TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Maschinenwesen Institut für Energietechnik, Professur für Thermische Energiemaschinen und -anlagen

Advancement of Operational Performance of the Huntorf CAES

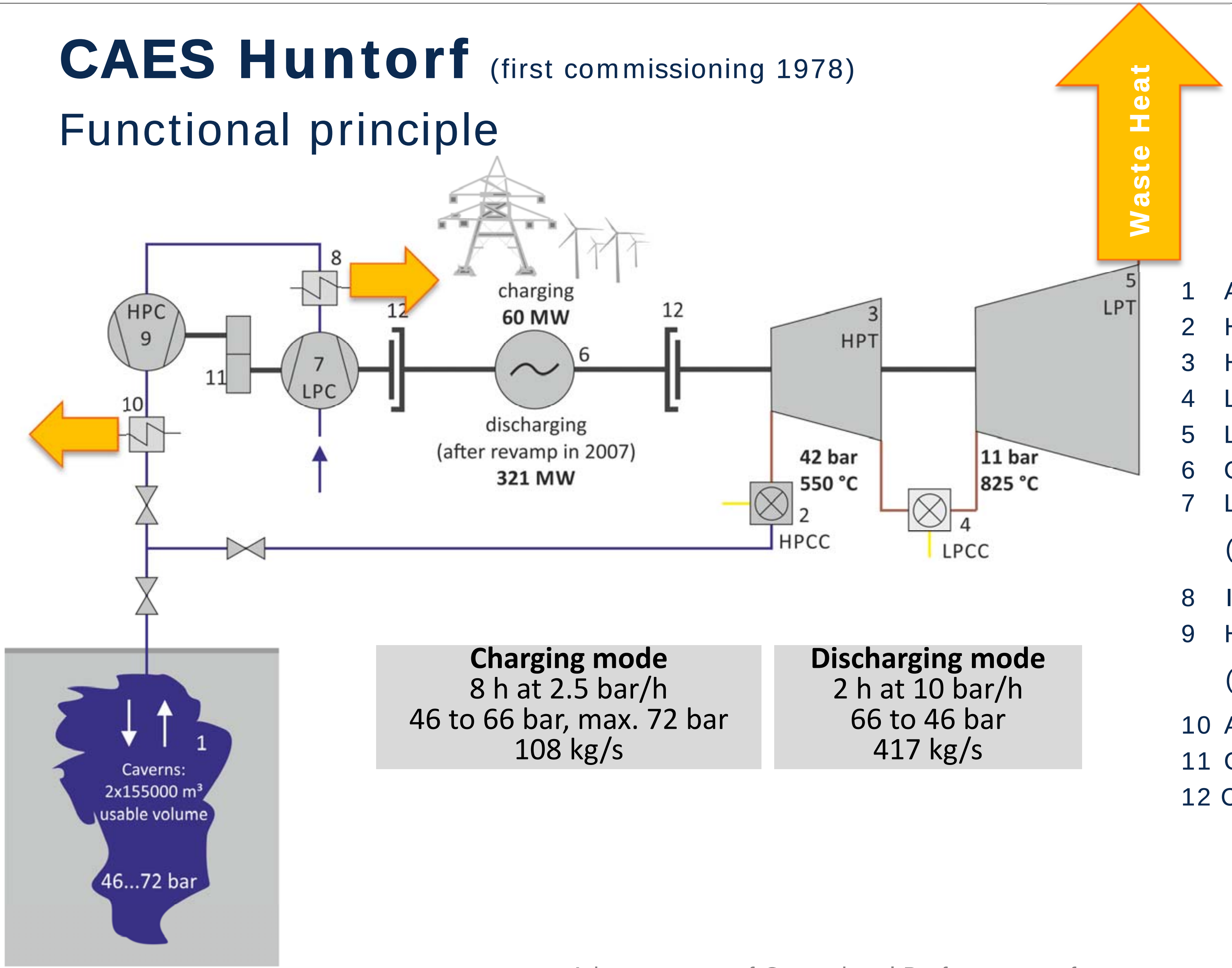
Heat recovery concept for compressed air energy storage power plant

Jasmin Lückert
Uwe Krüger Uniper Kraftwerke GmbH
Uwe Gampe
Guntram Buchheim

London, 12/09/2016

CAES Huntorf (first commissioning 1978)

