Hydrogen and Heat Storages as Flexibility Options for a Greenhouse Gas-Neutral German Energy System

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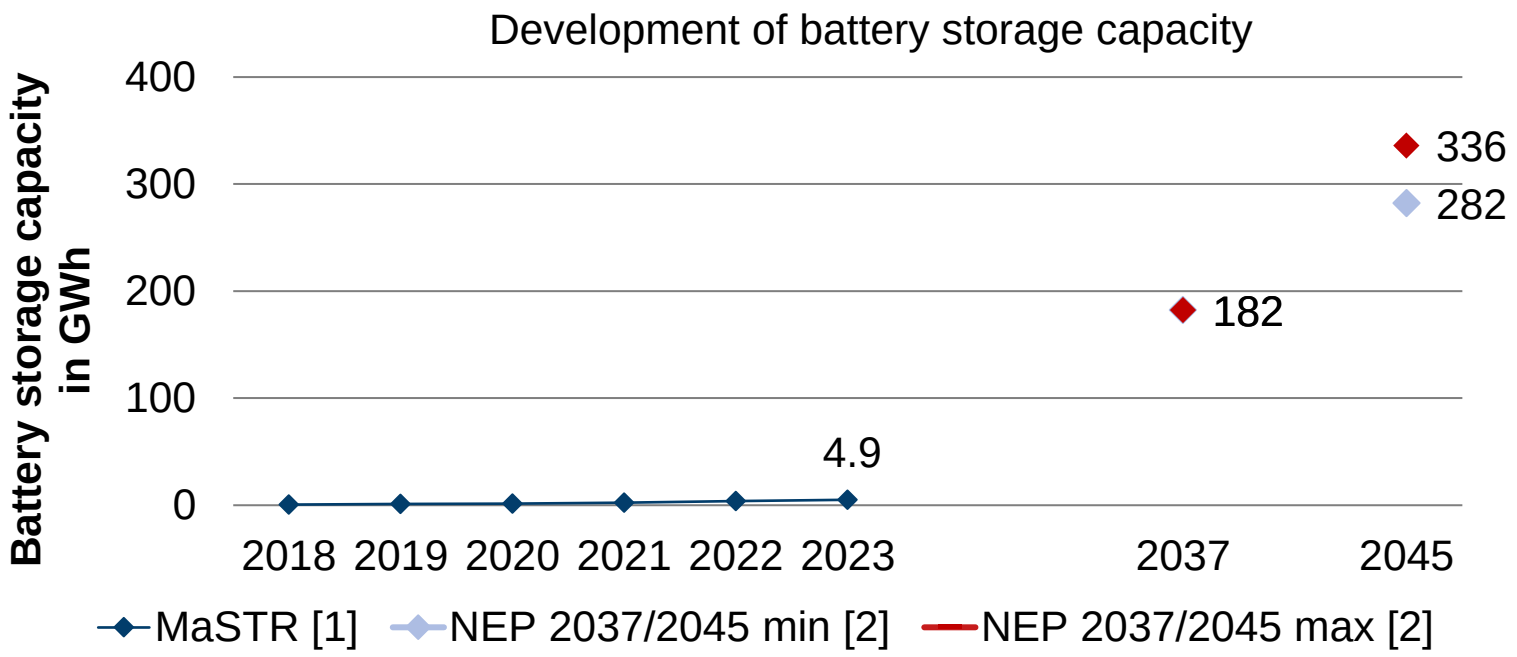
IEK-3: Institute of Techno-economic Systems Analysis

Motivation: Uptake of Battery Storage Installations in Germany



+ 39 GWh pumped hydro storage capacity

Does a greenhouse gas-neutral German energy system need other storages besides electricity storages?

What role can hydrogen and heat storages play in the year 2045?

[1] Figgener et al., The development of battery storage systems in Germany: A market review (status 2023), 2023

[2] Netzentwicklungsplan Strom 2037 / 2045 , Erster Entwurf der Übertragungsnetzbetreiber, 2023

