

# Transcritical CO<sub>2</sub> high temperature heat pump for the brewery industry

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15<sup>TH</sup> IEA  
HEAT PUMP  
CONFERENCE

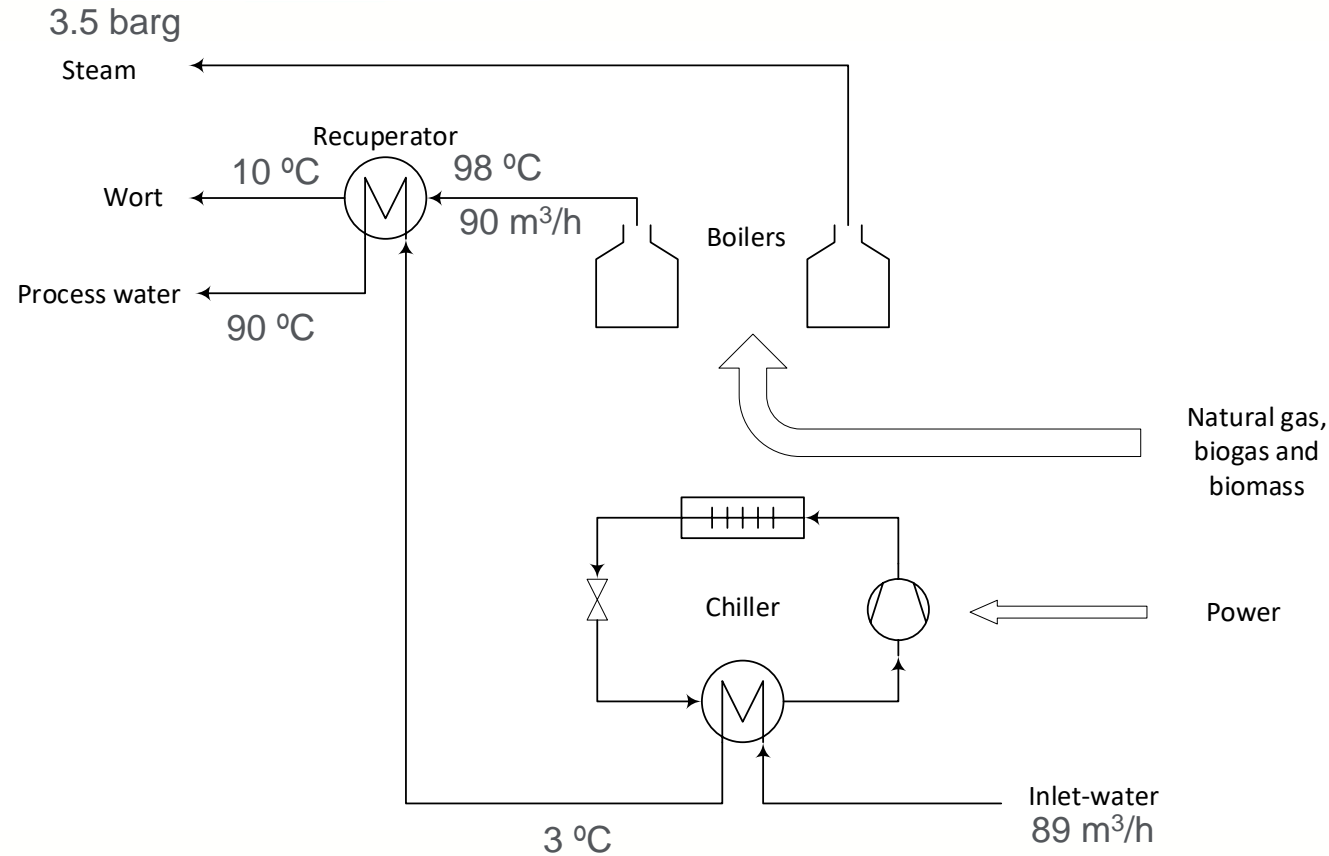


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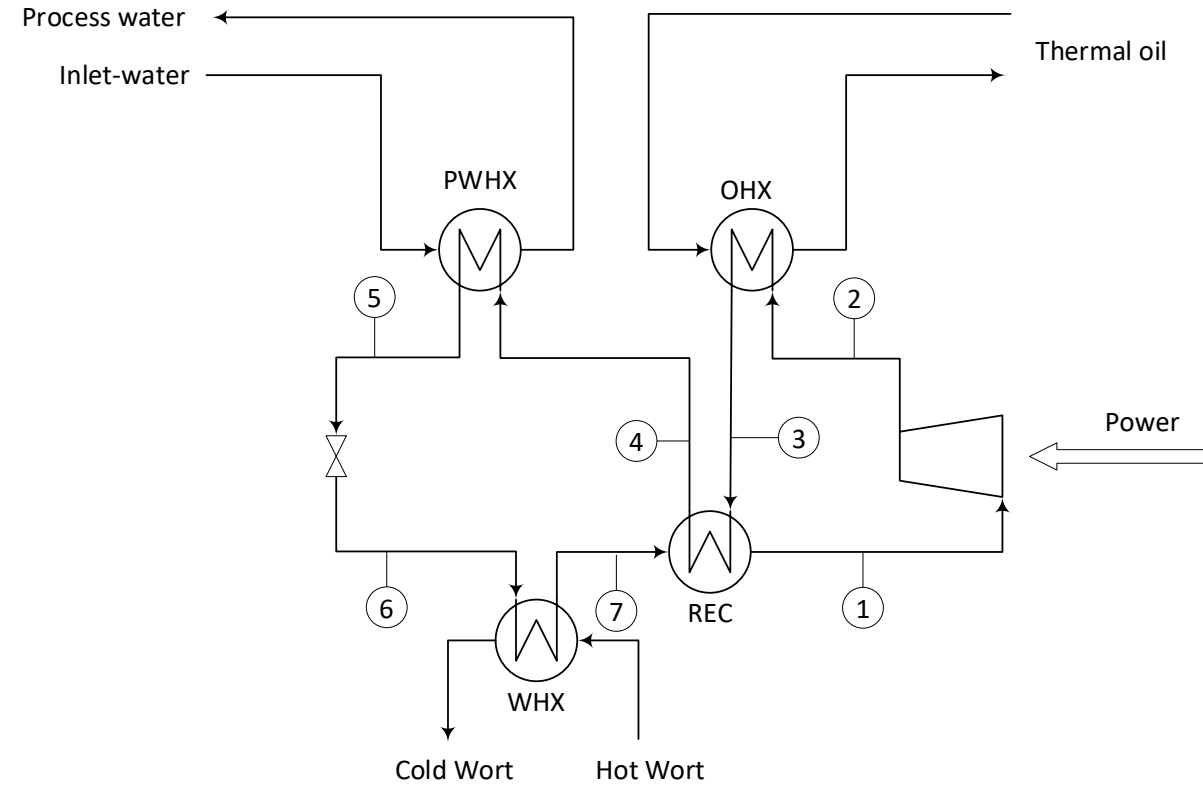
## Current situation

- Wort cooling & Process water heating
- Steam production with partially renewable fuel
- Ammonia chiller with cooling tower



## Proposed integration

- Wort cooling & Process water heating & steam production
- Steam production with fully renewable fuel
- Cooling tower is suppressed



Parameter	Value	Unit
Wort inlet temperature	98	°C
Wort outlet temperature	10	°C
Wort flow rate	90	m <sup>3</sup> /h
Inlet-water temperature	8–24	°C
Process-water outlet temperature	90	°C
Process-water flow rate	89	m <sup>3</sup> /h

$$LCOE = \left( \frac{INV}{Q_{OHX}} \right) \cdot (CRF + \gamma) + \frac{W \cdot T_e}{Q_{OHX}}$$

Capital recovery factor (CRF):

- wacc = 7.5%
- N = 25 years

Maintenance factor ( $\gamma$ )

- 5%

Electricity Price ( $T_e$ ):

- 75 €/MWh

$$NPV = (OPEX_{conv} - LCOE) \cdot \left( \frac{Q_{OHX}}{CRF} \right)$$

$$OPEX_{conv} = \frac{\left( \frac{Q_{OHX}}{\eta_{boiler}} \right) \cdot (T_g + T_{CO2}) + W_{chiller} \cdot T_e}{Q_{OHX}}$$

Baseline (conventional) case:

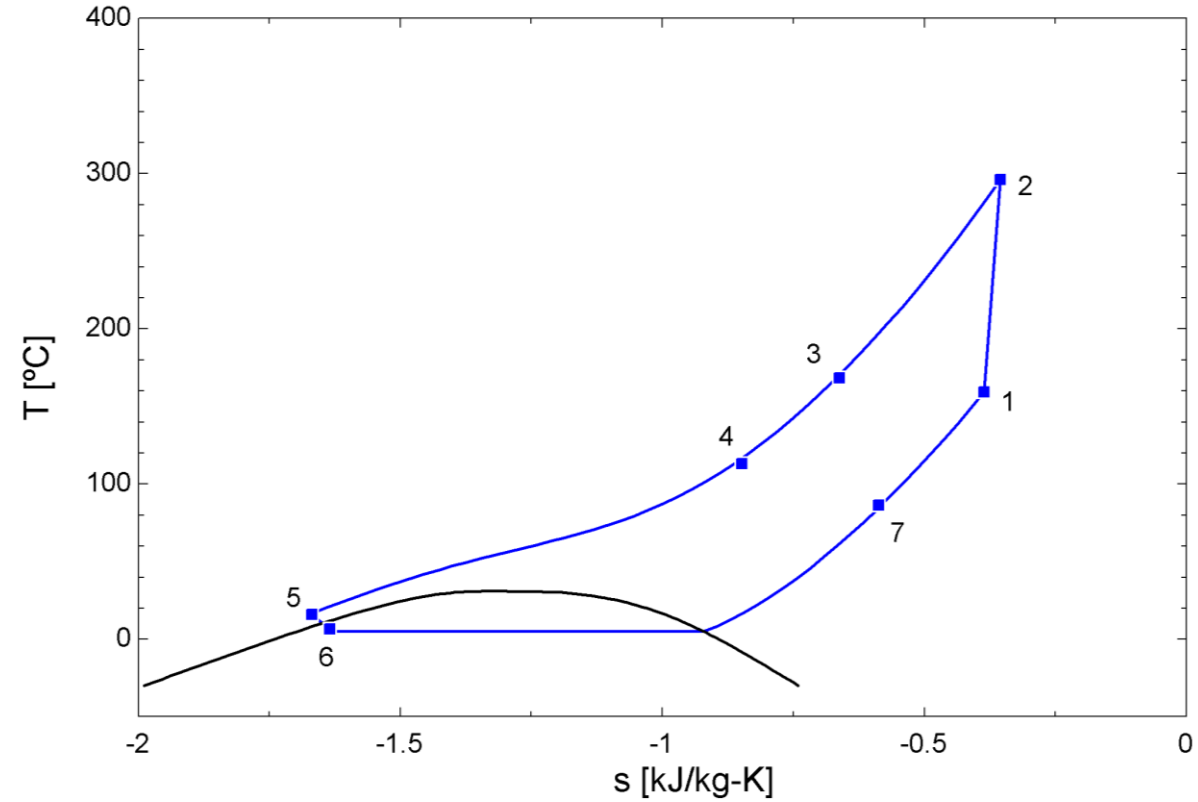
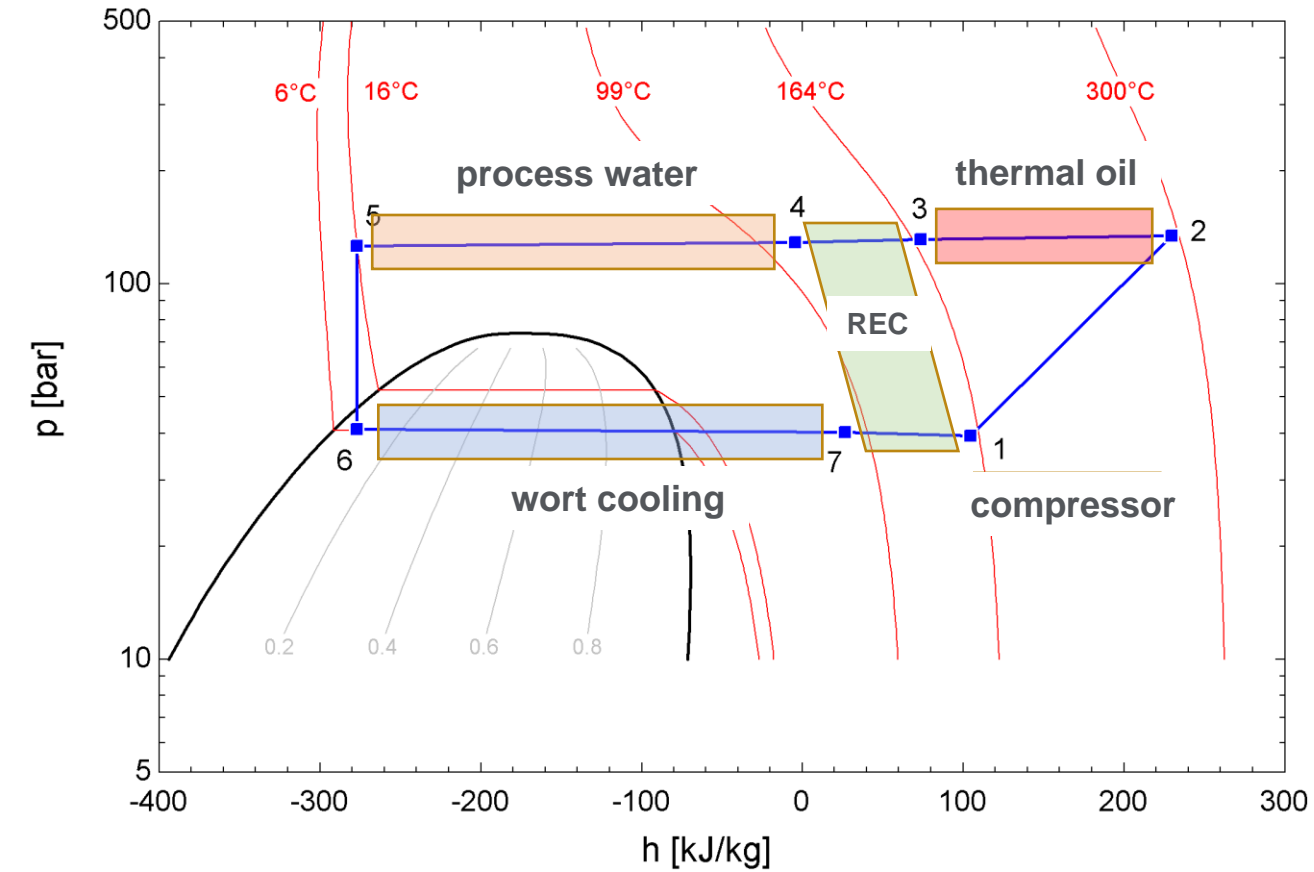
- Boiler efficiency: 90%
- Gas Price: 40 €/MWh-HHV
- CO<sub>2</sub> tax: 16 €/MWh-HHV
- COP of the chiller: 3





