Decarbonising industry with hydrogen-based fuels: Energy system analysis on the case of a reference lime plant

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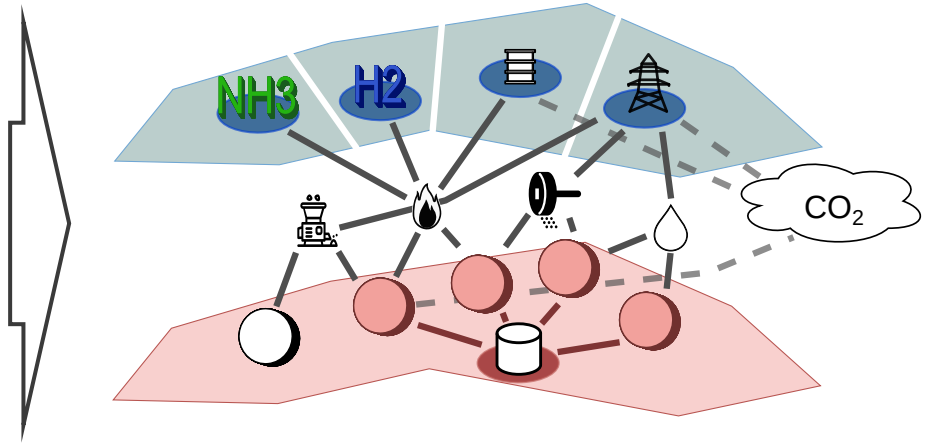
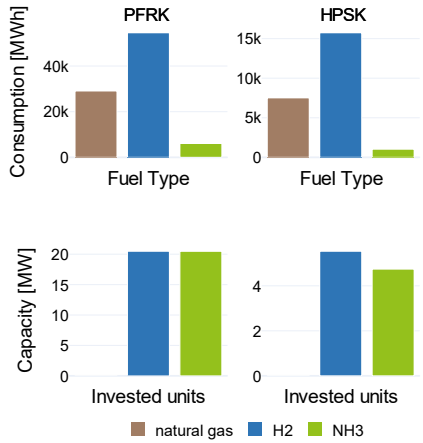
Reference lime plant

Decarbonisation through green H_2 and NH_3





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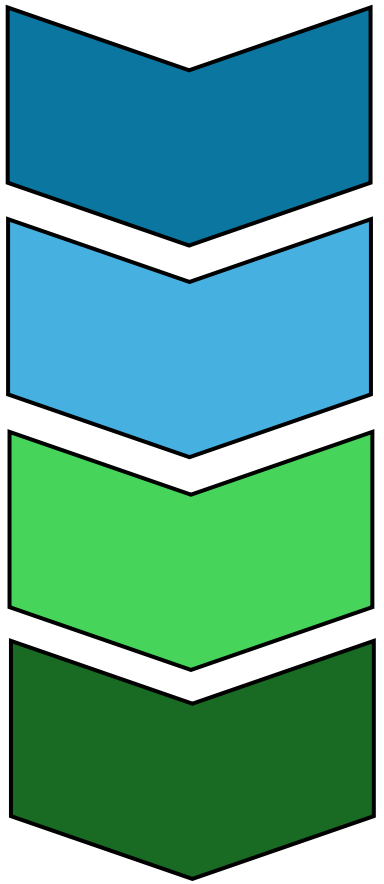
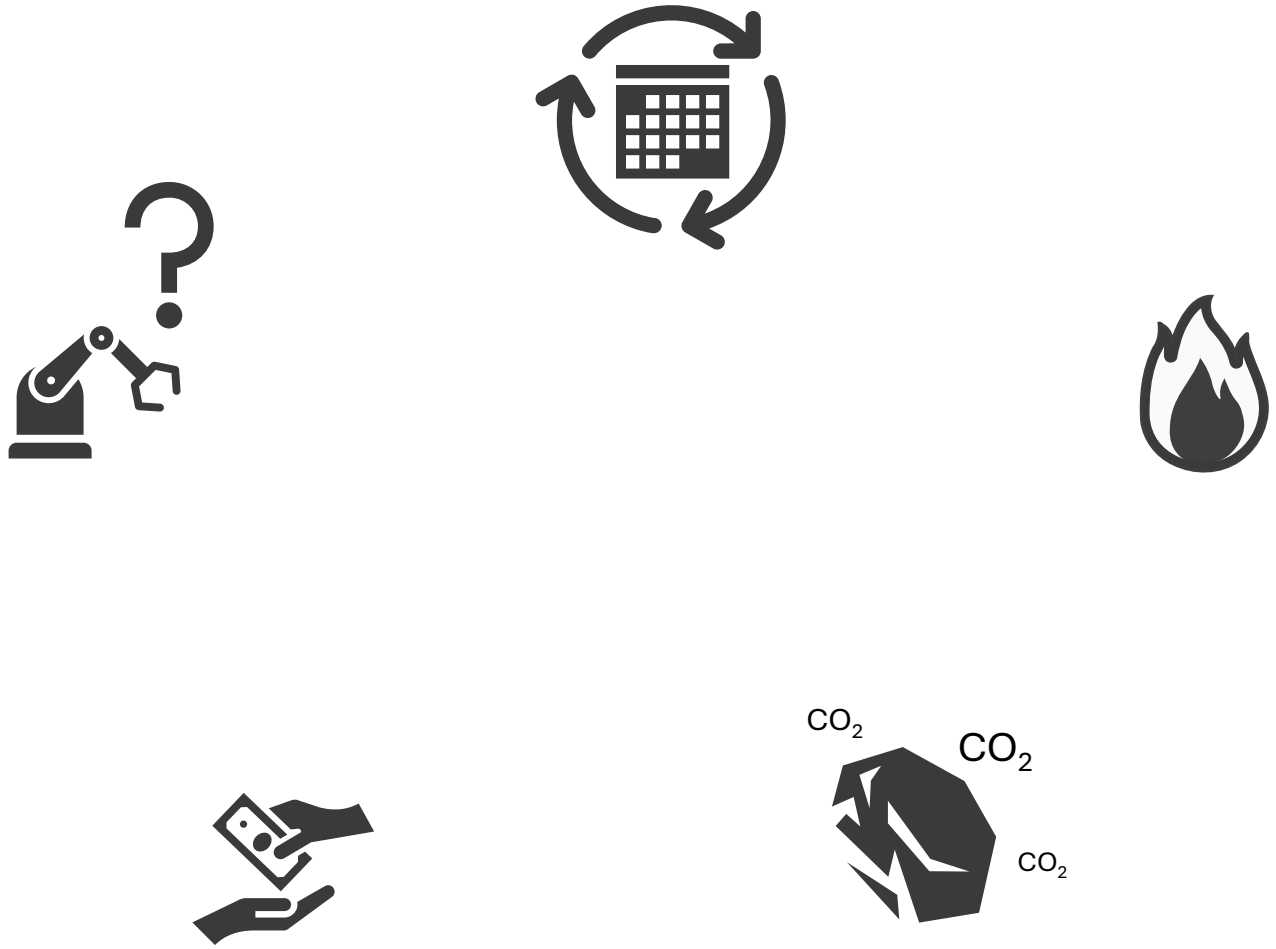
Structure