Agenda

1 Motivation

2 Methods: Energy system model ETHOS.NESTOR

3 Results

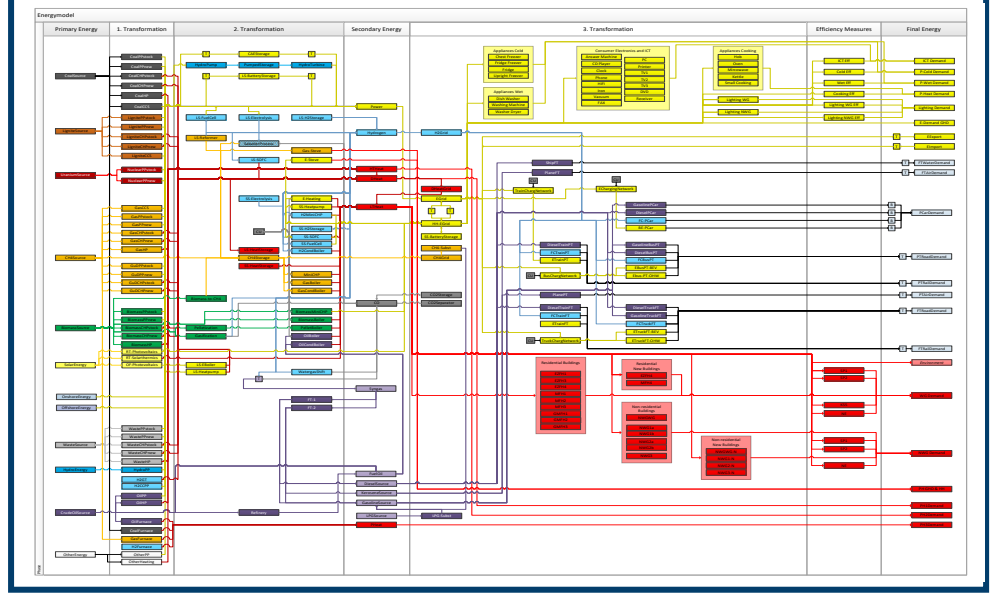
4 Conclusion

Methods: ETHOS.NESTOR Energy System Model [1], [2]

Framework data, targets
(import energy prices, GHG targets)

Techno-economic input data
(costs, efficiencies)

Integrated energy system model



Demands
(transport services, good production)

2020 2030 2040 2045

myopic transformation pathway

Characteristics

- German energy system
- Sectors: Energy supply, industry, buildings and transport
- PtX technologies for sector coupling
- Energy storages
- Hourly resolution

Methods

- Cost optimization
- Myopic transformation pathway

[1] Kullmann et al.,The value of recycling for low-carbon energy systems - A case study of Germany's energy transition, 2022
[2] https://github.com/FZJ-IEK3-VSA/FINE
NESTOR: National Energy System with SecTOR Coupling