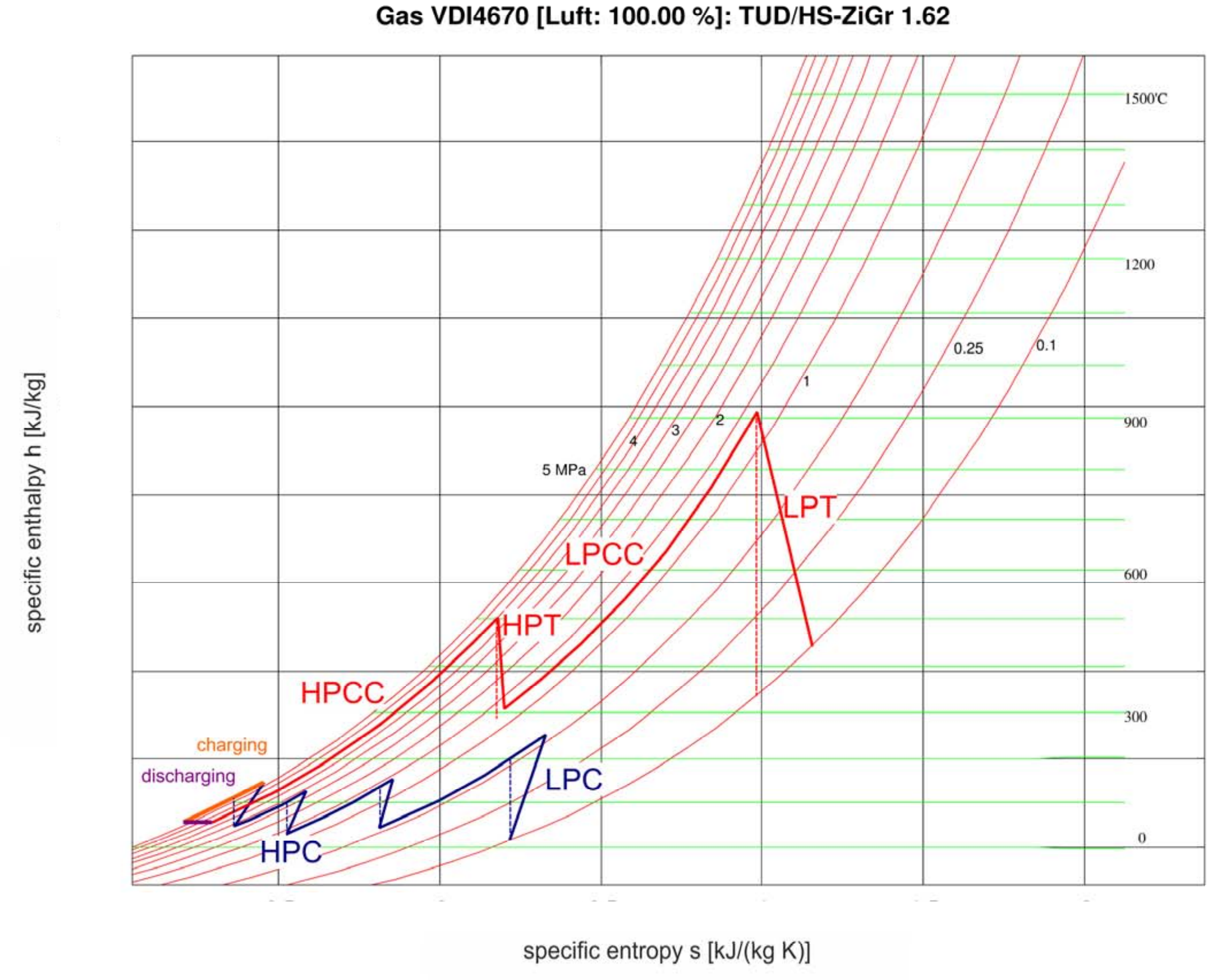
Functional principle



Charging mode	Discharging mode
8 h at 2.5 bar/h	2 h at 10 bar/h
46 to 66 bar, max. 72 bar	66 to 46 bar
108 kg/s	417 kg/s

1 Air-storage cavern
2 HP combustion chamber
3 HP turbine
4 LP combustion chamber
5 LP turbine
6 Generator/motor
7 LP compressor
(axial 20 stages)
8 Intercooler
9 HP compressor
(centrifugal 6 stages)
10 Aftercooler
11 Gearbox
12 Coupling

CAES Huntorf



$$\eta_{cycle} = \frac{P_{out}}{P_{in} + \dot{Q}_{in}}$$

η_{cycle}	…	Cycle efficiency
P_{out}	…	electrical Power output
P_{in}	…	electrical power input
$\dot{Q}_{in}$	…	Heat flow input

Cycle Efficiency (conventional) 42%

HPC	high pressure compressor
LPC	low pressure compressor
HPCC	high pressure combustion chamber
LPCC	low pressure combustion chamber
HPT	high pressure turbine
LPT	low pressure turbine

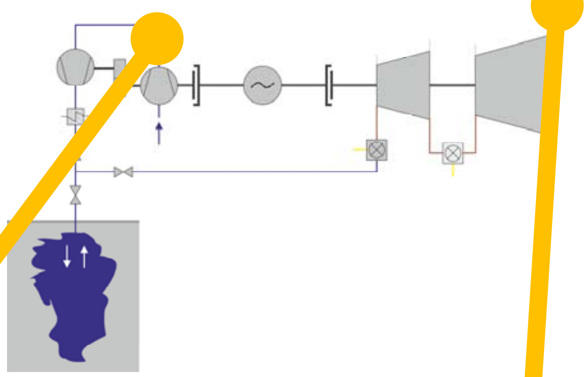
Objective

→ **Recovery of waste heat from compressor air cooling and turbine exhaust heat , exergetic storage and utilization for fuel saving in turbine operation (CAES discharge mode)**

Tasks

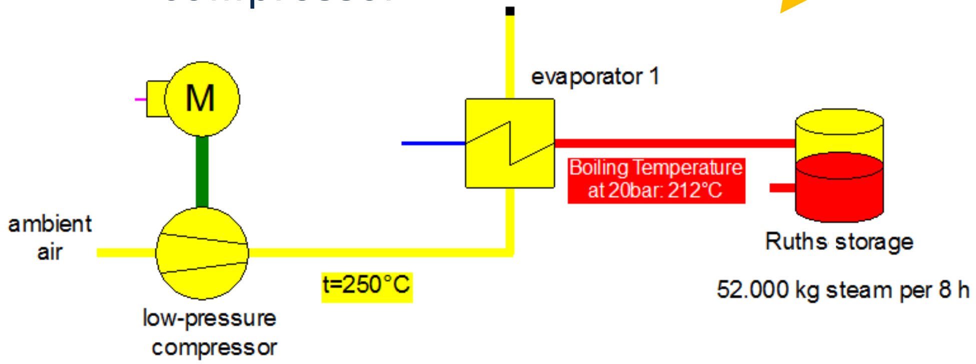
- Steam generation and storage
- Thermodynamic analysis of turbine operation with steam injection

