DECARBONIZATION OF HIGH-TEMPERATURE HEAT FOR INDUSTRY - A DLR PERSPECTIVE -

EUREC workshop on green high-temperature heat supply to industry

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High-Temperature Heat Pumps

DLR

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Aim

Reduce CO_2 and pollutant emissions from industrial processes and power plants

Mission

Research and development for a successful energy transition in industry

CO_2-reduction options for industry

Climate-neutral energy sources/feedstocks

- Electrification
- H_2 / synth. / carbon-free energy sources
- Biomass
- Solar process heat

H_2-utilization Biomass

High-Temperature Heat Pumps

Energy efficiency

Process analysis

CO_2 utilization & capture

- Carbon Capture and Use (CCU)
- Carbon Capture and Storage (CCS)

Process Chemistry

Reduction in demand for primary materials

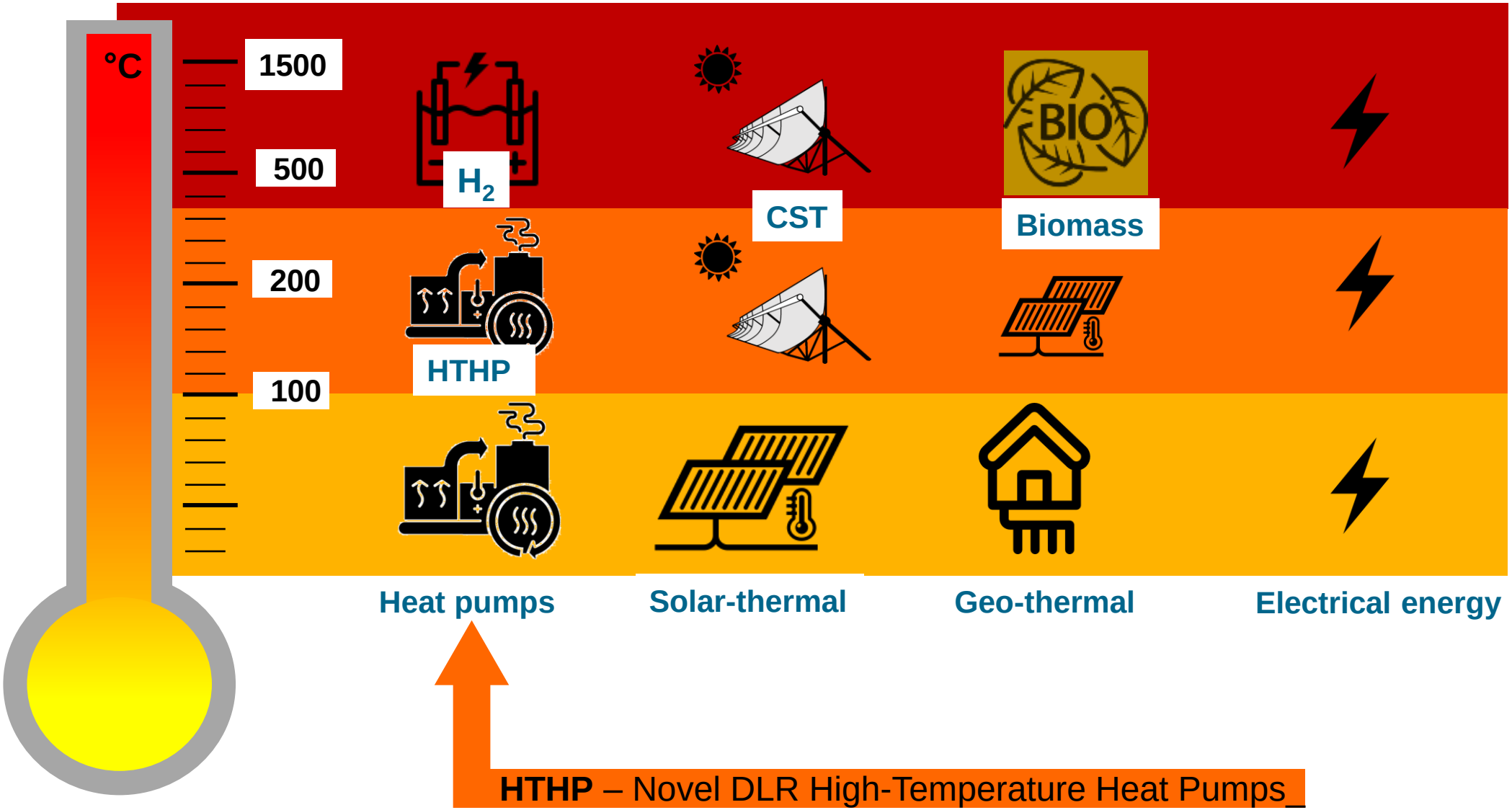
- Reduction of final demand
- Material substitution
- Circular economy
- Material efficiency