# RESULTS

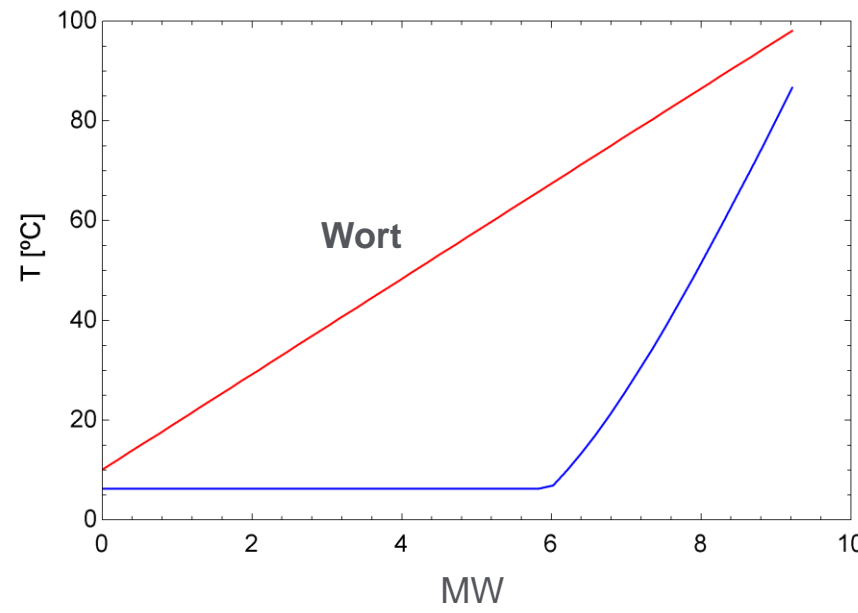
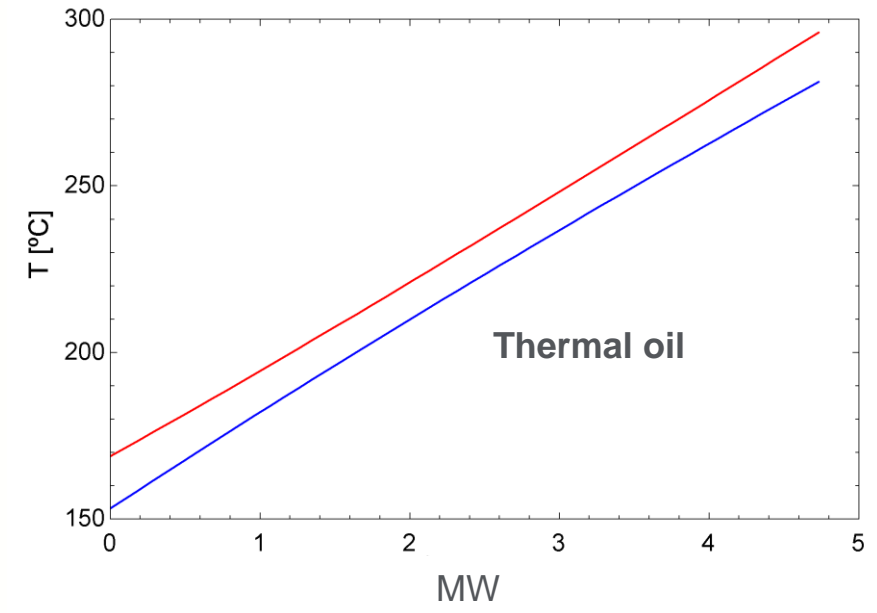
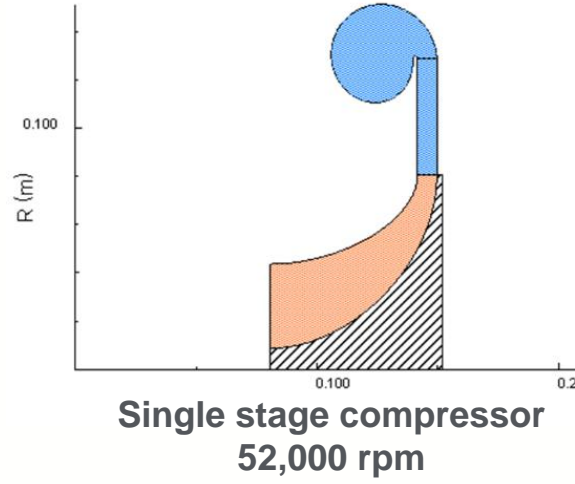
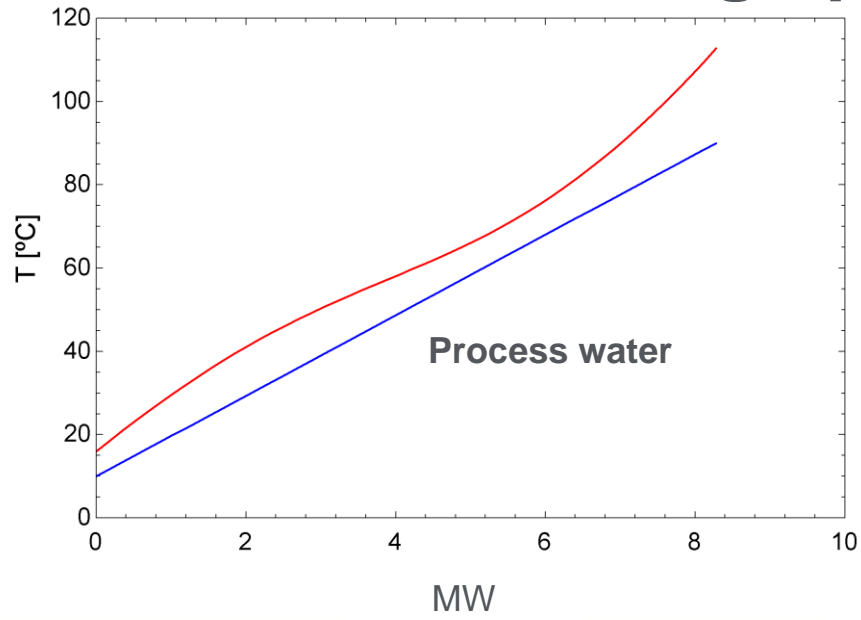
## Design point