Steam Production
Potential in CAES Huntorf



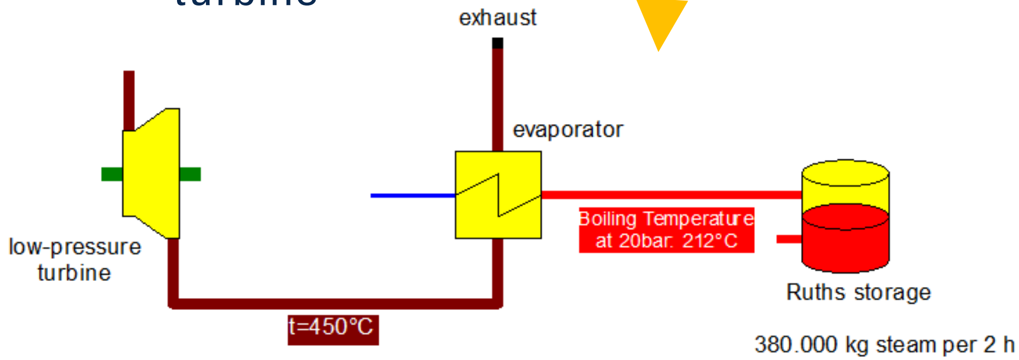
Air compression waste heat recovery (Option 1)

- During charging mode
- Evaporator behind low-pressure compressor



Turbine exhaust heat recovery (Option 2)

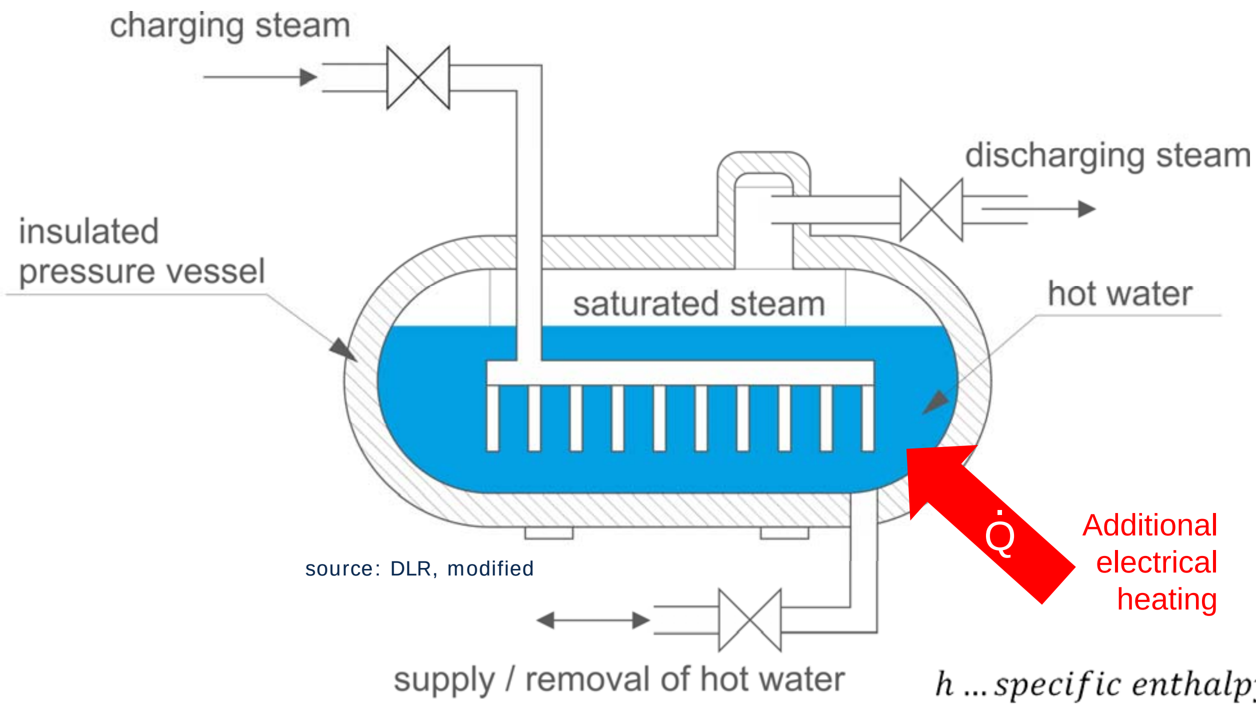
- During full load in discharging mode
- Evaporator behind low-pressure turbine