1. Introduction
2. Energy system model of a reference lime plant
3. Results
4. Conclusion



Challenges for decarbonisation in heavy industries

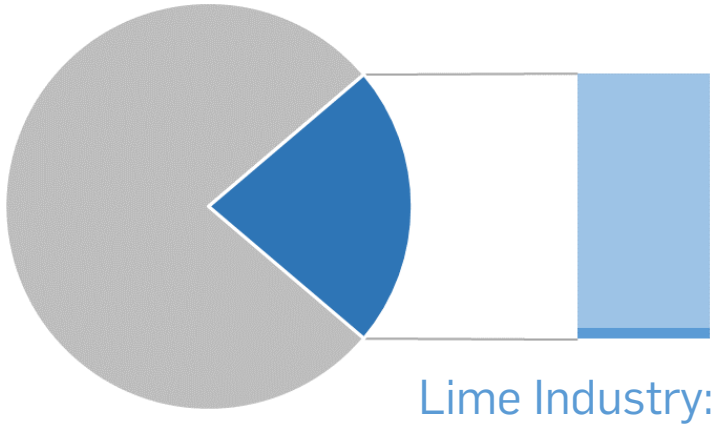


IEA (2020): The challenge of reaching zero emissions in heavy industry, IEA, Paris
https://www.iea.org/articles/the-challenge-of-reaching-zero-emissions-in-heavy-industry,

Emissions of the German lime industry

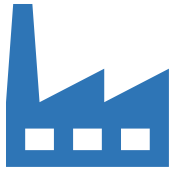
GHG Emissions 2022:
750 Mio. t CO_{2eq}

Industry:
168 Mio. t CO_{2-eq}



Lime Industry:
ca. 6,7 Mio. t CO_{2-eq}

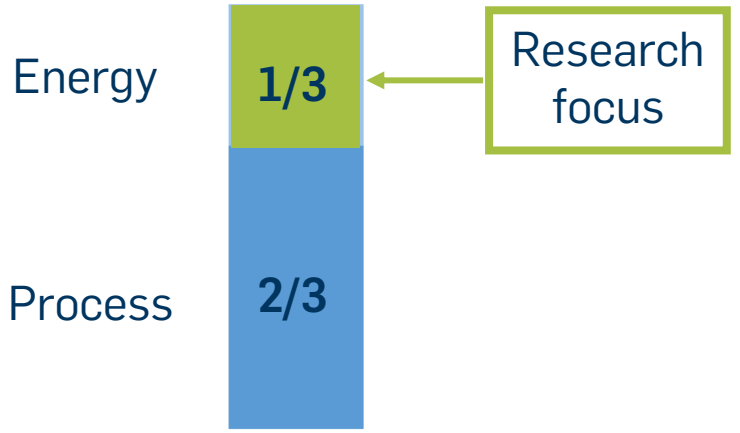
0.9 % of total GHG-Emissions in Germany



4 % of industry GHG emissions

Emission factor in lime industry:

1.1
t CO_{2eq} / t burnt lime



Umweltbundesamt (2023): Berichterstattung unter der Klimarahmenkonvention der vereinten Nationen und dem Kyoto-Protokoll 2023: Nationaler Inventarbericht zum deutschen Treibhausgasinventar 1990 – 2021, Dessau-Roßlau
DEHSt (2022): Treibhausgasemissionen 2022 emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland, Berlin