Results

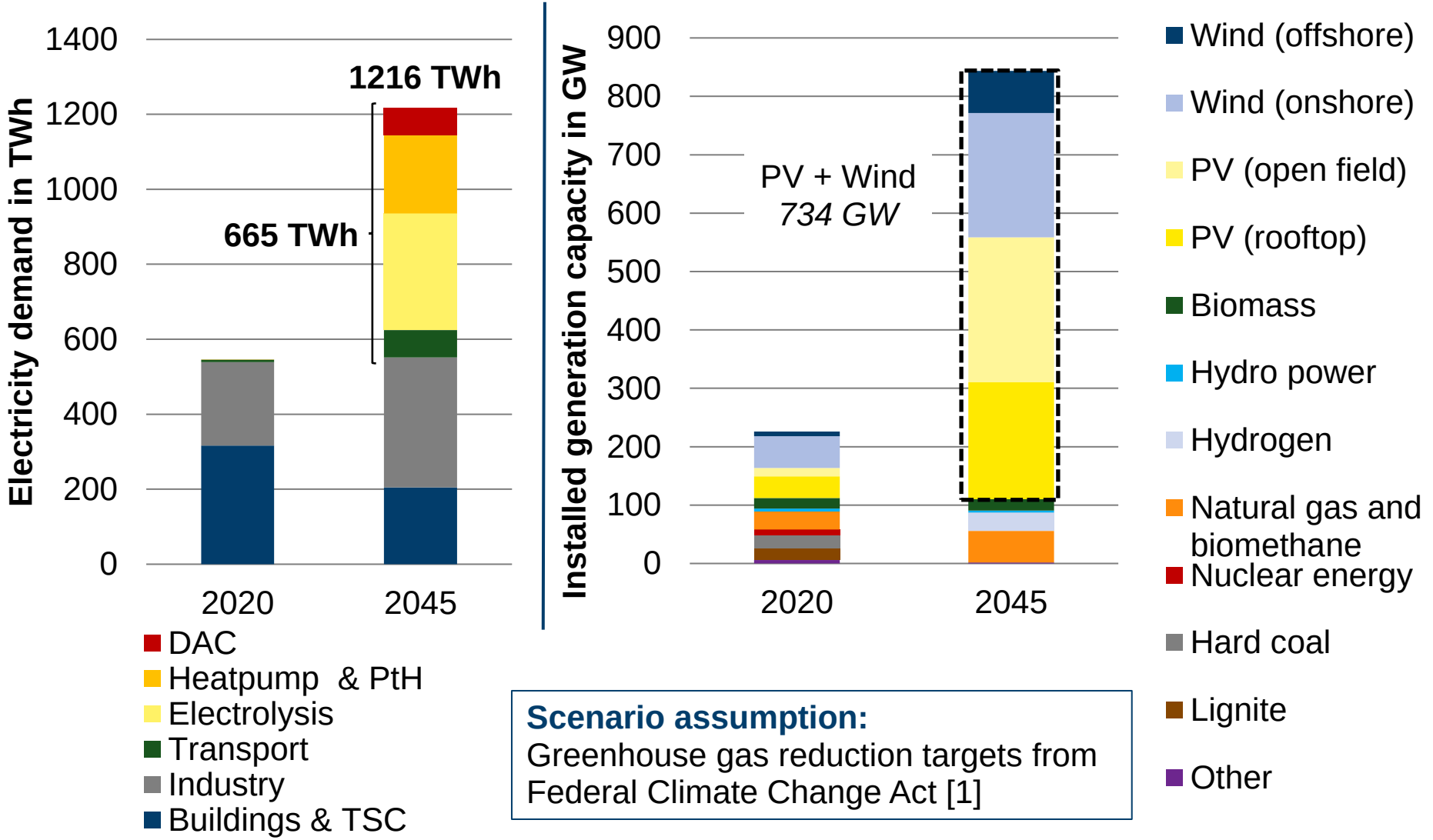
1 Motivation

2 Methods: Energy system model ETHOS.NESTOR

3 Results: Electricity Sector 2045

4 Conclusion