Nach Leipprand et al., DLR, FVEE-Tagung 2020

Climate neutral process heat

- Challenge:
  - Energy demand and energy carrier selection
- Possible solutions:
  - Differentiation according to temperature ranges: low - medium – high
  - well fitted assignment: Electrification, solar thermal energy, geothermal energy, hydrogen, biomass …
  - Barriers
- Summary

Temperature ranges and technological options



HTHP – Novel DLR High-Temperature Heat Pumps_

Low-temperature range

up to ~100 °C: many well established technologies and products exist

District heating networks

- Industrial heat pumps (up to ~160 °C)
- Geo-thermal
- Solar-thermal
- Electrical heating

R&D:

- System integration and optimization
- Solar-thermal: Energy storages required for 24/7

Medium-temperature range

up to ~500 °C: new solutions required and new product development

Many different applications and demands; e.g.:

- Industrial heating networks (chemical industry)
- Drying processes
- Food industry
- …

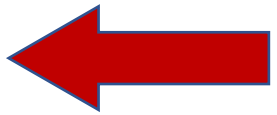
➔ simple use of electrical or chemical energy

- not efficient
- not the optimum for the economics

R&D:

- Industrial High-Temperature Heat Pumps
- Concentrated solar thermal
- Storage technologies
- Hybridization (e. g. HTWP + energy storages,...)
- System integration and optimization

Low TRL,
industrial demonstration of high risk for both:
manufacturer and customer



High-temperature range

> 500 °C: established technologies and products

Many different applications and demands; e.g.:

- Metals melting
- Ceramics firing/sintering
- Cement
- …

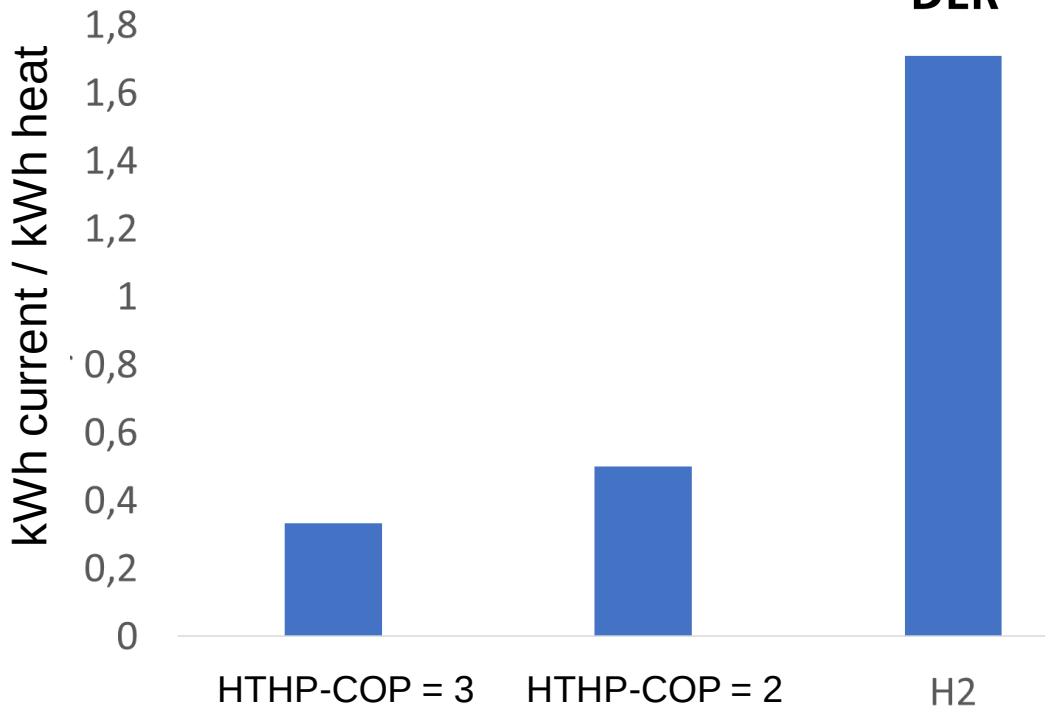
➔ use of electrical or chemical energy, hydrogen or synthetic fuels