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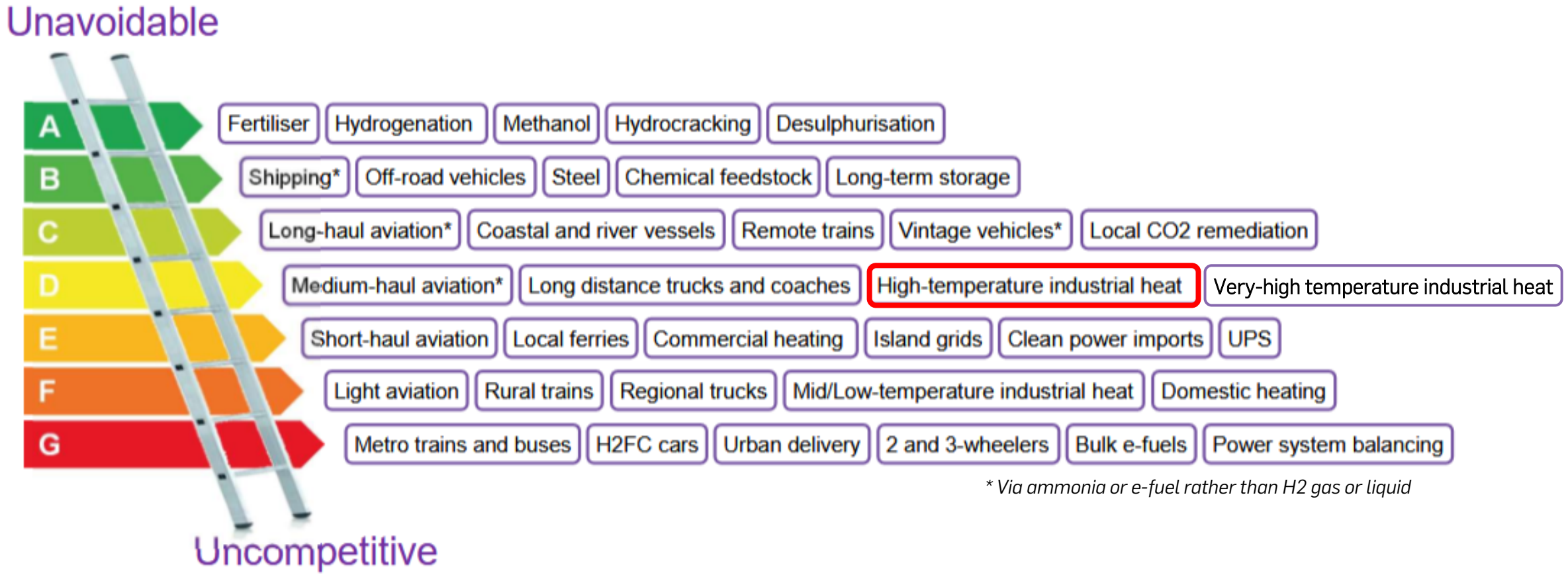
Scarce resources have to be allocated efficiently



Liebreich (2021): The Clean Hydrogen Ladder

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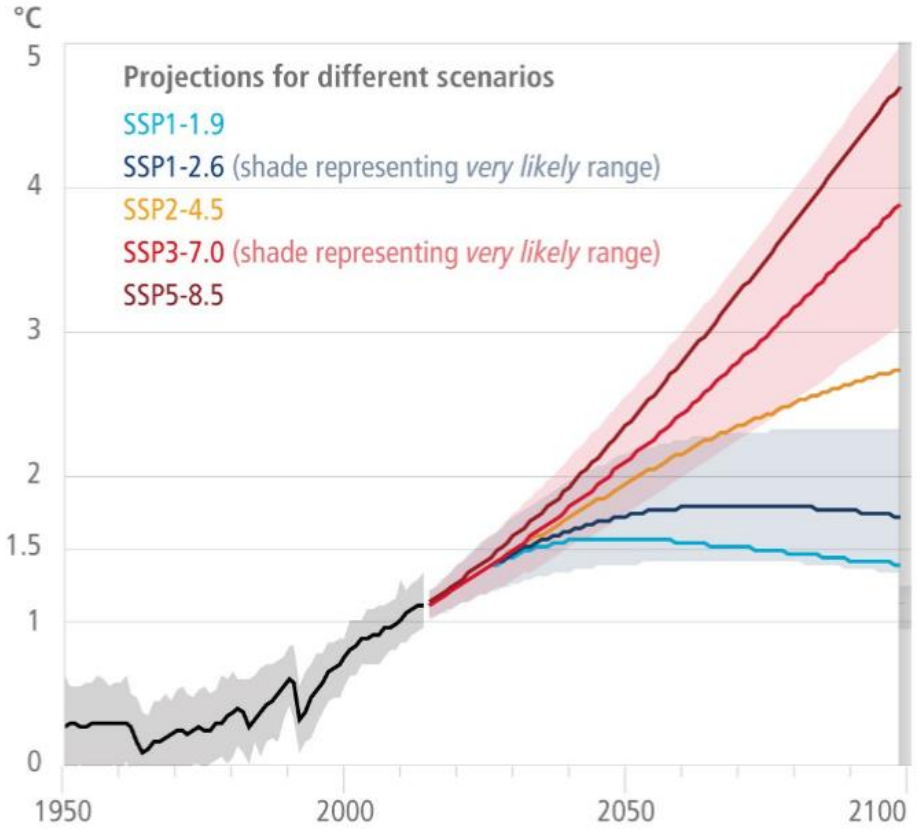
How can we examine dearbonisation pathways?

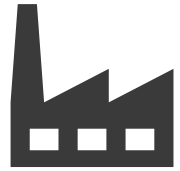
Source: © Brick This 2025



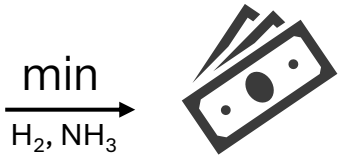
Source: IPCC

Research Questions

What are the main material and energy flows defining a lime plant that is representative of the German lime industry?

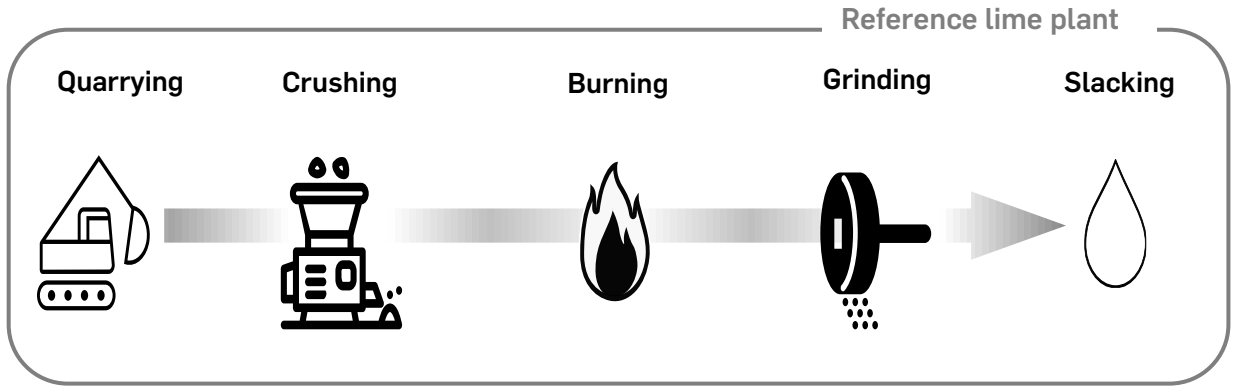


Under what conditions do hydrogen based fuels provide a cost effective alternative in the lime industry?