Results: Electricity Sector 2045



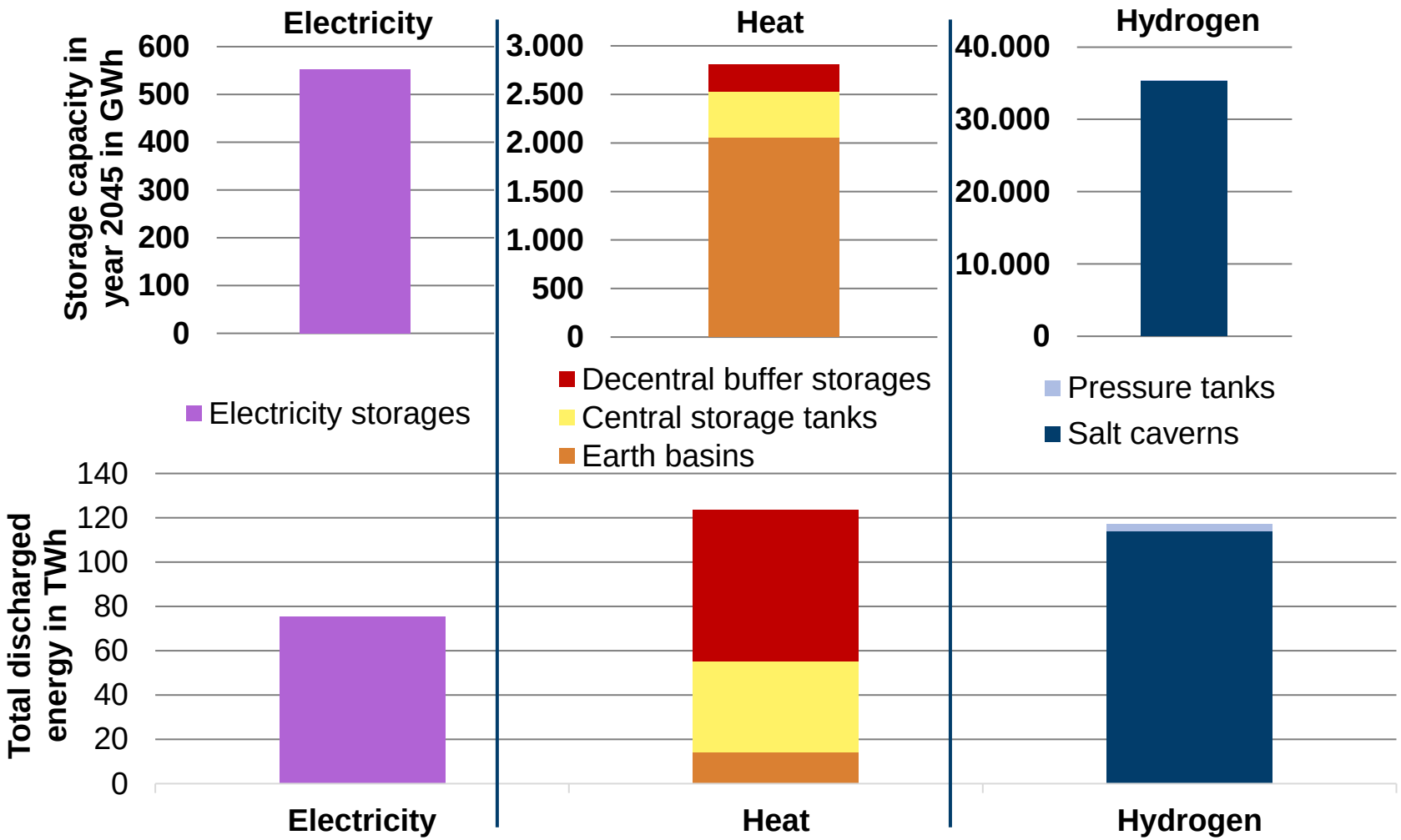
Scenario assumption:
Greenhouse gas reduction targets from Federal Climate Change Act [1]

