WASTE HEAT UTILISATION OF POWER TO HYDROGEN PLANTS FOR LOCAL AND DISTRICT HEATING

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www.ise.fraunhofer.de

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AGENDA

- Project presentation
- Motivation
- Introduction
- Methodology
- Results
- Conclusion and outlook


Source: Energiedienst Holding AG


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Project Presentation
Power-to-Gas-Leuchtturm Baden-Württemberg

- 1 MW electrolysis with trailer filling
  - Economical operation ensured by usage of hydropower
  - Commissioning fall 2018
- Run by german-swiss energy supplier EnergieDienst AG
- Supply of customers like hydrogen filling stations, carriers, industrial companies via trailer
- Heat extraction is taken into account for the near future
  - First assessment in this project
- Project homepage: www.ptg-bw.de

Research and development

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DLR

DVGW

ZSW

Associated companies

EnergieDienst

RBB

terranets bw

Stadtwerke Sindelfingen GmbH
Strom · Gas · Wasser · Fernwärme

e-mobil BW
Landesagentur für Elektromobilität und Brennstoffzellentechnologie Baden-Württemberg GmbH

NUCELLSYS
THE FUEL CELL SYSTEM COMPANY

McPhy
Driving clean energy forward

Motivation – Power to Hydrogen
An important puzzle piece against climate change

- Large share of renewable energy (> 80 %) targeted by the german government until 2050
- PtH_2 is one of the missing links between the different sectors in the energy system

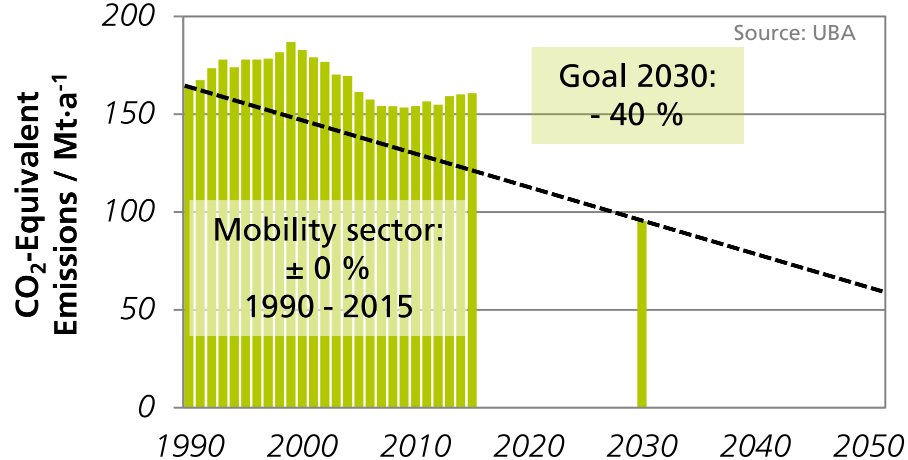
\+ Highly flexible operation

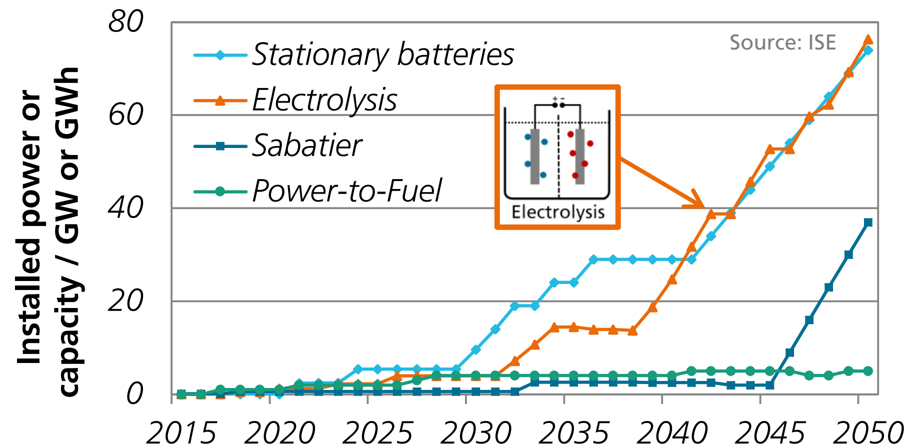
\+ Max. power and storable energy can be varied independently

\+ Large scale storage (caverns)

– Critique: allegedly low efficiency of the whole process compared to direct use of electricity

