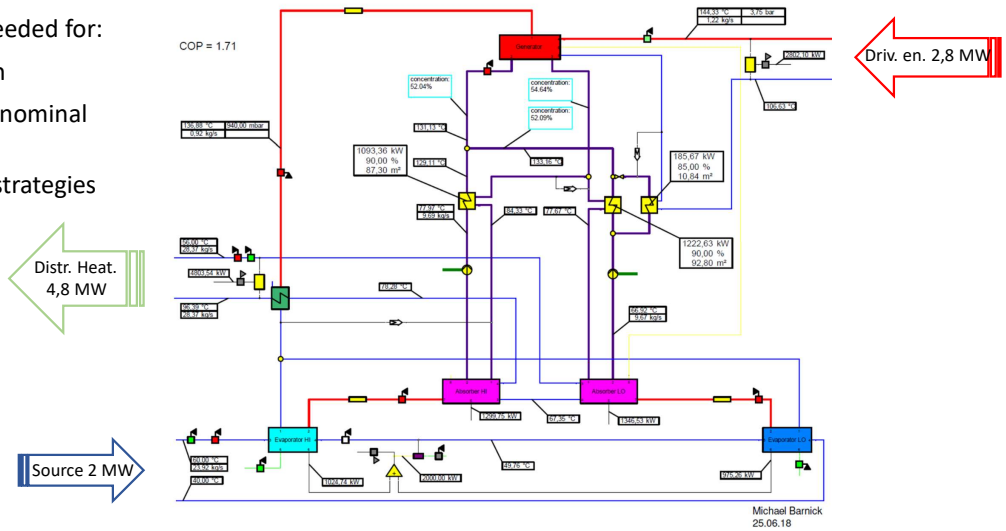
Interreg CENTRAL EUROPE ENTRAIN

STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Ebsilon simulation Absorption Maschine:

Detail knowledge is needed for:

- Part load operation
- Operation beyond nominal setpoints
- Advanced control strategies



Interreg CENTRAL EUROPE ENTRAIN

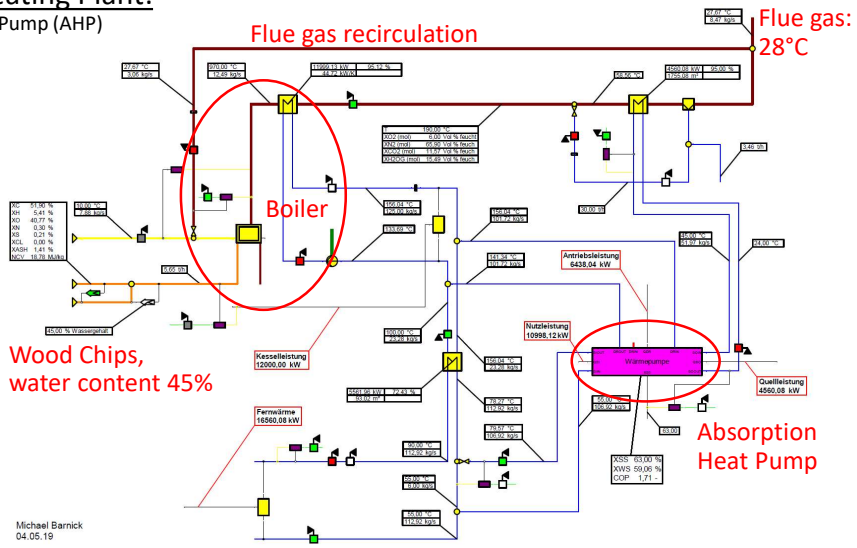
STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

Ebsilon simulation Biomass Heating Plant:

Flue gas condensation with Absorption Heat Pump (AHP)

Full simulation including surrounding components:

- Interaction of the AHP with the heating system
- Assuring optimized setup
- Avoiding design flaws
- Trusted calculation of economical benefits



STEPSAHEAD
OPTIMIZED INDUSTRIAL ENERGY SYSTEMS

StepsAhead Energiesysteme GmbH
Merangasse 84, 8010 Graz, Austria
Tel.: +43 316 318 719
Fax: +43 316 318 719
office@stepsahead.at

Harald Blazek: +43 664 8427 954
Michael Barnick: +43 680 3030 627