[1] Federal Climate Change Act of 12 December 2019 (Federal Law Gazette I, p. 2513), as last amended by Article 1 of the Act of 18 August 2021 (Federal Law Gazette I, p. 3905)

DAC – Direct Air Capture of CO_2; PtH – Power-to-Heat; TSC – Trade, Services and Commercial

3 Results: Storage capacities 2045

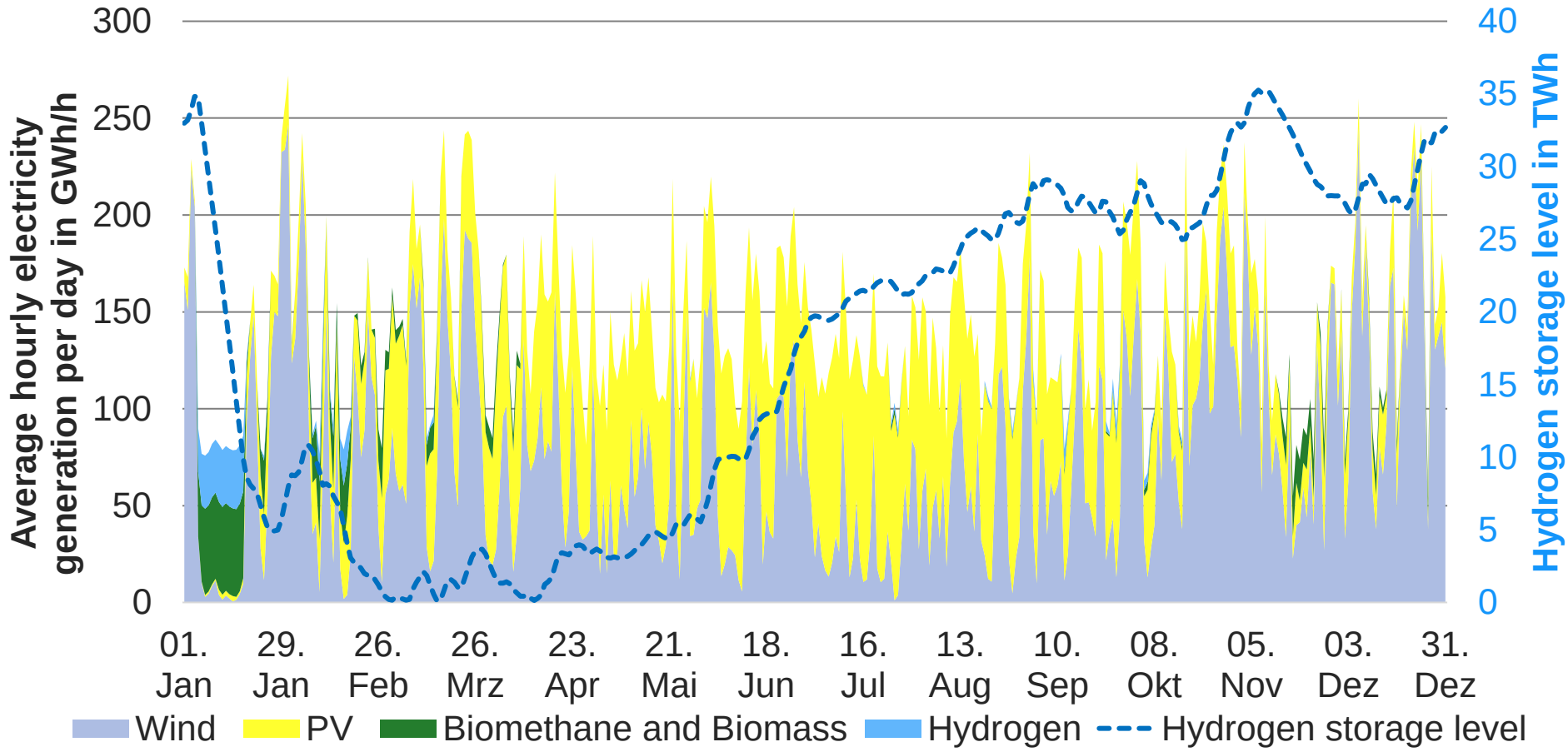
Heat and Hydrogen Storage Expansion Necessary until 2045