→ Integrated energy system





References
ISE: Henning, Palzer, Was kostet die Energiewende?, **2015**
UBA: Umweltbundesamt, Nationale Inventarberichte zum Deutschen Treibhausgasinventar 1990 bis 2015 (Stand **02/2017**) and estimation for 2016 (state **03/2017**)

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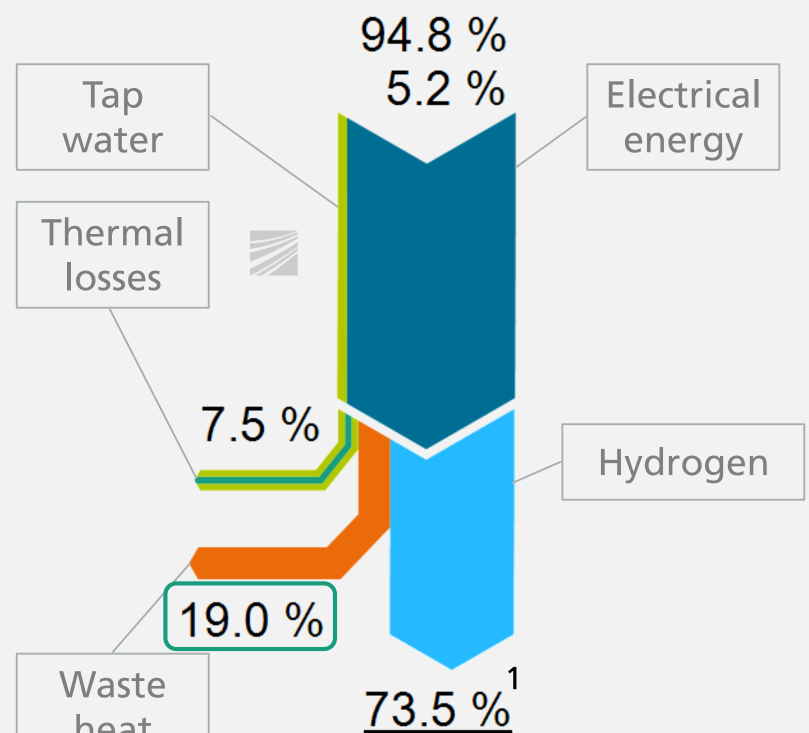
Motivation - Waste Heat Extraction from PtH_2 plants

A first footstep to largely increase the efficiency

- About 7 % of the German CO_2 emissions are caused by district heating purposes[1]
  - Only 11 % of the end energy used in households is from renewable source[2]

  → Decarbonization slightly advanced
- 73.5 % of input energy in electrolysis stack is converted to hydrogen
- Up to 19 % of the input energy needs to be cooled in the PtH_2 process

  → Enormous potential for usage in local and destrict heating grids



[1] no faraday losses considered in this chart

References
1: Umweltbundesamt, Nationale Inventarberichte zum Deutschen Treibhausgasinventar 1990 bis 2015 (Stand **02/2017**) and estimation for 2016 (state **03/2017**)
2: BMU: Klimaschutz in Zahlen, **06/2015**

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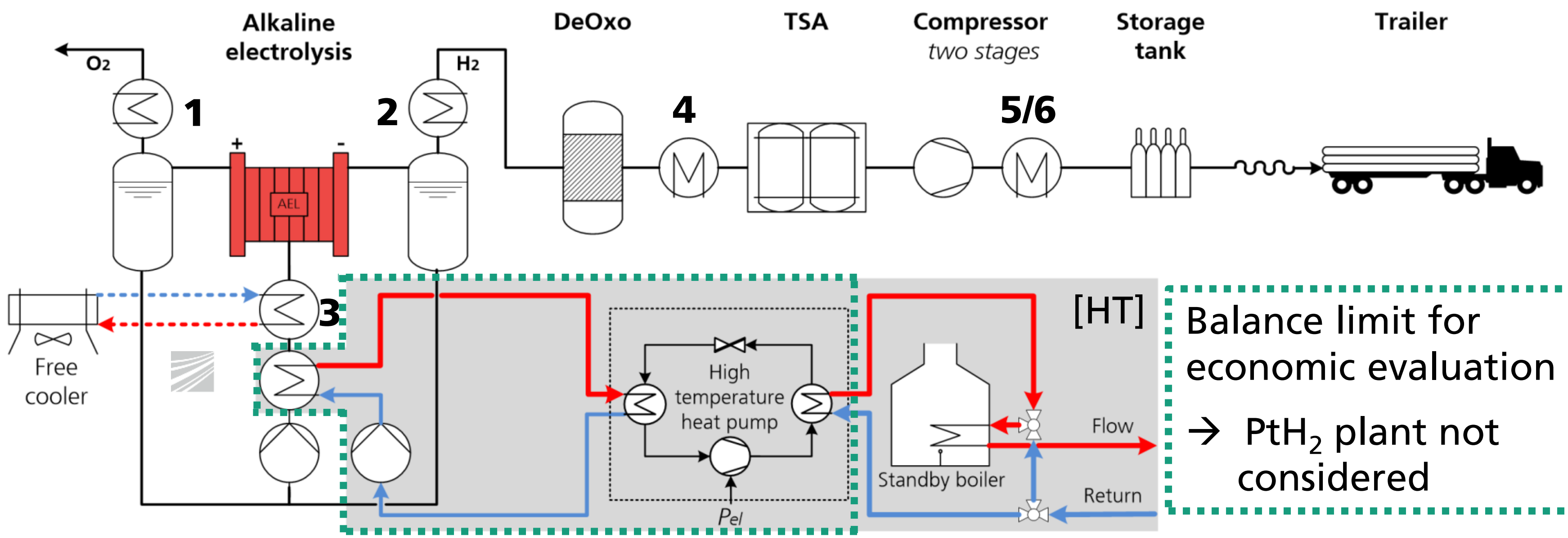
Introduction