Ruths-Storage

Functional Principle

- Steam storage for direct steam supply
- Saturated water/steam inside storage tank
- Operation of the storage between maximum and minimum pressure



source: DLR, modified

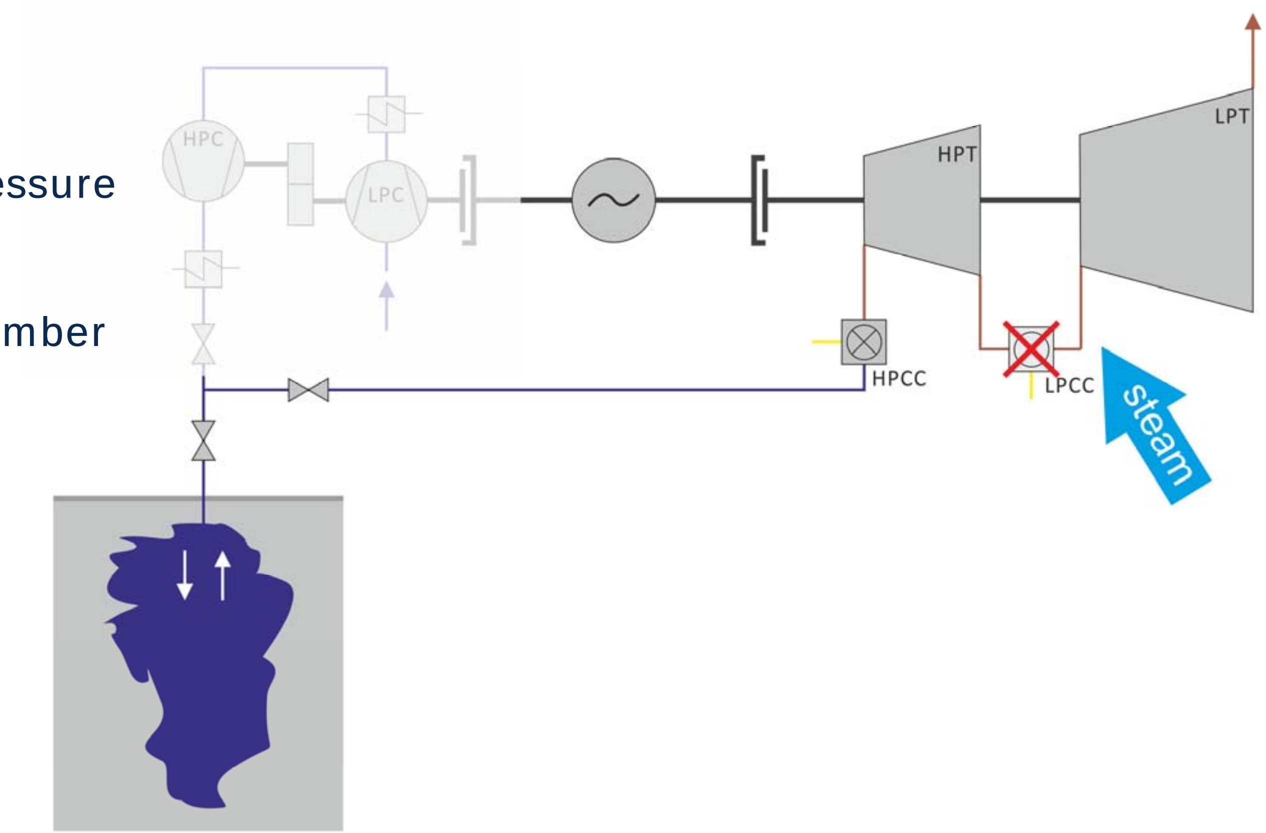
storage density: $b = \frac{m_{steam}}{V_{tank}} = \frac{\beta}{v'_{max}} \frac{h'_{max} - h'_{min}}{0.5\,(h''_{max} - h''_{min}) - h'_{min}}$

h ... *specific enthalpy*
m ... *mass*
V ... *volume*
β ... *degree of filling*
v ... *specific volume*
$'$ ... *fluid*
$''$ ... *vapor*