- Maximum efficiency is required here
  for both the company and the economics

R&D:

- System integration, optimization – including sector coupling
- …(not the focus of this talk)

Medium- and High-temperature range Hydrogen / Biomass



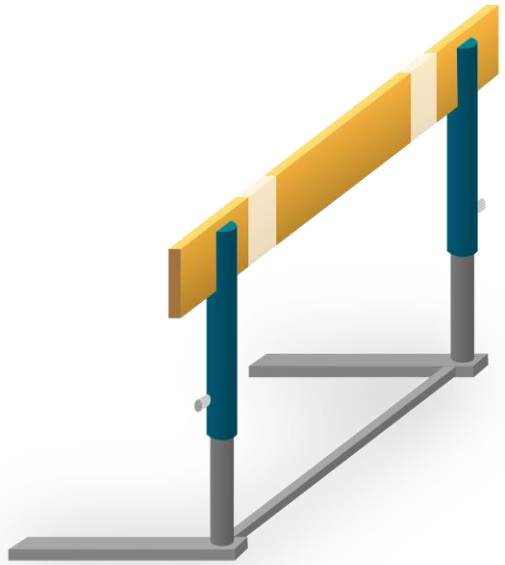
Not covered here, but…

- Green Hydrogen will be the most expensive energy carrier
- Biomass is a limited resource, whose use must be very well balanced

Medium-temperature range:

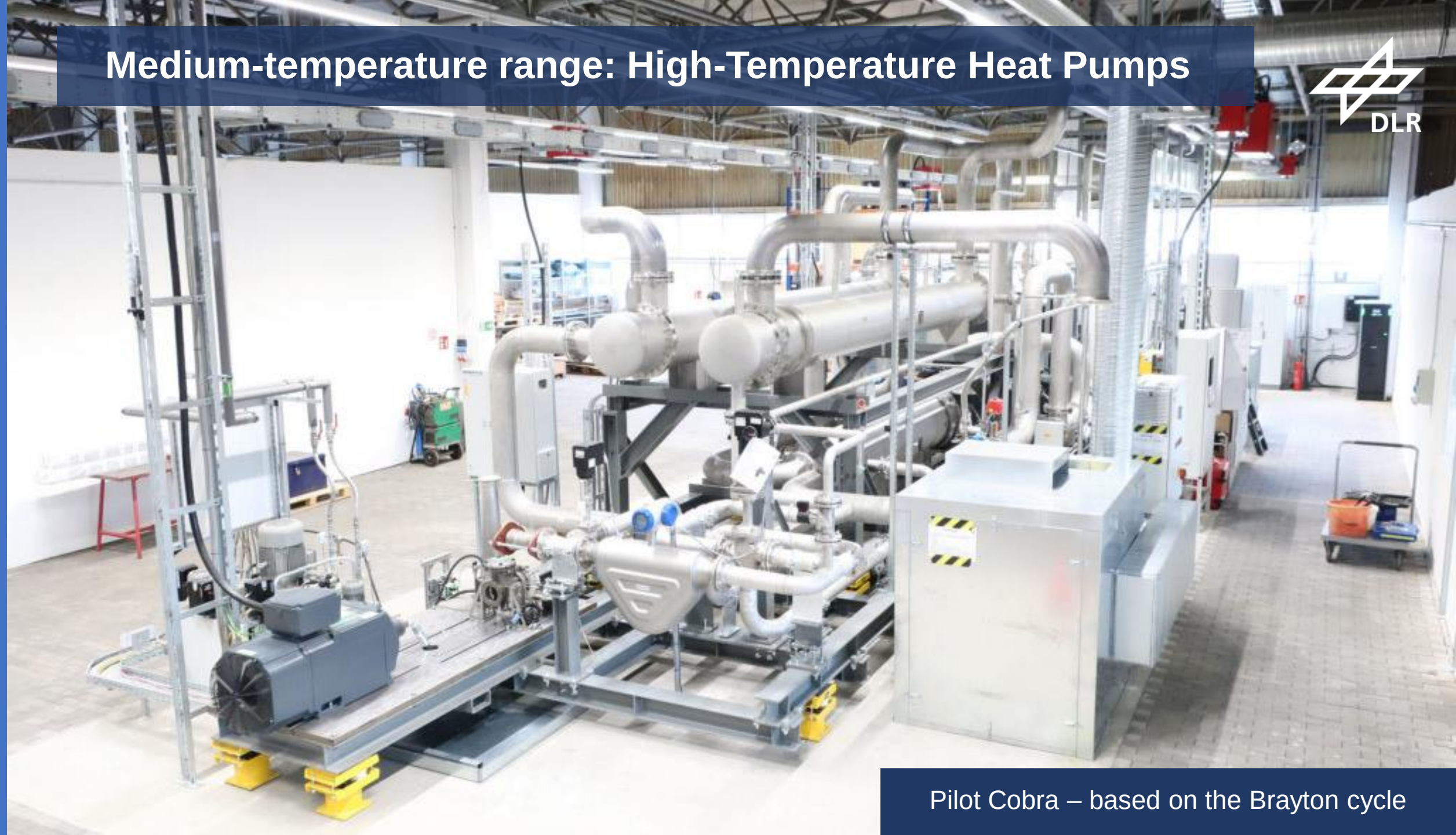
- The technology I discuss here and we develop can be a „Wasserstoffeinsparmaschine“ = Hydrogen saving machine