**R744**

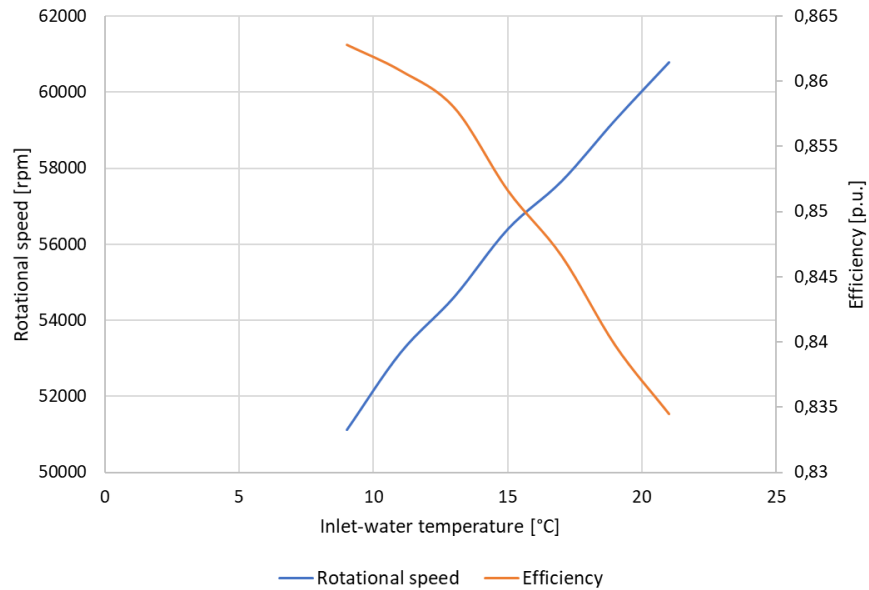
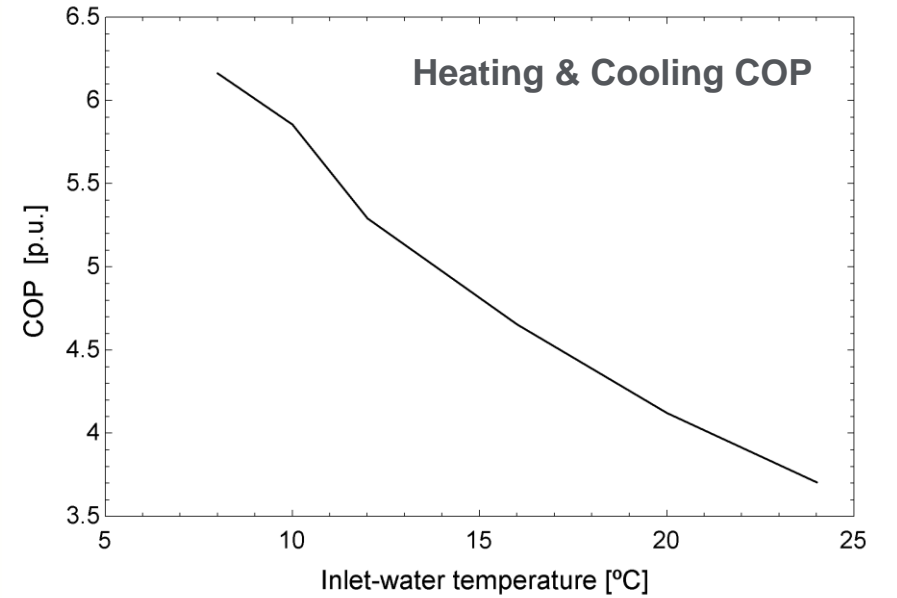
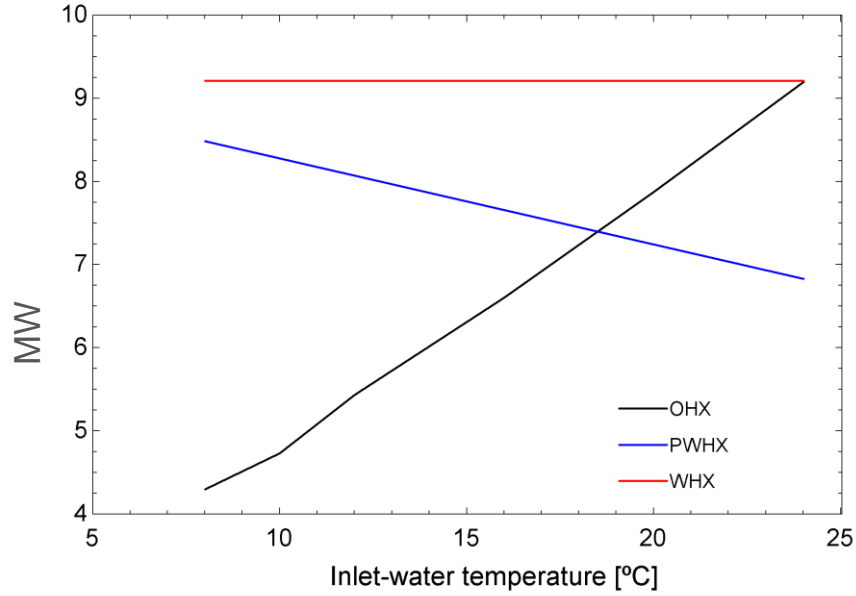
# RESULTS