Steam

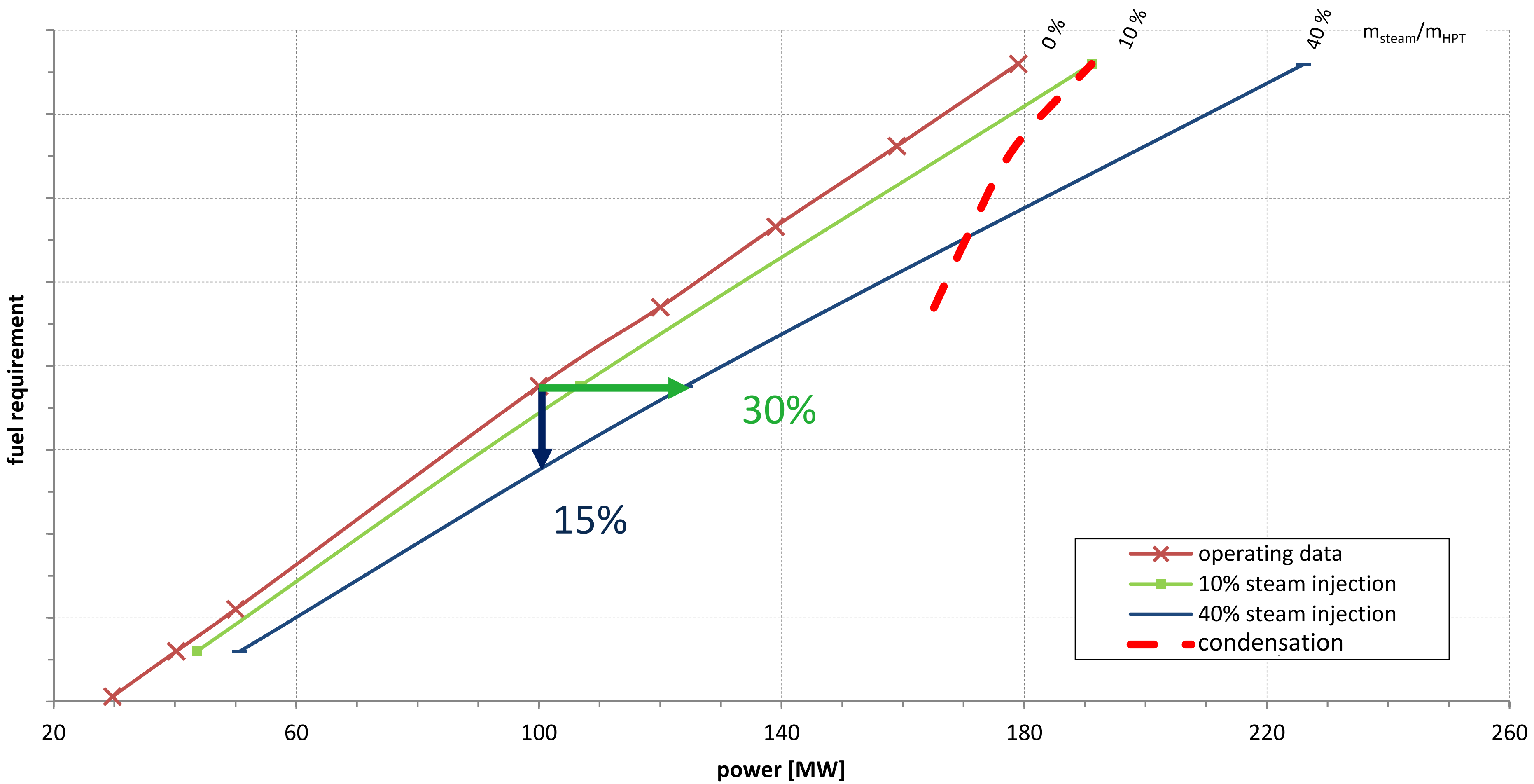
Possible utilisation in CAES Huntorf

- Steam injection to the low-pressure turbine during partial load (low-pressure combustion chamber **turned off**)
    - Improvement of cycle efficiency
    - Improvement of turbine efficiency
    - lower part load possible
    - Fuel saving