Waste heat potential of PtH_2 and ways of utilisation



	1	2	3	4	5 / 6
Temperature	80 °C	80 °C	80 °C	150 °C	90 °C
Heat output	3,2 kW	6,3 kW	212 kW	11,2 kW	2 · 4,5 kW

Methodology

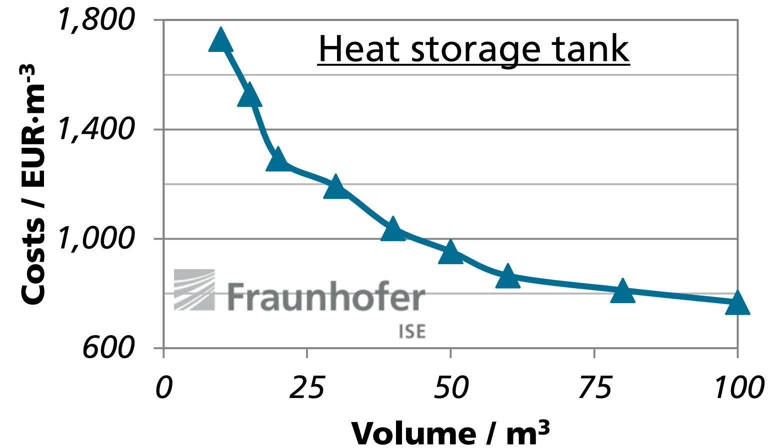
Technical and Economical Input Values and Assumptions

- Input time series
  - EEX Day ahead price } 2017
  - Temperature profile } 2017
  - Heat demand from standard load profiles (SLP)
- Boundary conditions
  - Space heating & domestic hot water

$$\eta = \frac{m_{H2} \cdot HHV + (Q_{heat})}{E_{el}}$$

$$LCOHeat = \frac{ANF \cdot \Delta CAPEX + \Delta OPEX}{Q_{injected}}$$

Component	Costs	Unit
Heat exchanger	10.000	EUR
Grid connection	50.000	EUR
Industrial heat pump	250	EUR/kW
Piping	250	EUR/m
Surcharge	30	%
OPEX	1	%/a