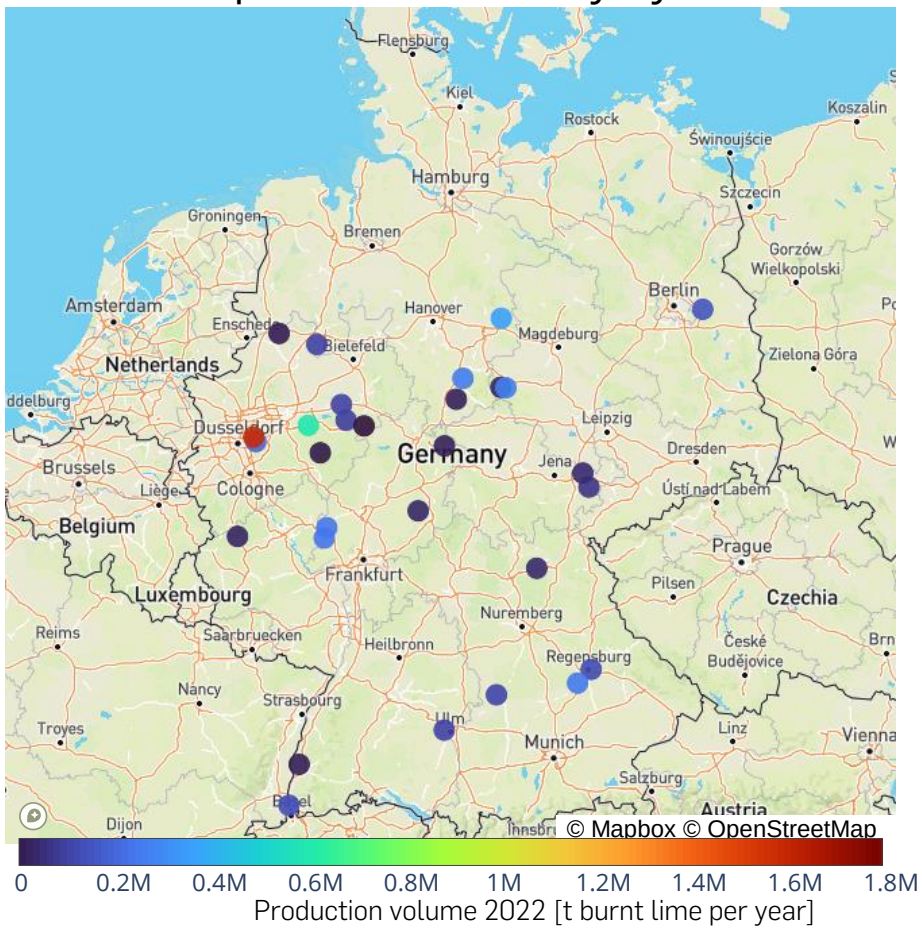


Methodology: Defining a reference lime plant

- Data collection:
  - Literature
  - Statistical Data
  - Experts
- Data verification:
  - Stakeholder interaction workshops



Lime plants in Germany by Size



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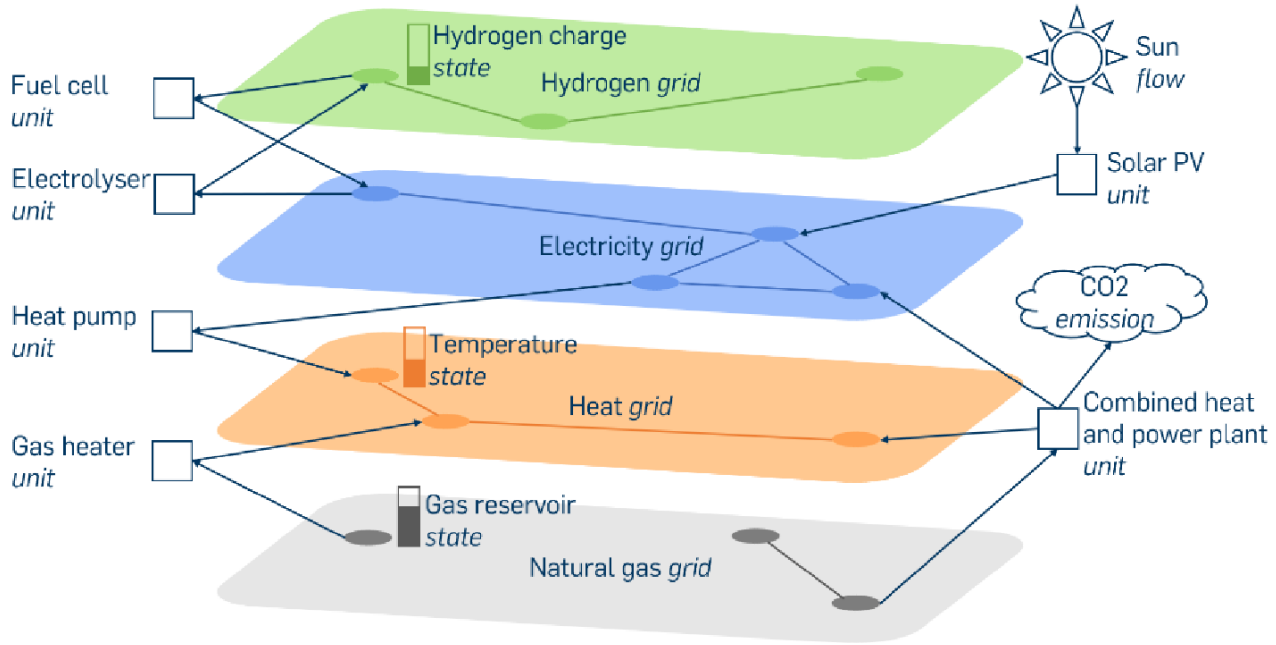
Using Backbone for Energy system models