Barriers



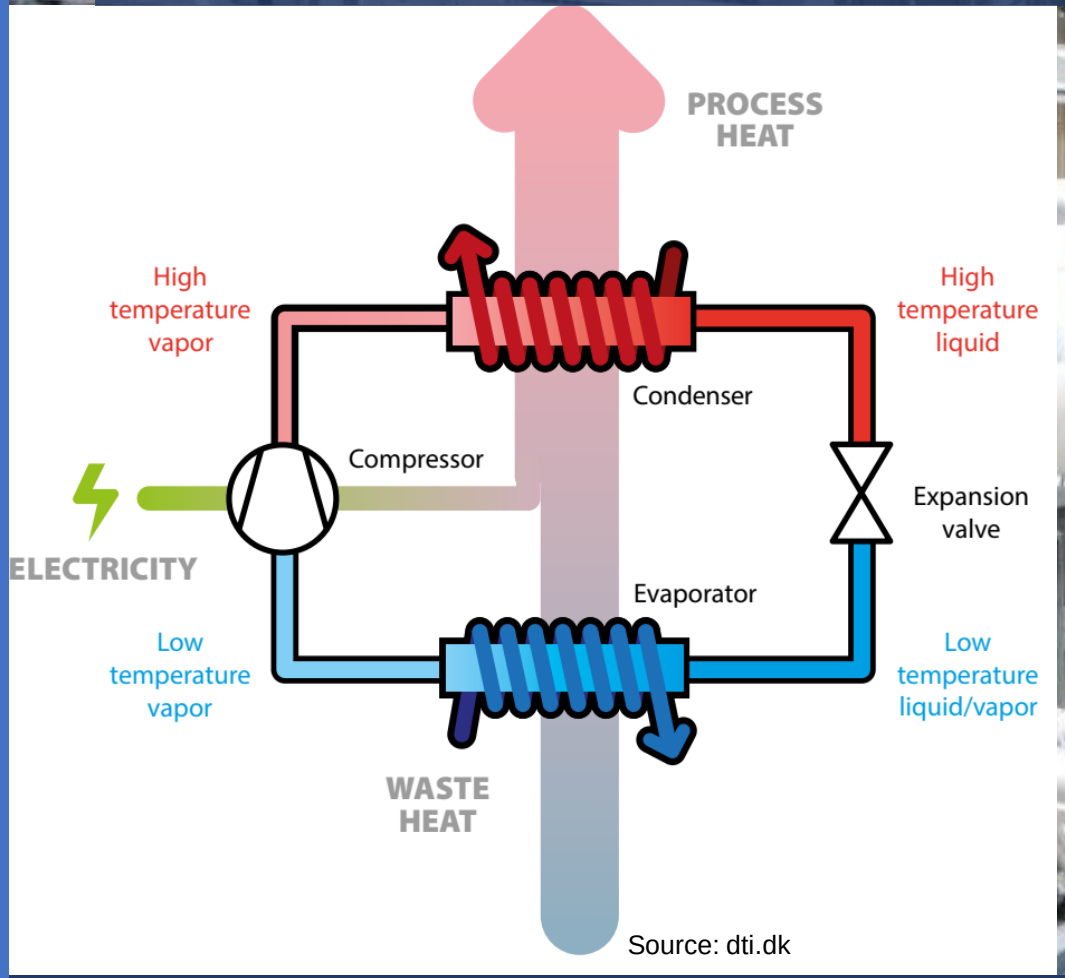
- **Technical**
  - Spatial / temporal decoupling of source and sink
    - Generation of RE and heat demand incongruent
  - Hybrid technologies required
  - Digitalization
- **Economical**
  - Economics
  - Planning security
  - Expected payback period
  - Lack of incentives for early demonstrators
- **Overarching**
  - Challenging time line for the energy transition
  - Legal topics
  - Information deficit
  - Shortage of skilled labor
  - Acceptance – „not in my backyard“

Medium-temperature range: High-Temperature Heat Pumps



Pilot Cobra – based on the Brayton cycle

Medium-temperature range: High-Temperature Heat Pumps



Research goal of DLR:

- Sink-temperature: > 300 °C (up to 500 °C), power: Megawatt range
- Development of the HTHP-system and the main components
- Process analysis