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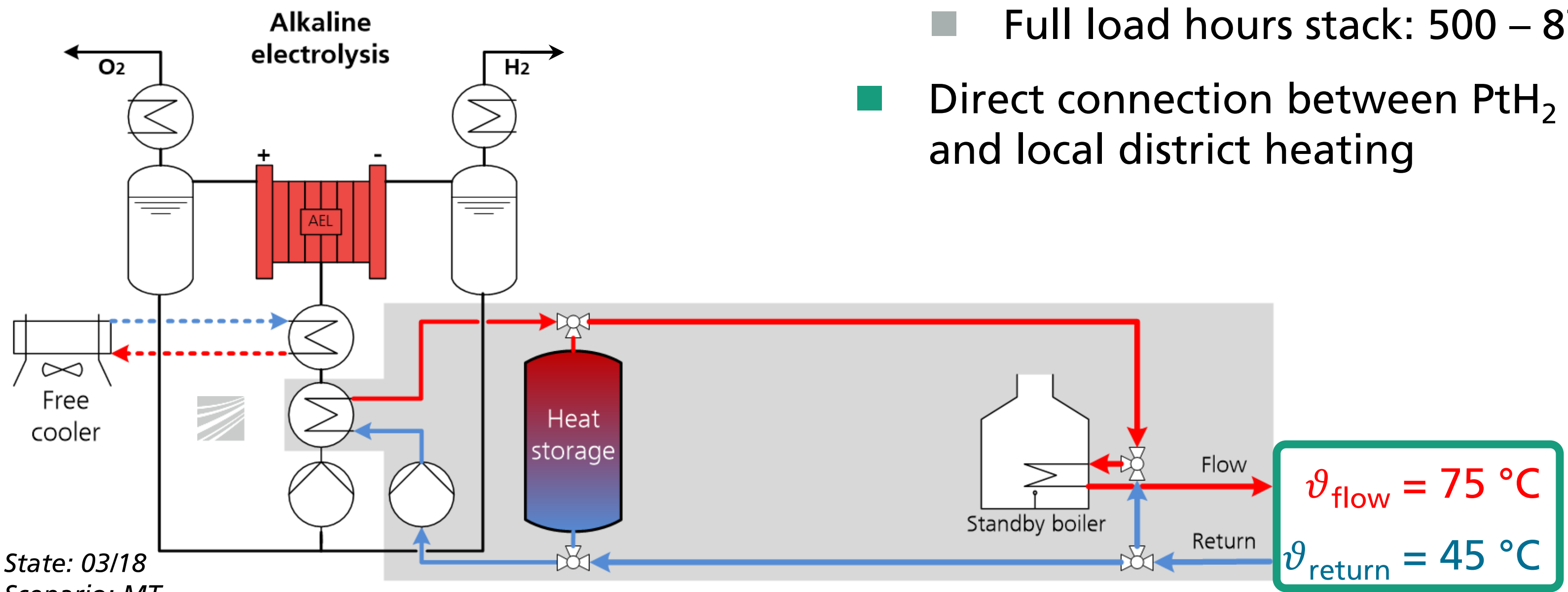
Results - Concept
Supply of a New Housing Estate (Medium Temperature)

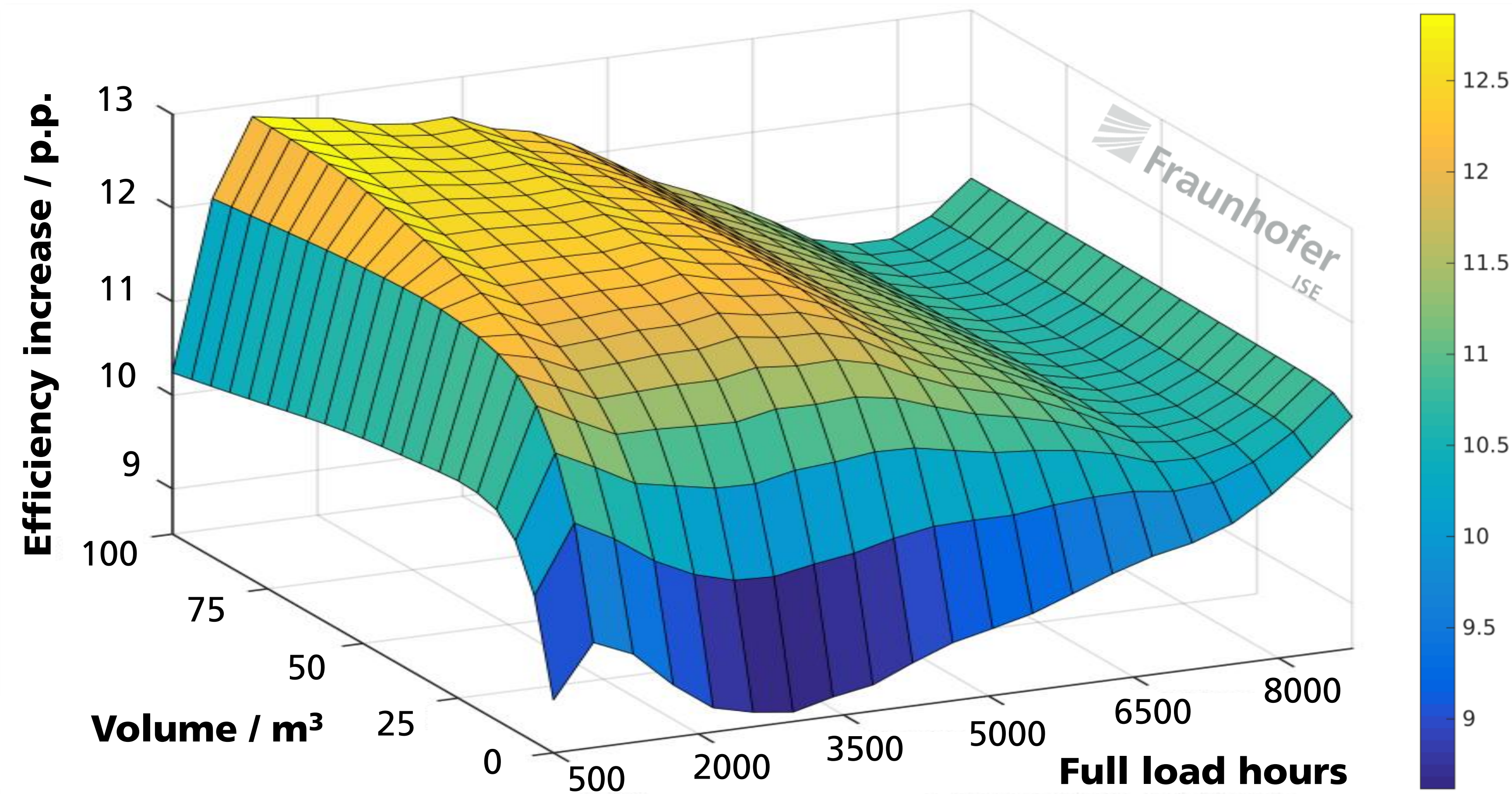
- **Role of PtH_2** plant in the heat grid
  - **Medium to large supporter**
- Peak heat load grid: **500 kW**
- Annual heat demand grid: **1.25 GWh**
- PtH_2 plant with **1 MW stack power**
- Heat grid length: 2,500 m
- Varying design:
  - Heat storage volume: 0 – 100 m^3
  - Full load hours stack: 500 – 8760 h
- Direct connection between PtH_2 plant and local district heating