- Backbone an open-source energy system model framework
- Grids: contain multiple „nodes“ of the same energy type
- Nodes: energy-balances
- Units: convert energy
  between nodes of different grids
- Investment and Scheduling
- Minimise costs while
  satisfying constraints



Helistö, N., Kiviluoma, J., Ikäheimo, J., Rasku, T., Rinne, E., O'Dwyer, C., Li, R., & Flynn, D. (2019). Backbone: An adaptable energy systems modelling framework. *Energies*, *12*(17), Article 3388. https://doi.org/10.3390/en12173388

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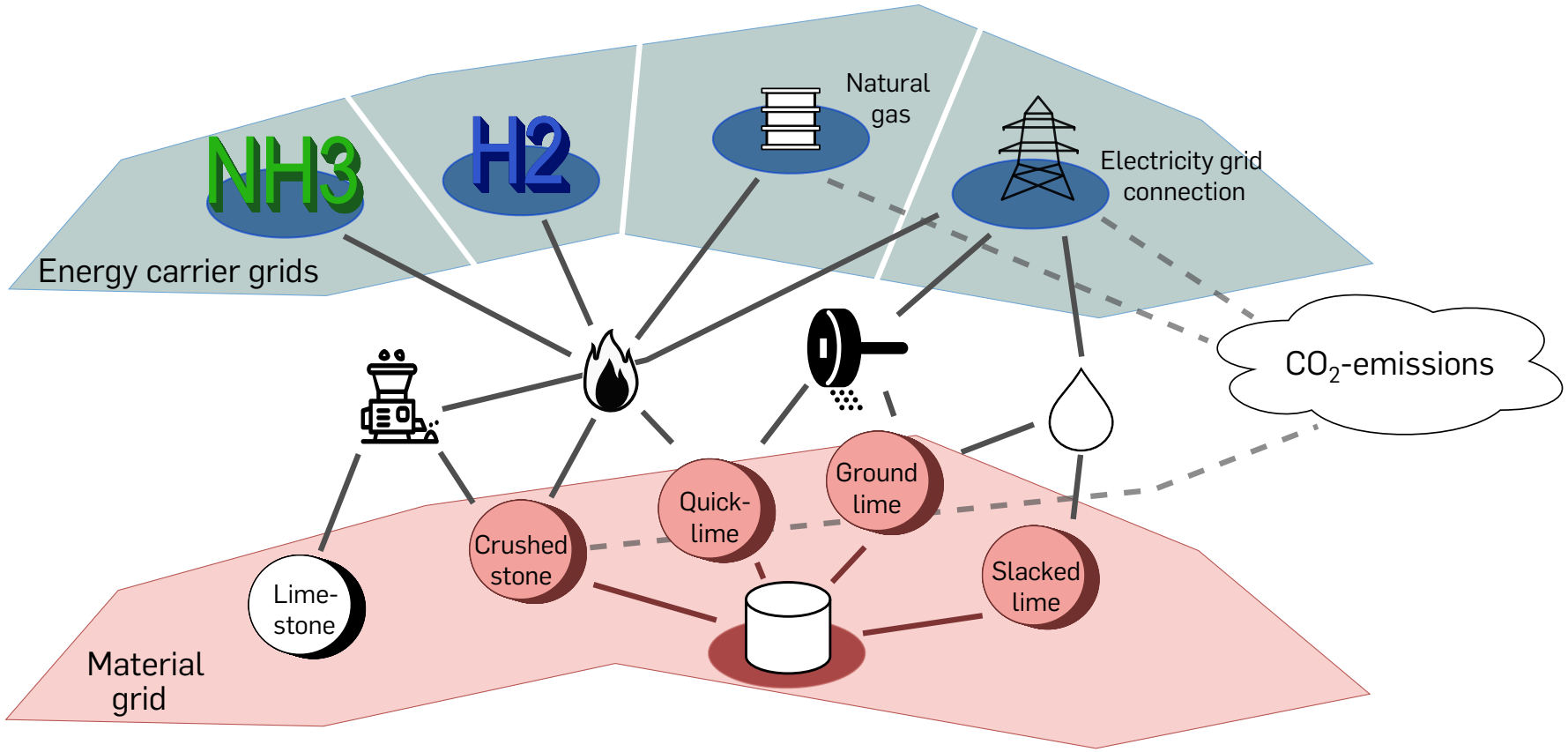
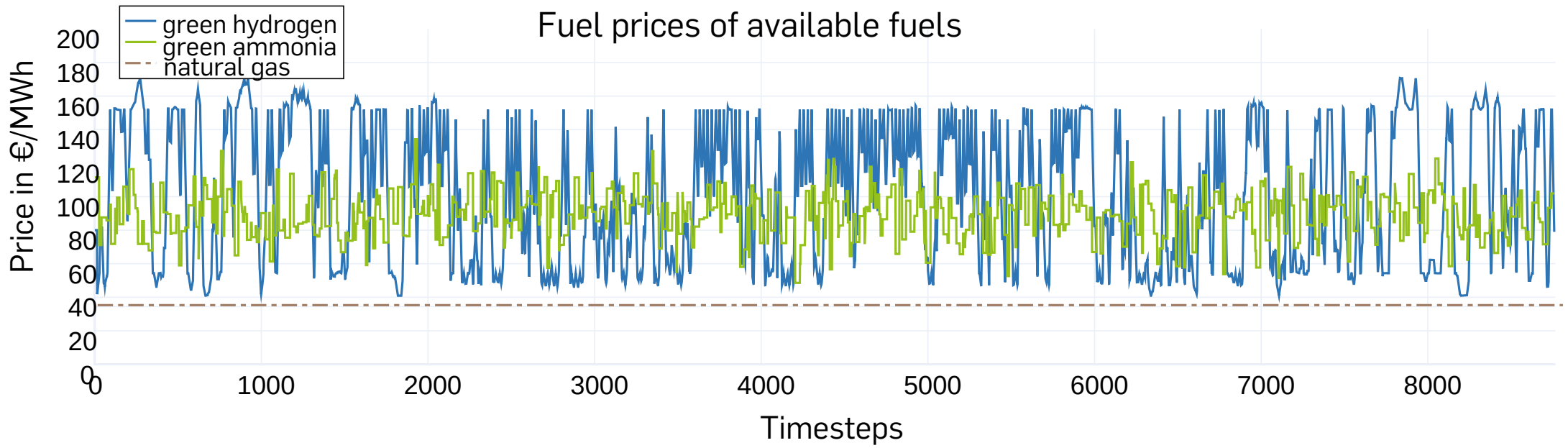
Applying ESM to the reference lime plant