- Decentral heat storages with 281 GWh capacity (10% of storage capacity), supply 68 TWh (55%) of heat

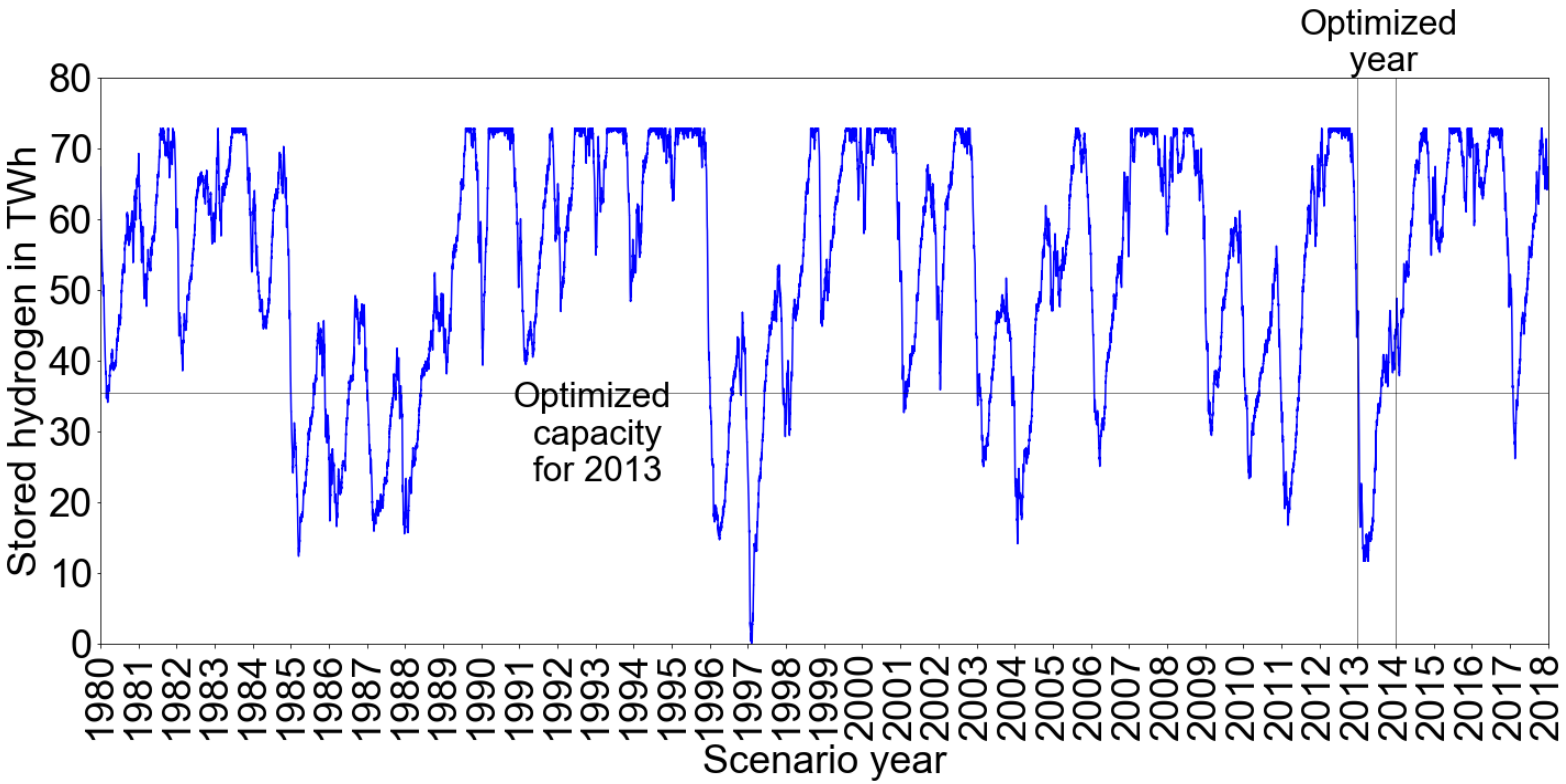
3 Results: Role of hydrogen storages

Hydrogen Storage for Security of Supply in the Year 2045



➢ Around 35 TWh H_2 storage needed to bridge dark, cold lulls in 2045

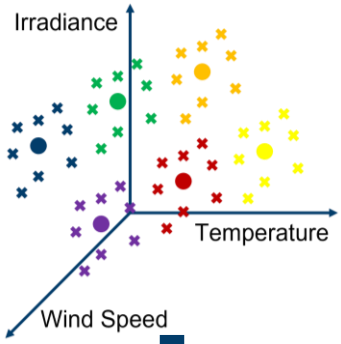
Robust Design of Hydrogen Storage Capacity for 38 Scenario Years



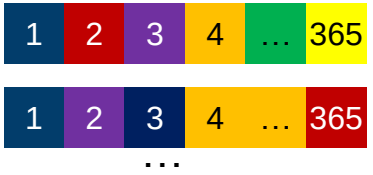
Approach:

Operation schedule for weather year 2013

Assignment of days from 37 weather years to 365 typical days of 2013

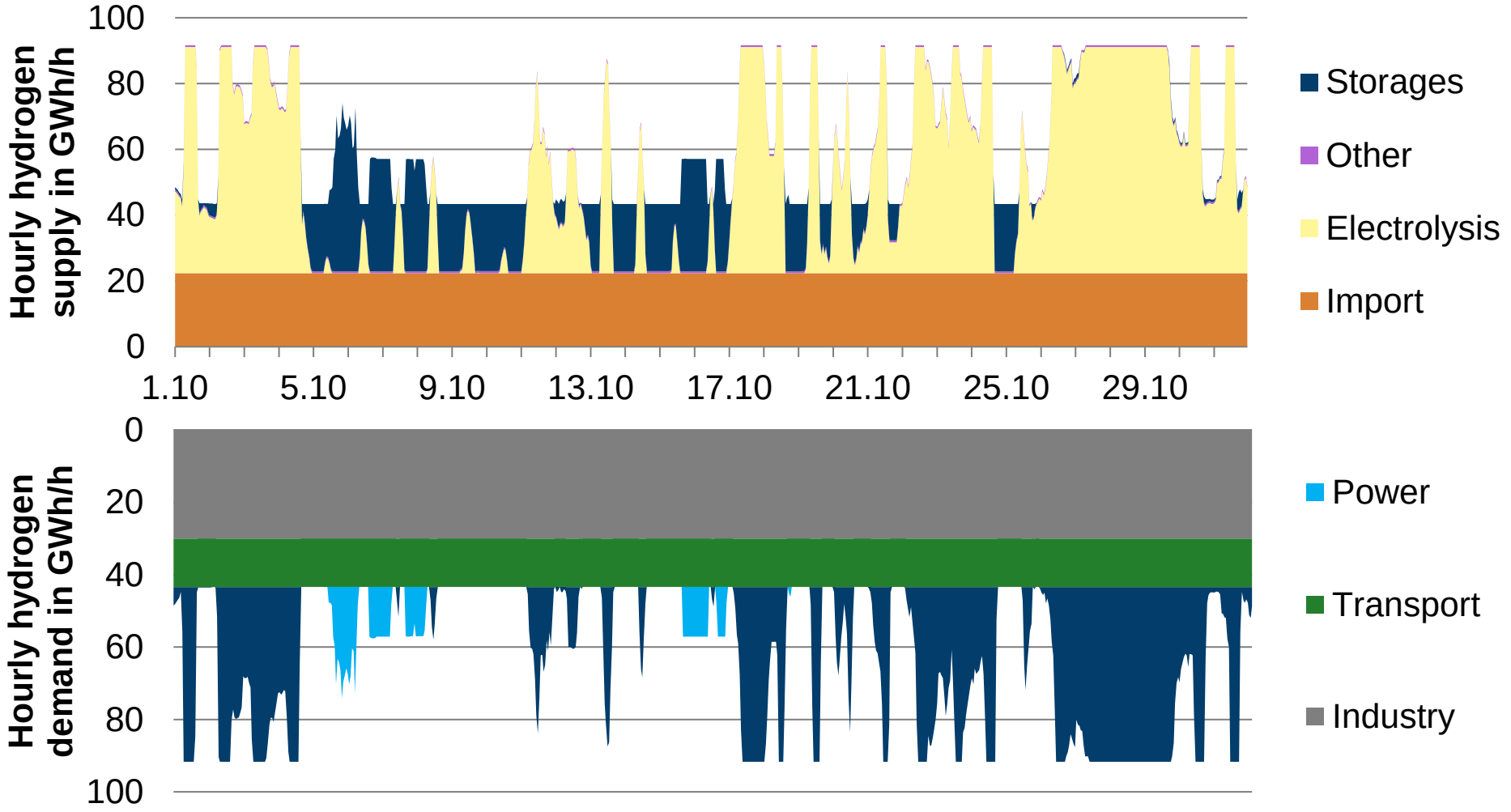


37 new storage operation schedules



- Robust design of H_2 storage for 38 scenario years: Around 73 TWh storage capacity needed
- Sufficiently large storage potential in salt caverns exists, but construction of new caverns required

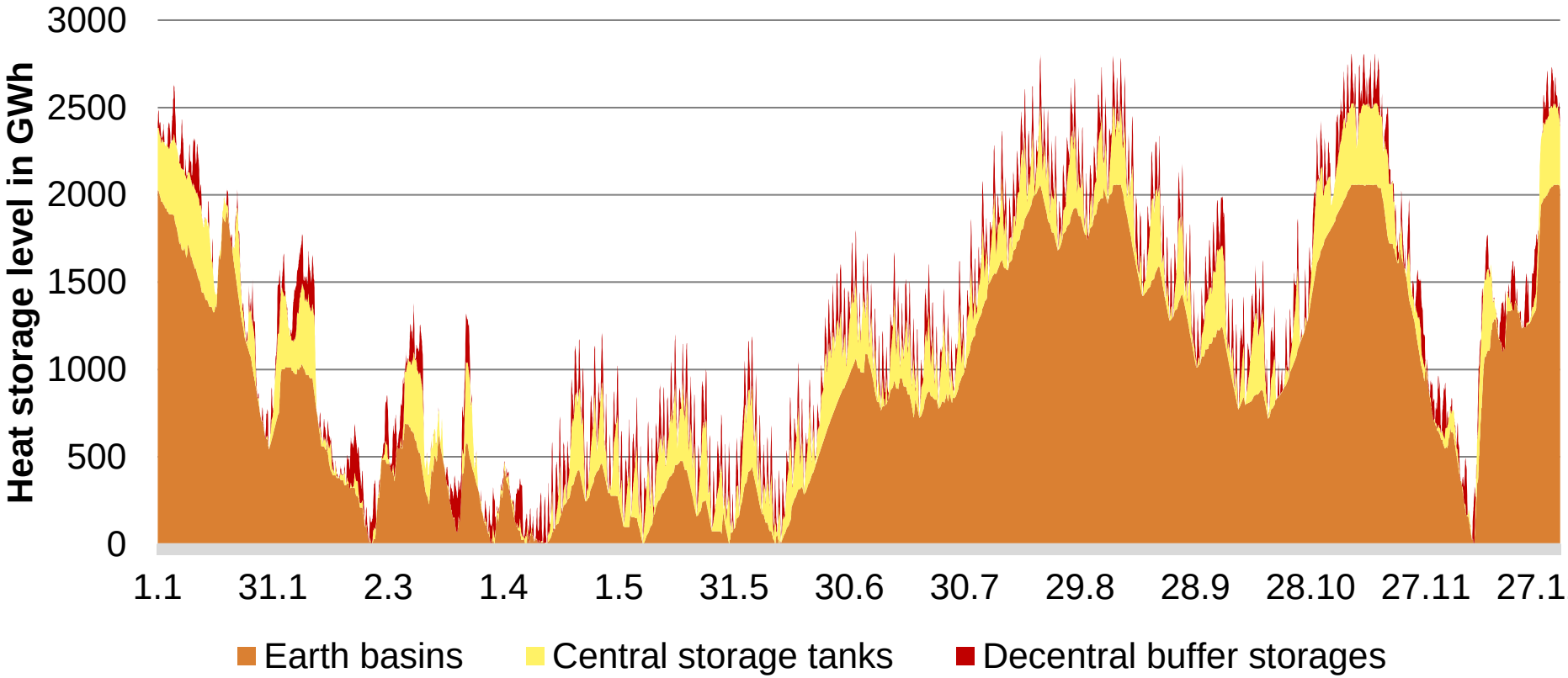
Flexibility Provided by Hydrogen Storages in October 2045