State: 03/18
Scenario: MT

Results – Technical

Supply of a New Housing Estate (Medium Temperature)



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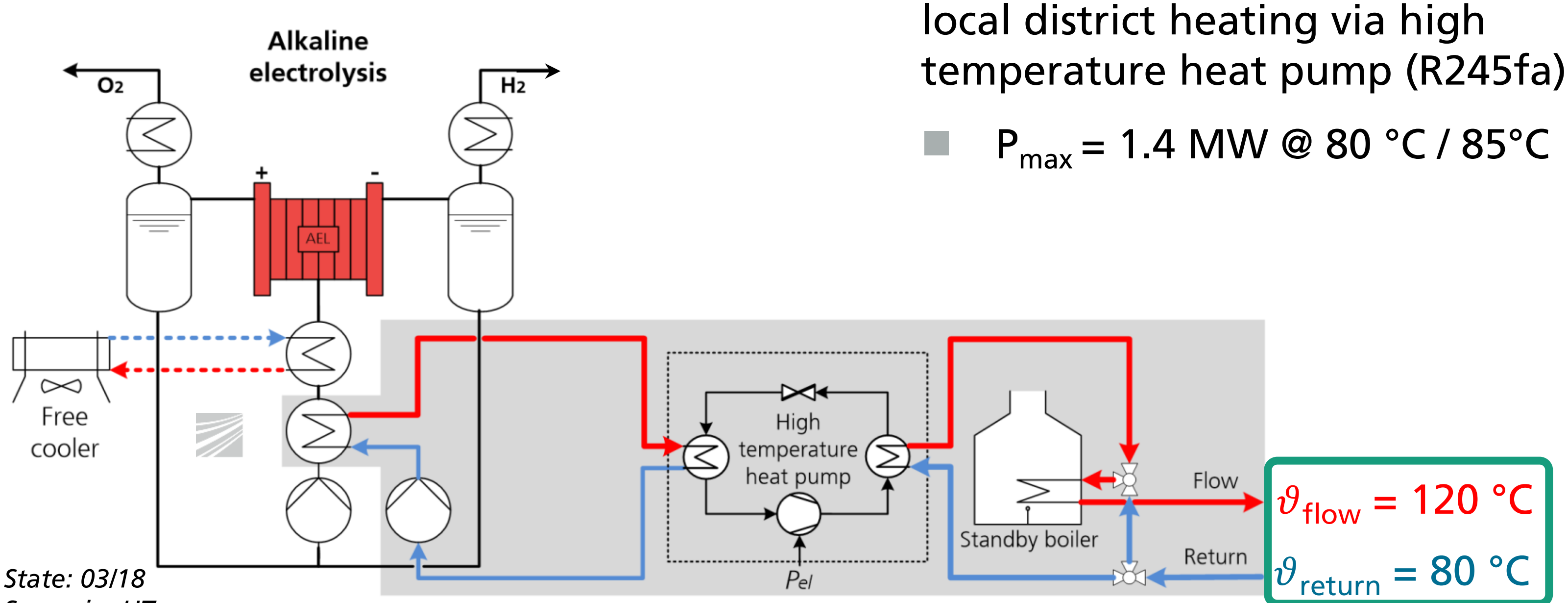
Results - Concept