Simplified version

Input Data



- Carbon price: 180€/t
- Existing units as defined in reference lime plant
- Investment into H_2 and NH_3 infrastructure units

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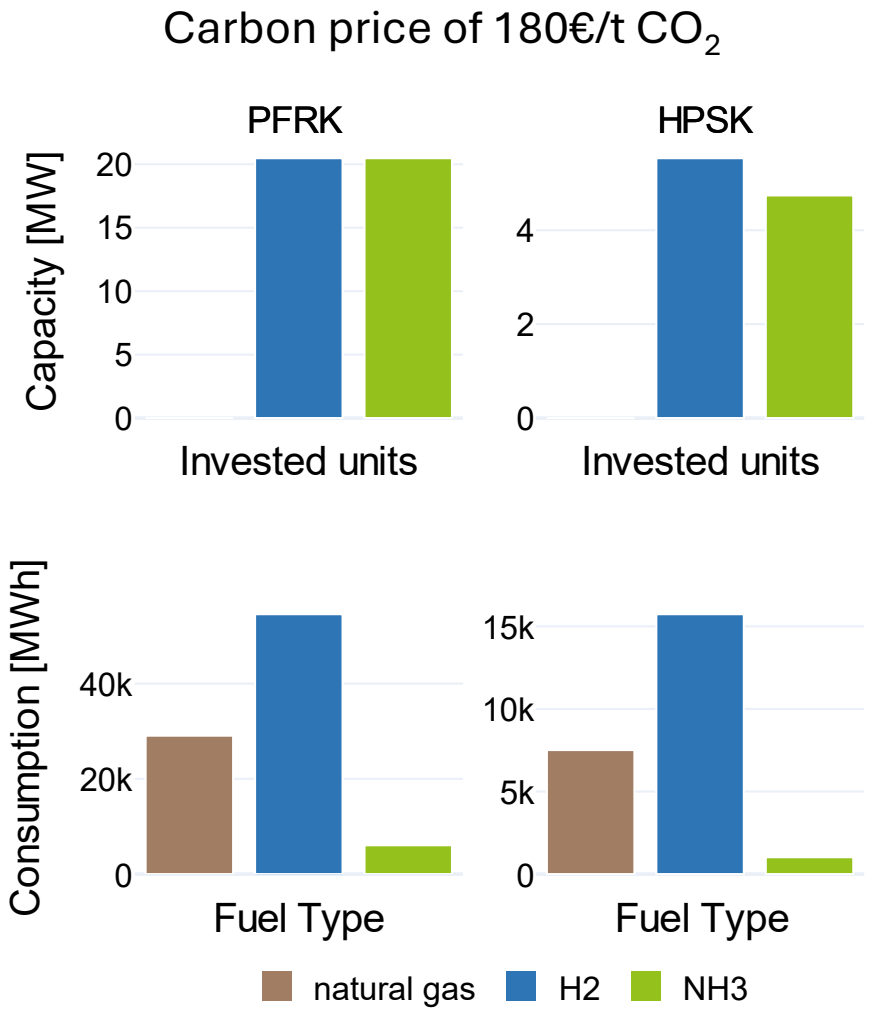
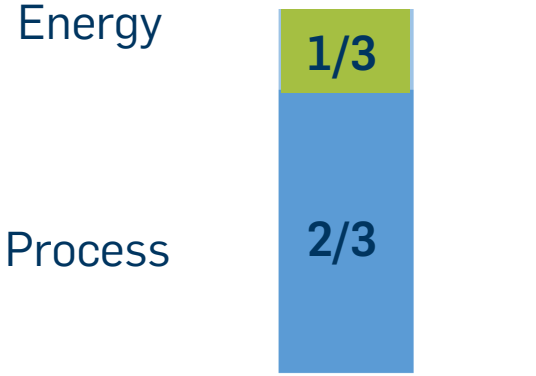
Investment Results