## Design point



# RESULTS

## Off-design point



### Annual simulation

- 40.6 GWh thermal oil
- 50.7 GWh process water
- 59.9 GWh wort cooling
- 31.4 GWh compressor consumption
- Seasonal H&C COP: 4.82

# RESULTS

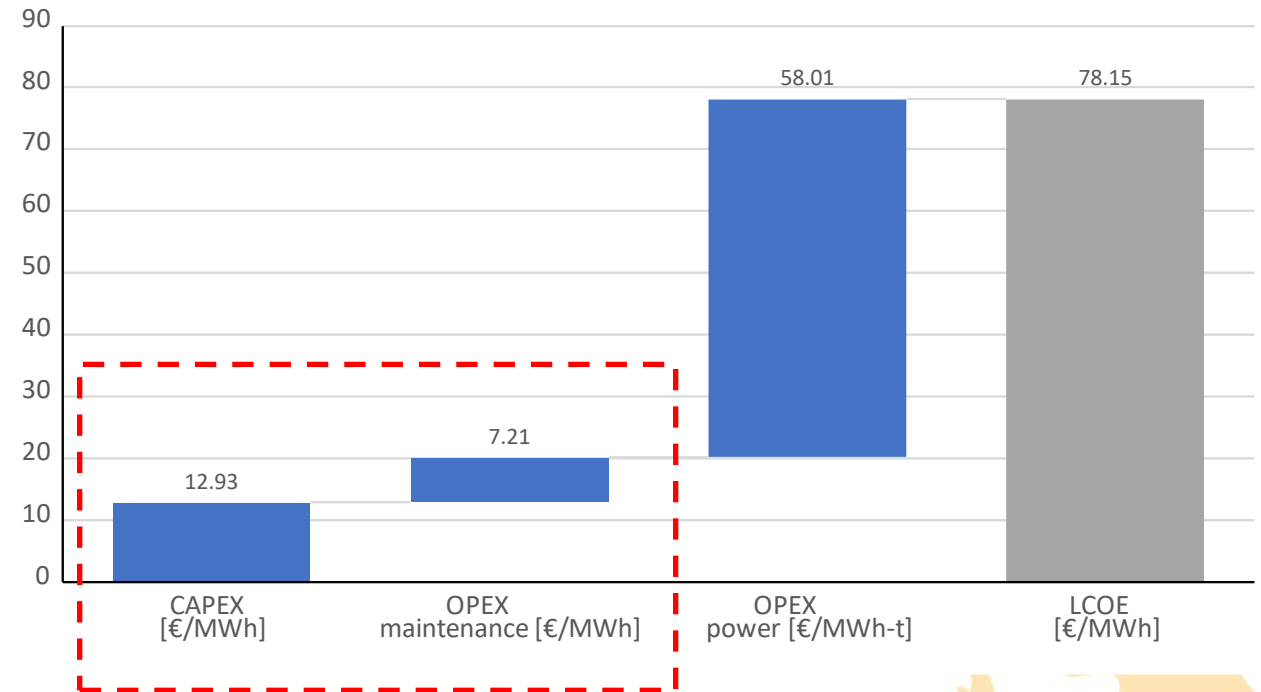
## Economics

### Original assumptions

Component	Cost [€ <sub>2024</sub> ]
OHX	6,174
PWHX	11,218
WHX	6,196
REC	3,102
Compressor	3,572,272
Installation and piping	1,079,689
Indirect costs	1,169,663
<b>TOTAL Investment</b>	<b>5,848,314</b>