High-Temperature Heat Pumps using steam

Challenges

Compression of the “light” gas – water steam

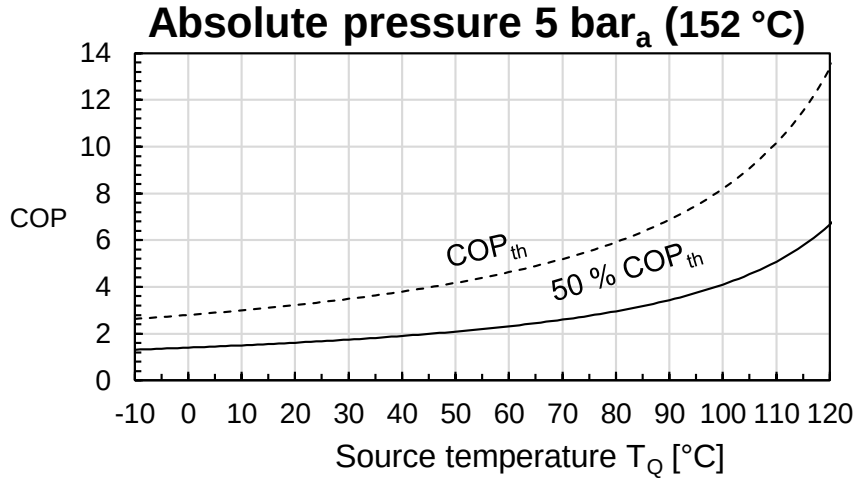
- molar mass: 18 g/mol compared to 29 g/mol of air
- Small pressure ratio and high superheating per stage

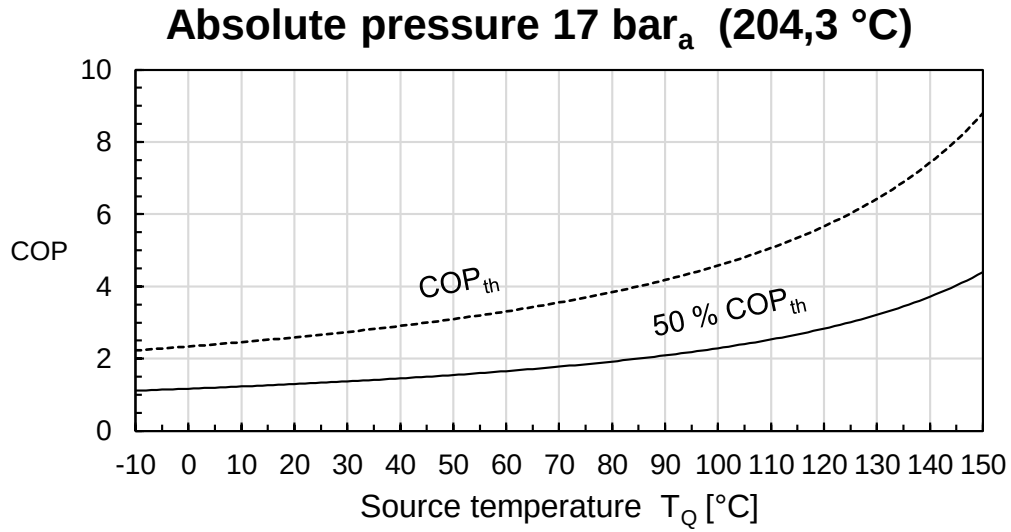
State of the art

- Mechanical vapor recompression (MVR) with $\Delta T = 10\ K\ - 20\ K$
- Available only for high mass flow rates

Research and development goal

- Compressor for $\Delta T \geq 35\ K$
- Reduced number of stages, compact design, easier integration
- Heat sink temperature >= 250 °C