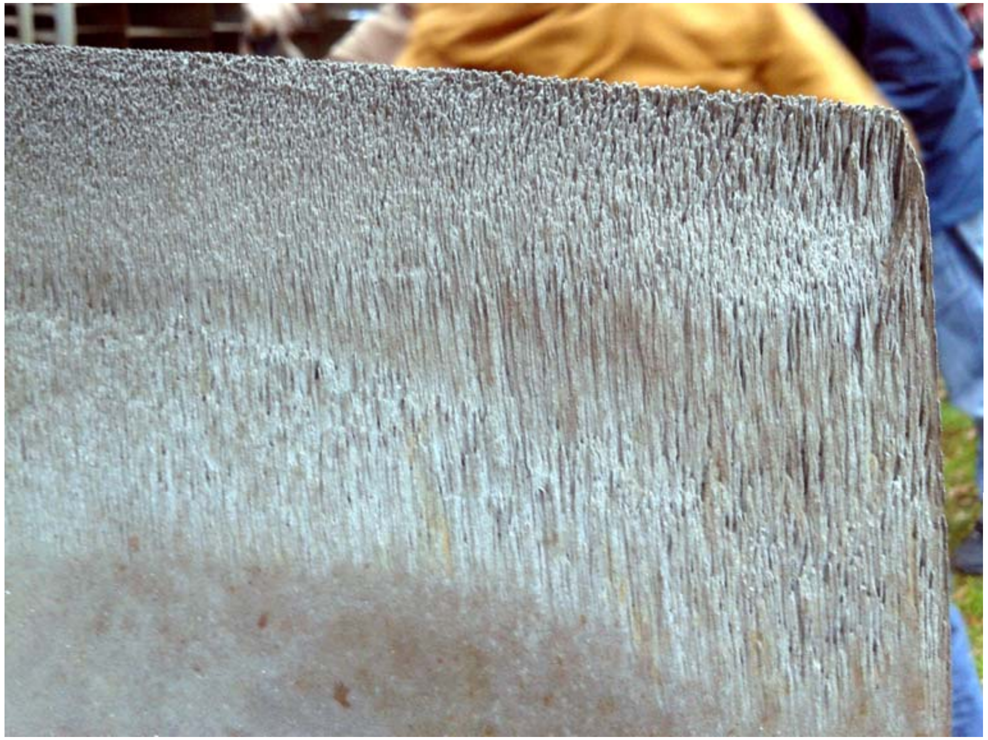
Steam Injection

Fuel saving



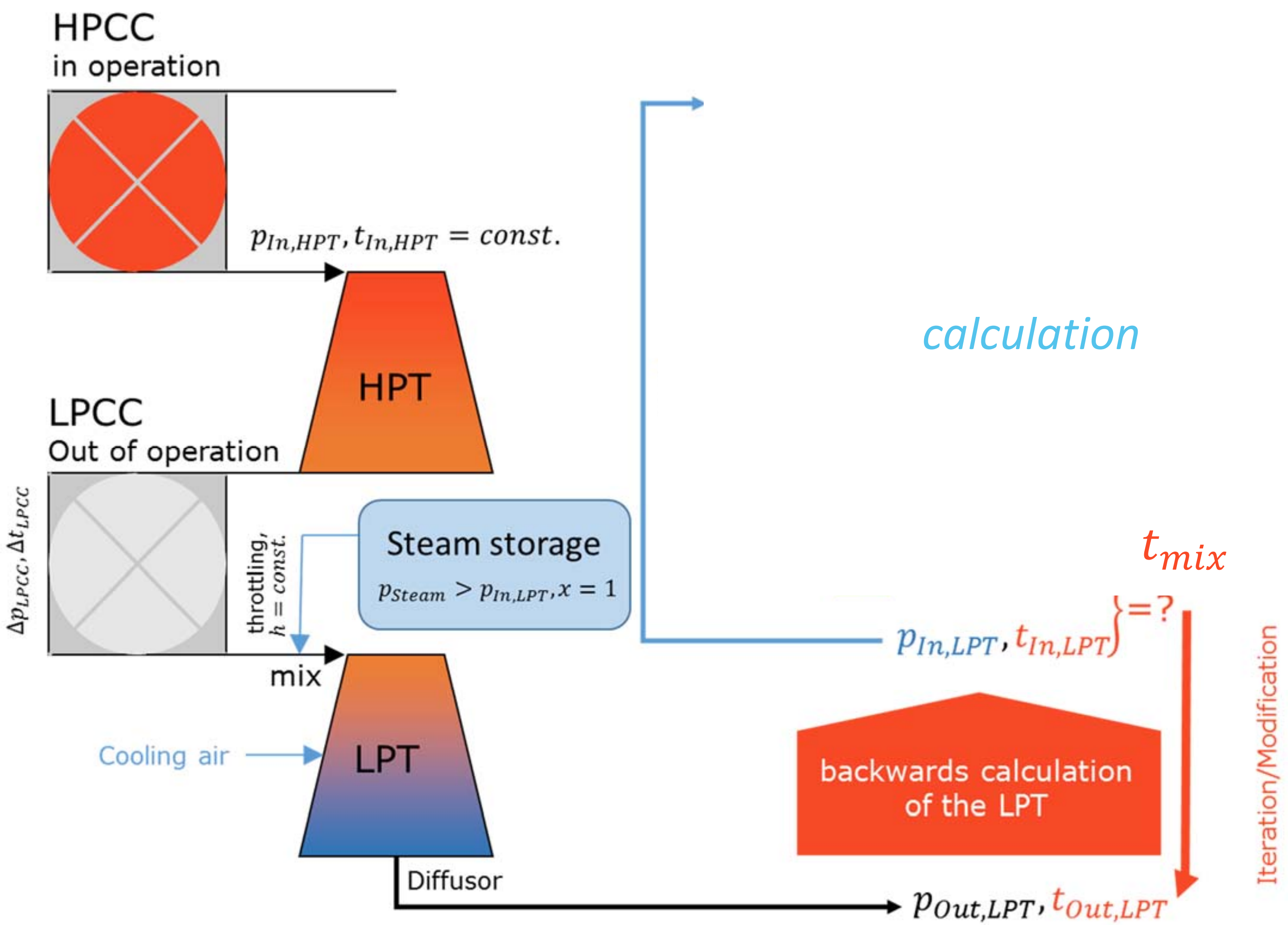
- Avoiding of condensation inside the turbine - *water drop erosion*
- Change of pressure level inside the turbine