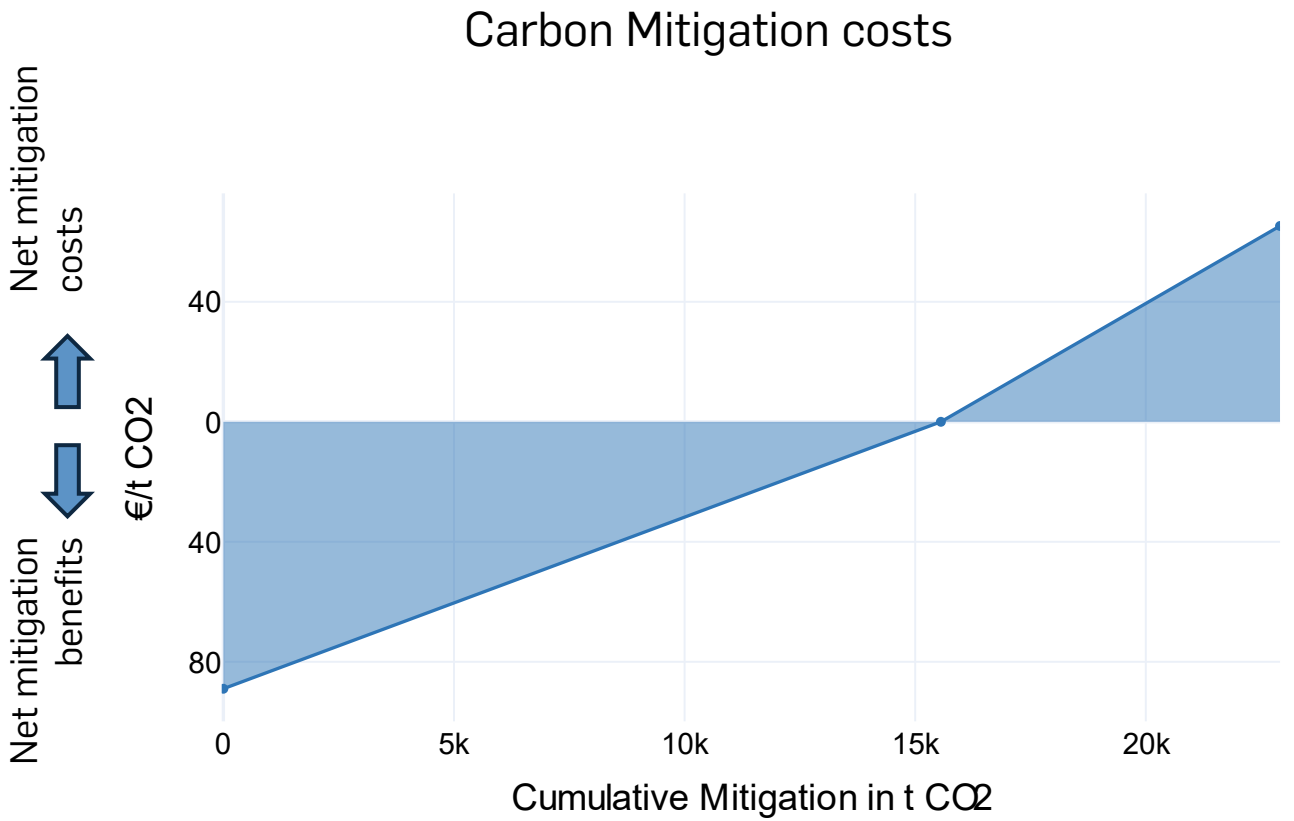


PFRK = Parallel-flow-regenerative kiln
HPSK = high performance shaft kiln

Decarbonisation potential



→ Reduction of
14,8 % CO_2 emissions



PFRK = Parallel-flow-regenerative kiln
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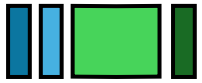
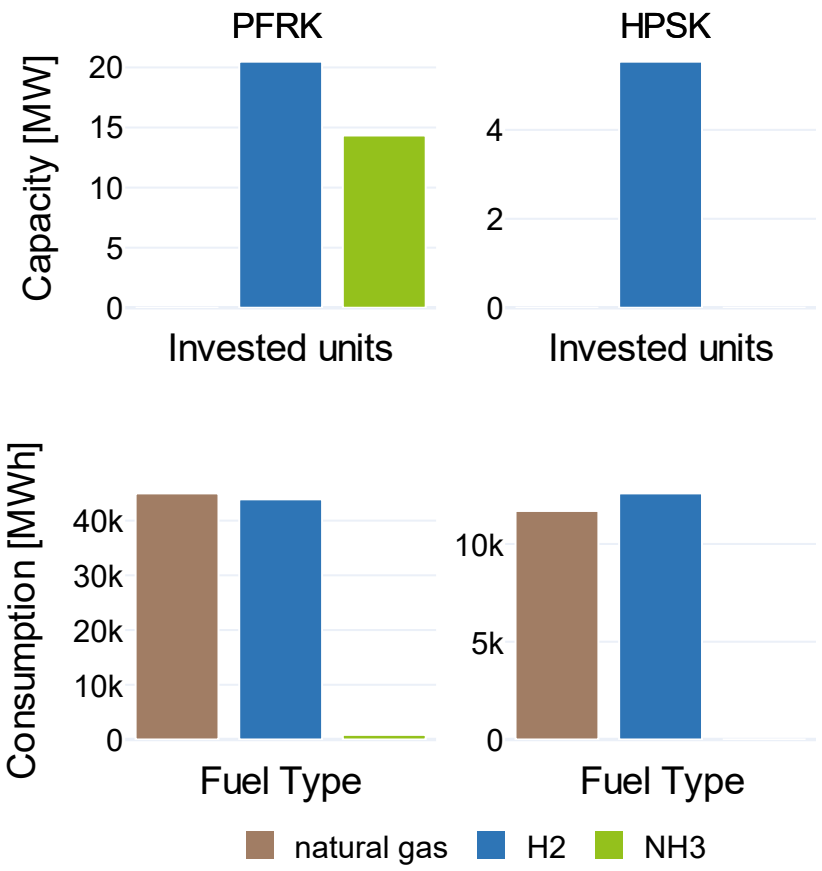
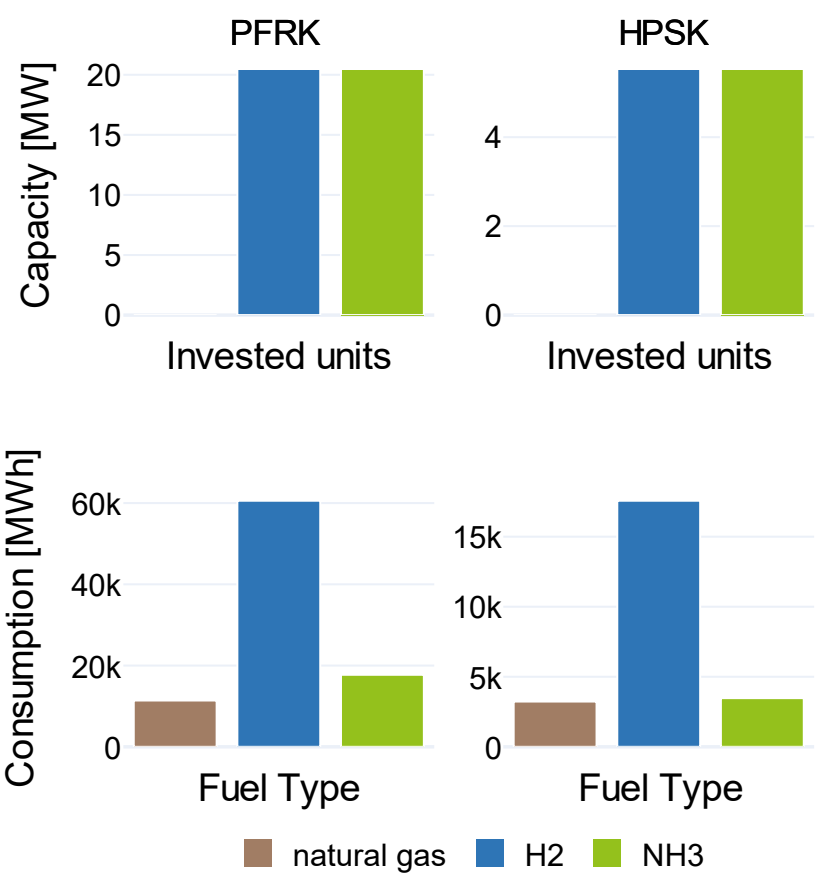
Effect of carbon pricing on hydrogen-based fuels