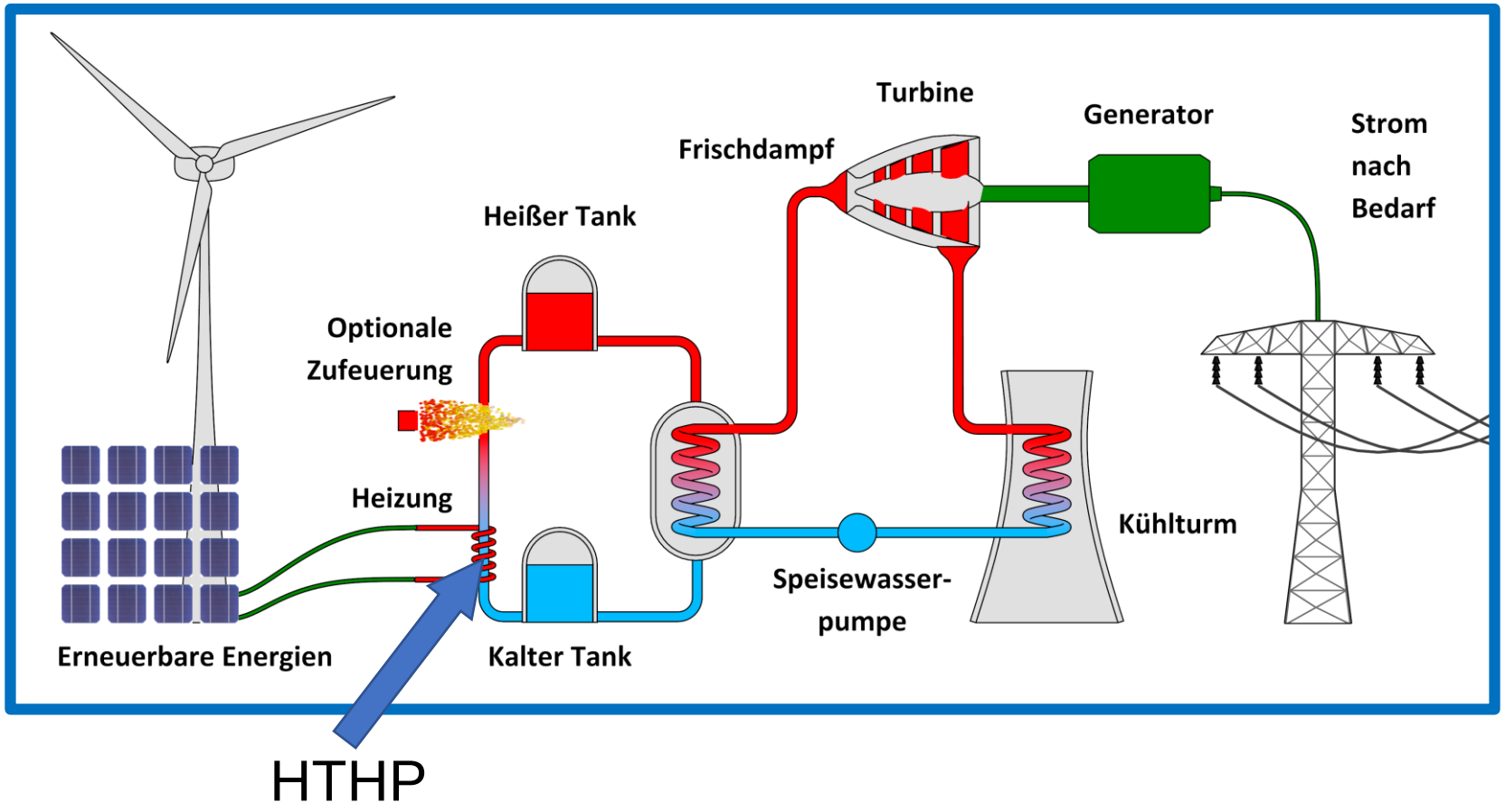




Coefficient of performance (COP)
for industrial steam grids

Thermal storage power plants

- Cost-effective and resource-saving energy storage
- Provision of electricity and process heat is possible
- Low CO_2-avoidance costs



Summary
Decarbonization of the industry – focus process heat

Solution must be well adapted to the production – including all boundary conditions

- One-Fits-All won't work
- Customized solutions are required in covering all needs: Heat, Steam, Cold

➔ **New way of sector coupling**

R&D:

- New technologies,
  e.g.: HTHP, Storage, CSP, CST
- Potential of hybridization

Our answer:

- HTHP test-facilities
  - Based on Brayton-cycle built
  - Based on Rankine-cycle ready in one year
- Industry processes:
  - Analyses of the energy and material flows;
  - concepts for the restructuring and
  - integration of the HTHP

➔ Demonstrator project must be the next step