→ Thermodynamic analysis



Performance Calculation

Low Pressure Turbine with steam injection

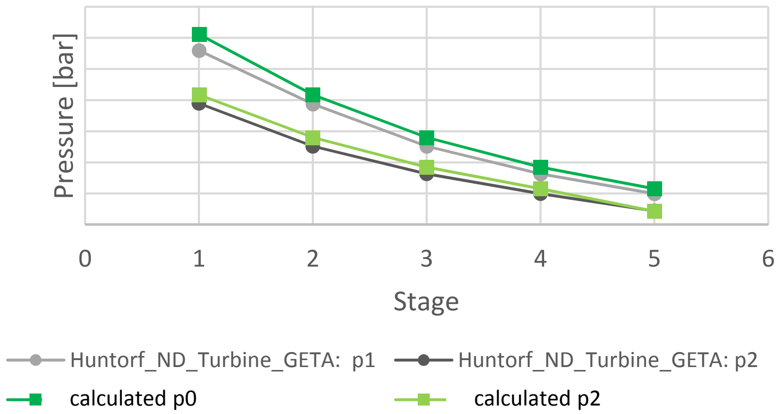


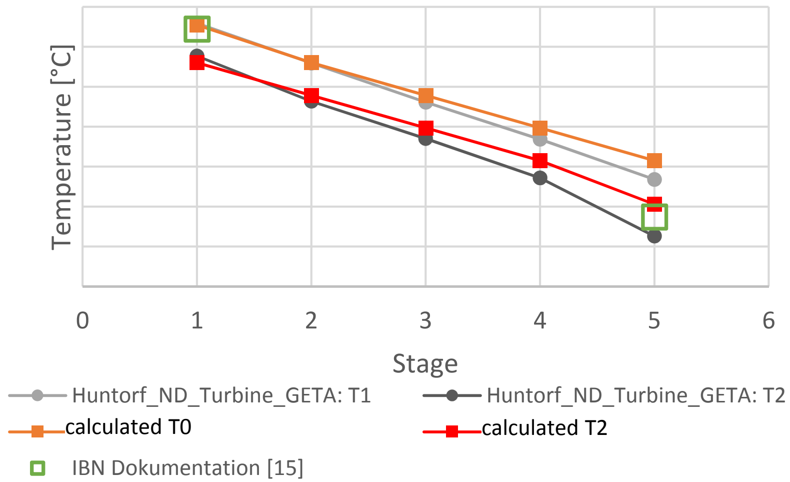
Performance Calculation

Validation

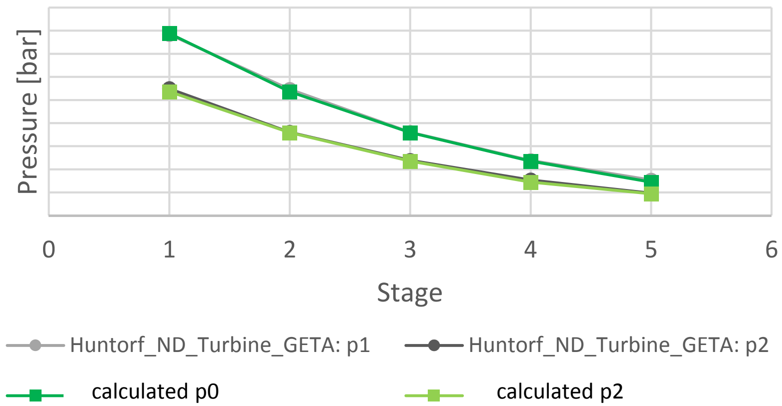
HPCC in operation
LPCC in operation

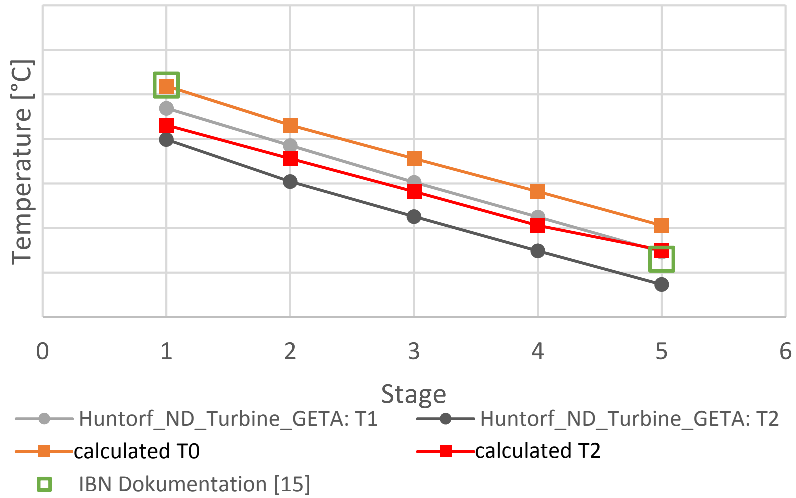
320 MW





200 MW





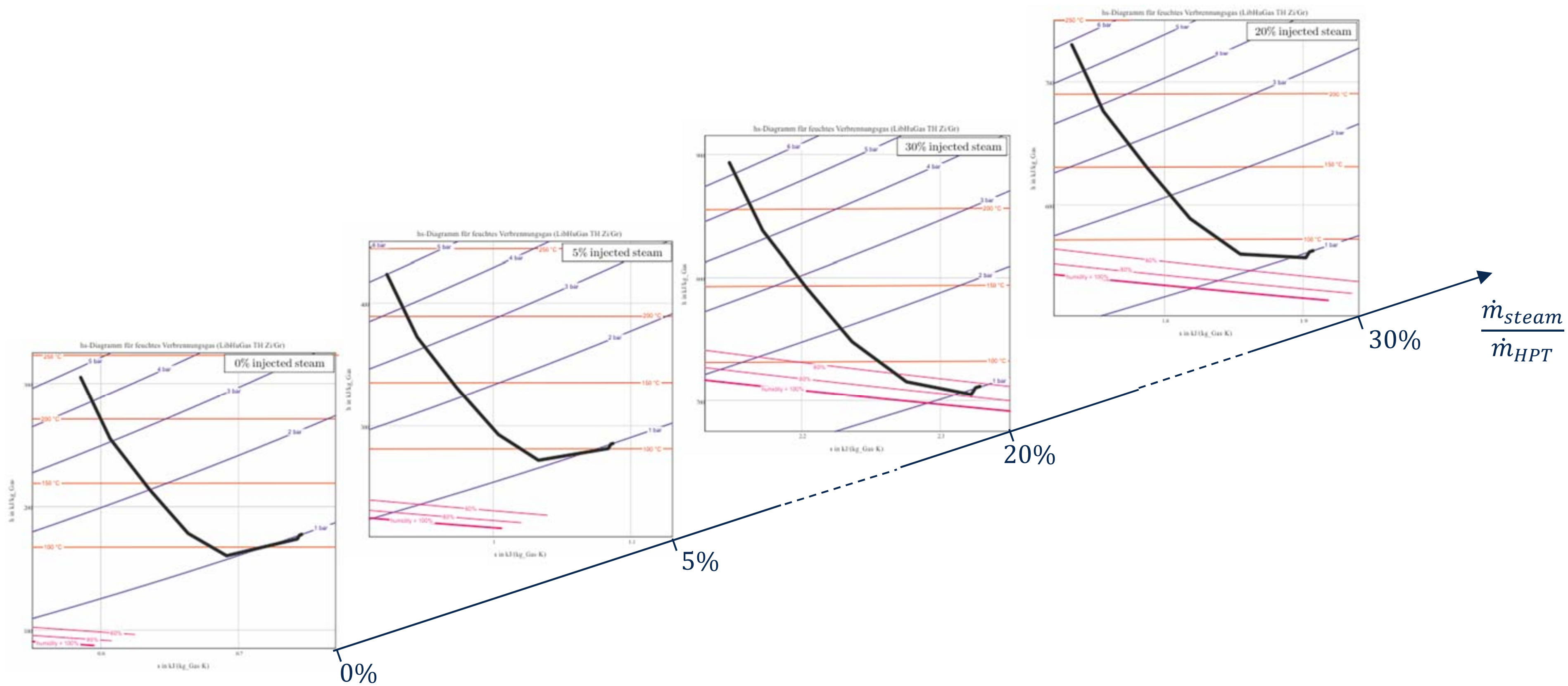
TECHNISCHE UNIVERSITÄT DRESDEN

uniper

Performance Calculation

HPCC in operation
LPCC out of operation

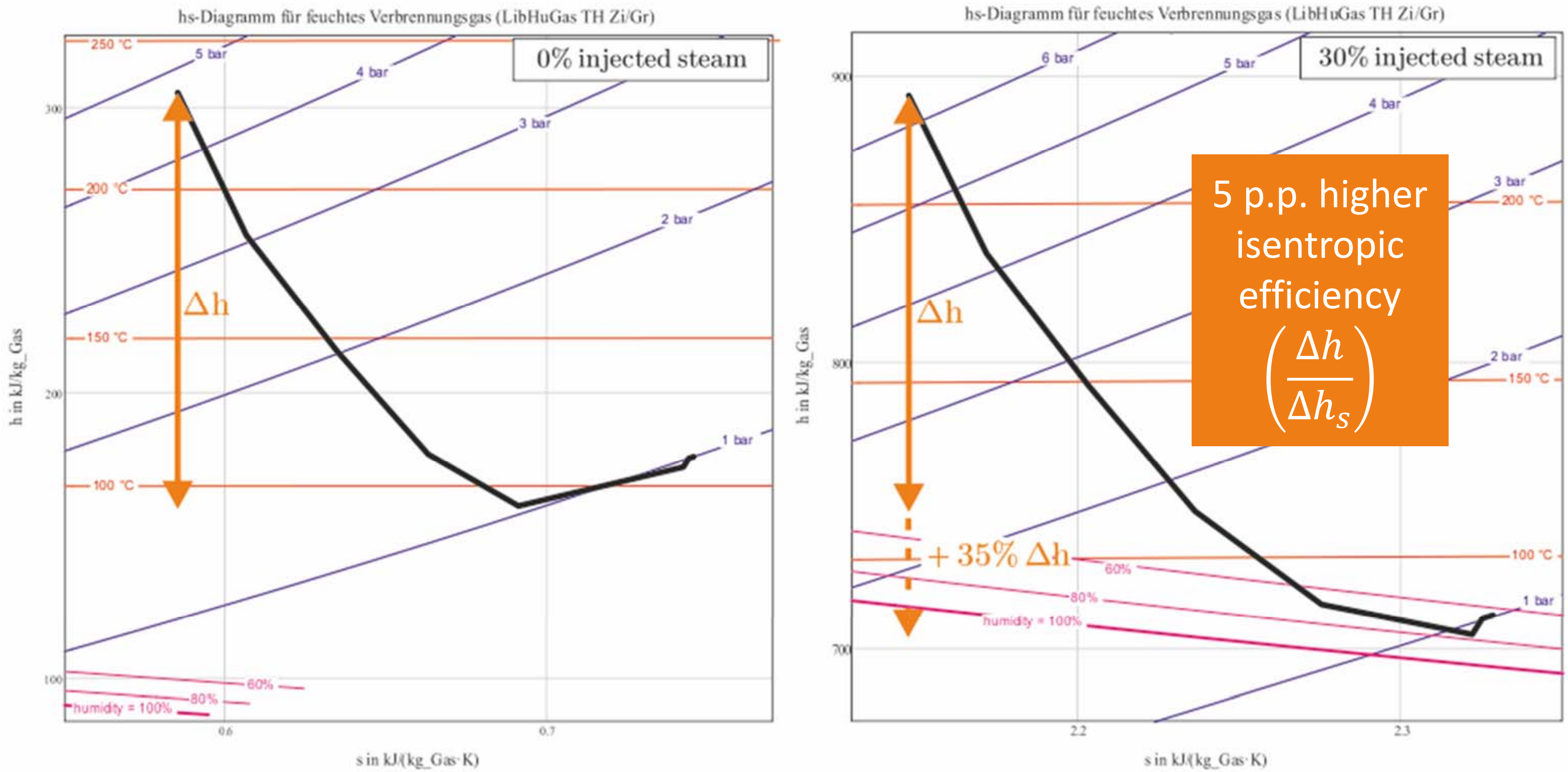
Low pressure turbine with steam injection



Performance Calculation

HPCC in operation
LPCC out of operation

Low pressure turbine with steam injection



Summary and Outlook

CAES Huntorf

- Improvement of an exisiting compressed air energy storage (CAES) plant to meet current demands of energy market
  - Changed requirements profile for operation
  - Efficiency improvements at partial load with in-process waste heat utilisation
- Solution: combination of available technologies
  - Steam injected gas turbine (STIG)
  - Ruths storage

Project partners: Uniper (formerly E.ON) and TU Dresden

- Determination of operation limits due to condensation with performance calculation
- First operation tests with steam injection

»Wissen schafft Brücken.«