Supply of an Existing Heat Grid (High Temperature)

- **Role of PtH_2** plant in the heat grid
  - **Small to medium supporter**
- Peak heat load grid: **50 MW**
- Annual heat demand grid**: 125 GWh**
- PtH_2 plant with **10 MW stack power**
- Heat grid length: 25 km
- Varying FLH, **no heat storage** tank
- Connection between PtH_2 plant and local district heating via high temperature heat pump (R245fa)
  - P_{max} = 1.4 MW @ 80 °C / 85°C



State: 03/18
Scenario: HT

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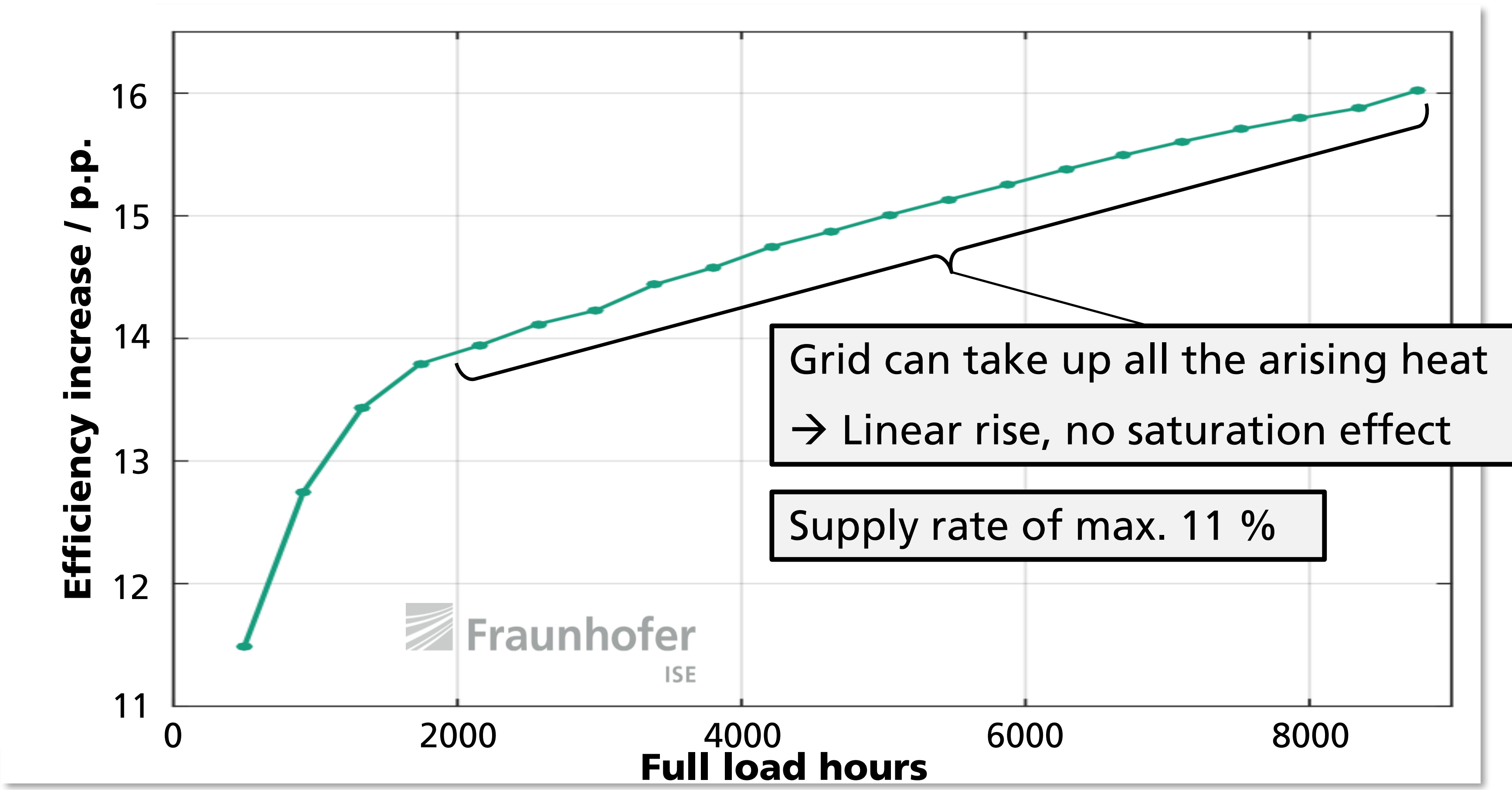
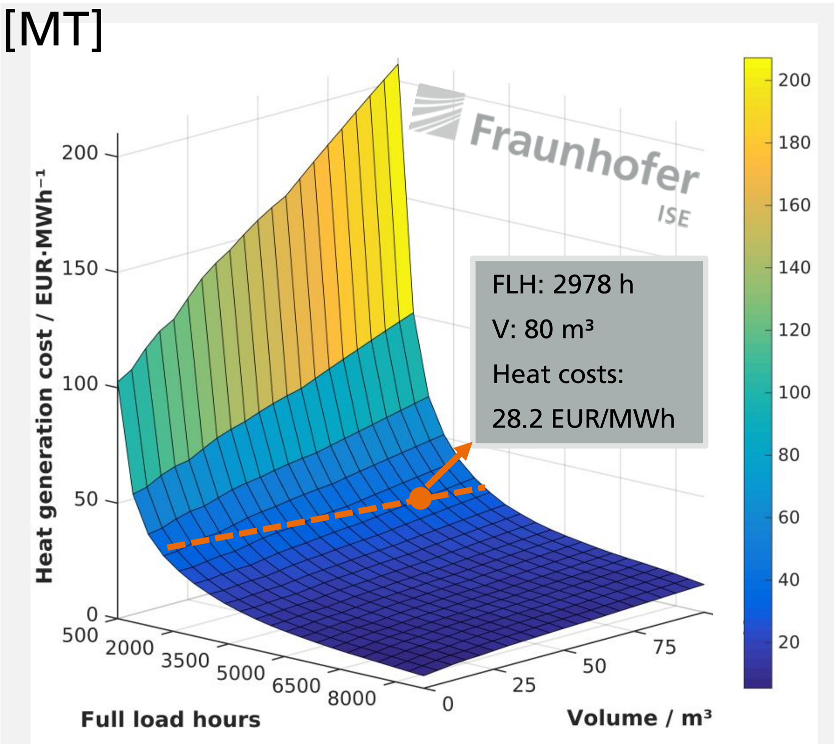
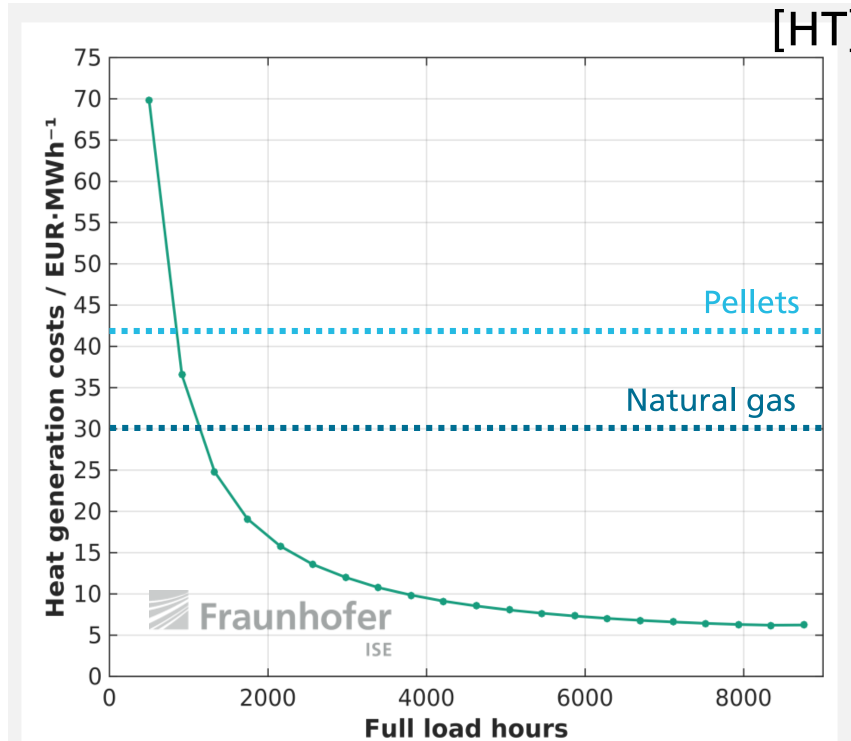
Results – Technical