**450 €/kW<sub>heating</sub>**

(close to the higher value of the range given from manufacturers: 300 €/kW<sub>th</sub> to 500 €/kW<sub>th</sub>)



25% of LCOE

# RESULTS

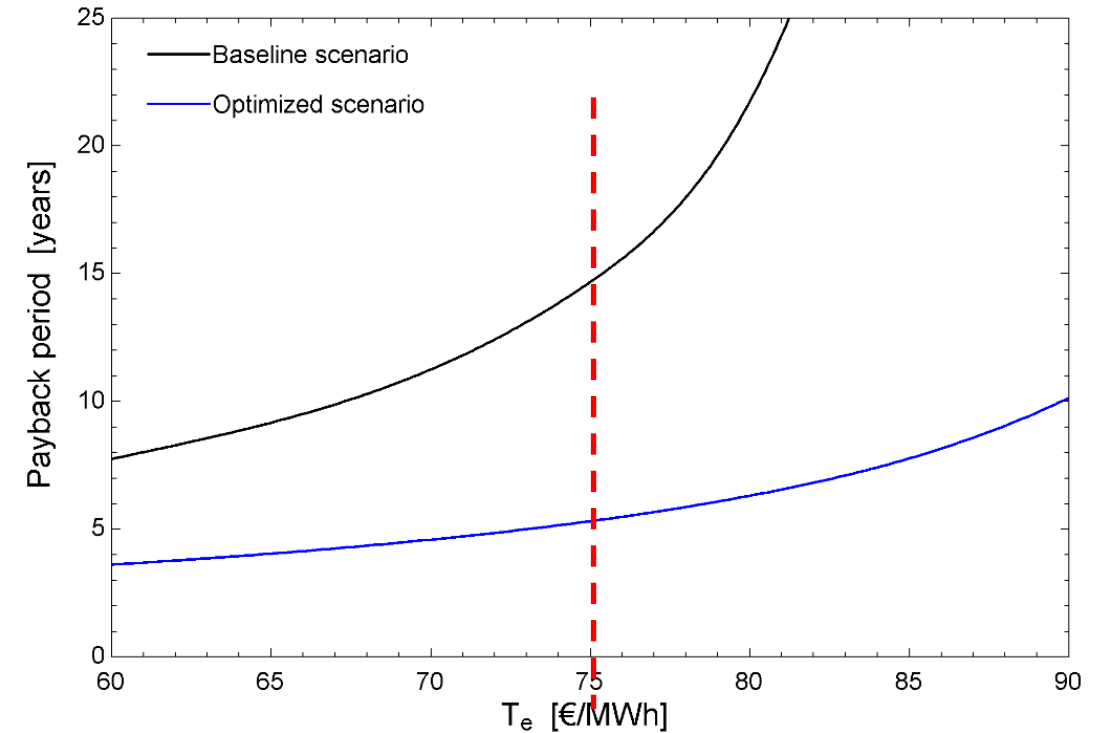
## Economics

### Optimized assumptions

- wacc: 7.5% → 5%
- scale: 1 → 2
- maintenance factor: 5% → 3%

Parameter	Baseline scenario	Optimized scenario
CAPEX [€/MWh]	12.93	6.76
OPEX maintenance [€/MWh]	7.21	2.86
OPEX power [€/MWh]	58.01	58.01
LCOE [€/MWh]	78.15	67.63
Payback period [years]	14.7	5.31

Optimized assumptions reduce the costs to do with investment in 50%, enough to reduce the payback period in 66%



- Feasibility of electrifying medium-temperature heat in a large brewery by thermal integration using a heat pump has been assessed
- Reverse transcritical Rankine cycle working with CO<sub>2</sub> (R744) has been proposed
- Original thermal integration (wort cooling with process water heating) is replaced by a fully integrated system: wort cooling as thermal source and hot water heating plus part of steam generation as thermal sink
- Variable speed turbocompressor maintains high efficiency across seasonal grid water
- Design point: 8.28 MW to process water + 4.73 MW to steam production / 9.21 MW from wort cooling
- Optimized economic scenario: low wacc (5%), moderate maintenance costs (3%) and double capacity:
  - LCOE: 78 → 68 €/MWh (82 €/MWh in conventional solution)
  - Payback period: 15 → 5 years
- CO<sub>2</sub> savings: 1.43 kg CO<sub>2</sub>/hl



Thank you for your attention

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