Carbon price of 110€/t CO_2



Carbon price of 250€/t CO_2



PFRK = Parallel-flow-regenerative kiln
HPSK = high performance shaft kiln

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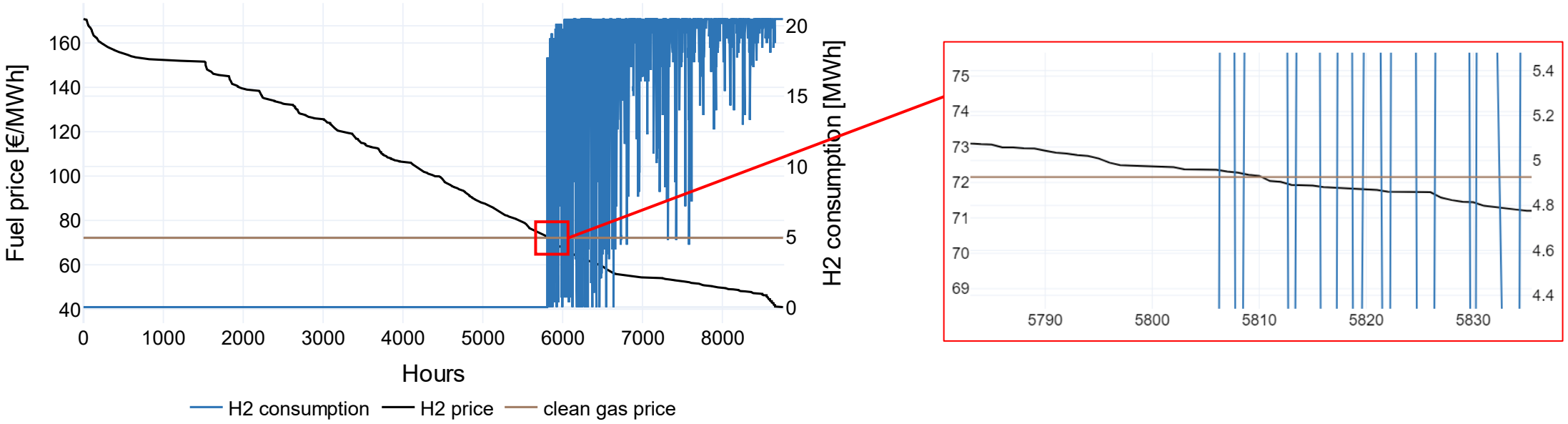
Effect of fuel prices on energy consumption



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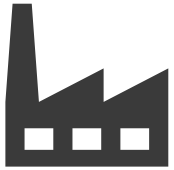
Answers to Research Questions



What main process and unit parameters define a lime plant that is representative of the German lime industry?

- Definition of production volumes, process descriptions and component design
- Choice and design of lime kiln has the biggest impact

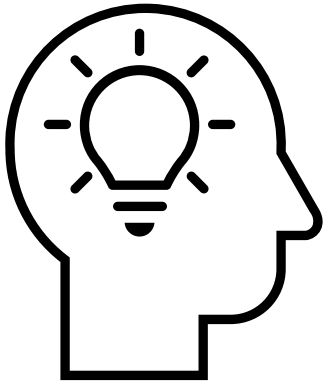
min

H_2, NH_3

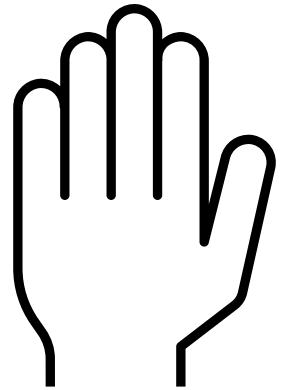
Under what conditions do hydrogen based fuels provide a cost effective alternative in the lime industry?

- Investment into renewable fuels if prices are below carbon adjusted gas price
- Relevance of influencing factors: price of fuel > carbon price > Investment costs

Conclusion



- Definition of a reference lime plant:
  - Description of energy and material flows
  - Inventories of relevant processes enables Life Cycle Assessment
- First energy system model of a lime plant



- Reference lime plant limitations:
  - Data mostly based on 2022
  - Simplifications and assumptions
- Energy system model limitations:
  - Other decarbonisation strategies (bioenergy, CCS/CCU) not analysed
  - Renewable-fuel modeling: emissions, availability and forecasts
  - Focus on minimising costs, not on ecological impacts

Thank you for your attention!

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