Supply of an Existing Heat Grid (High Temperature)



Results – Economic
Comparison of Heat Generation Cost





- High number of full load hours is beneficial for heat generation costs

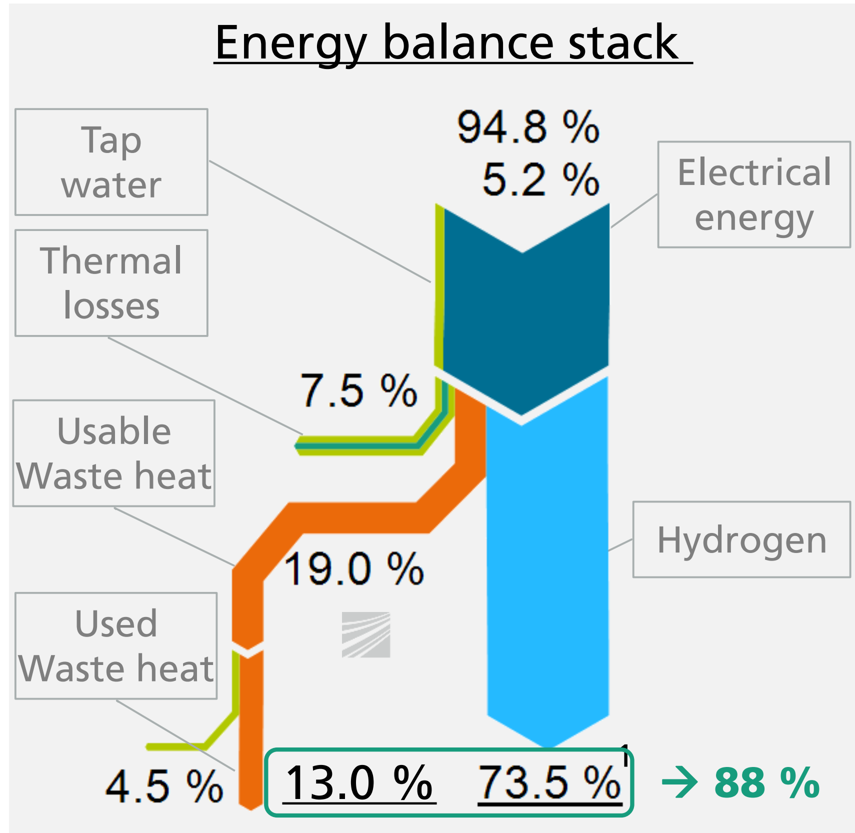
→ Best trade-off between heat production costs and efficiency increase important

Conclusion
What can we learn?

- Efficiency increase between 8.5 and 16 p.p. easily possible
- Up to 68 % of the generated waste heat was used for heating purposes
- Low LCOHeat of 5 – 30 EUR/MWh can be achieved
- Conclusion
  - Enormous potential to save primary energy and increase the efficiency of PTH_2 systems
  - Results are strongly depending on the scenario

  → No universal statement possible

  → New calculation for each scenario



[1] no faraday losses considered in this chart

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Outlook
What else can be thought?

- Large scale heat storage for seasonal heat storage > 100 m^3
  - Useful in case of electricity usage from photovoltaics
  - Not considered in this project
- Usage of the generated oxygen (O_2) for optimized combustion processes
  - Gas-fired or pellet boiler with OxyFuel combusti on → NO_x reduce
- Validation of the system simulation in this project scheduled for spring 2019
  - Heat extraction parts can't be validated at the moment, due to lack of measurement data

Fig 1: Hydrogen feed-in plant at Fraunhofer ISE

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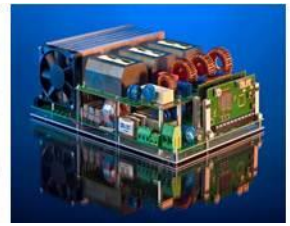
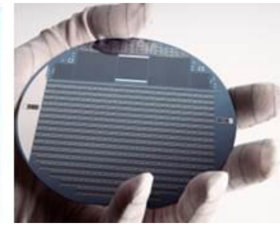
Thank you for your attention!

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