➢ Hydrogen storages enable flexible operation of electrolyzers

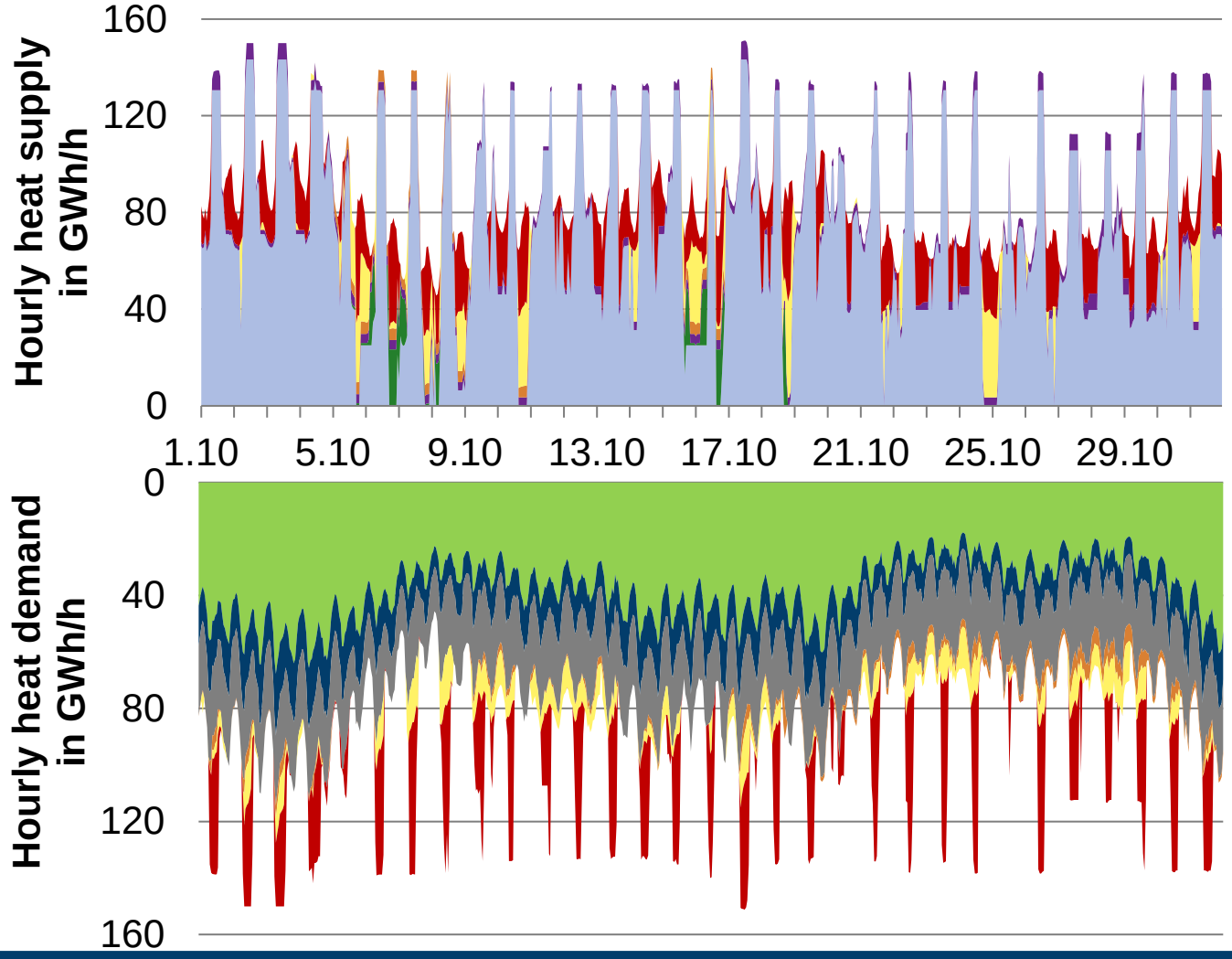
3 Results: Role of heat storages

Heat Storage Level in the Year 2045



- Earth basins in district heating networks for mid- and long-term storage
- Decentral buffer storages in buildings only for short-term storage

Flexibility Provided by Heat Storages in October 2045

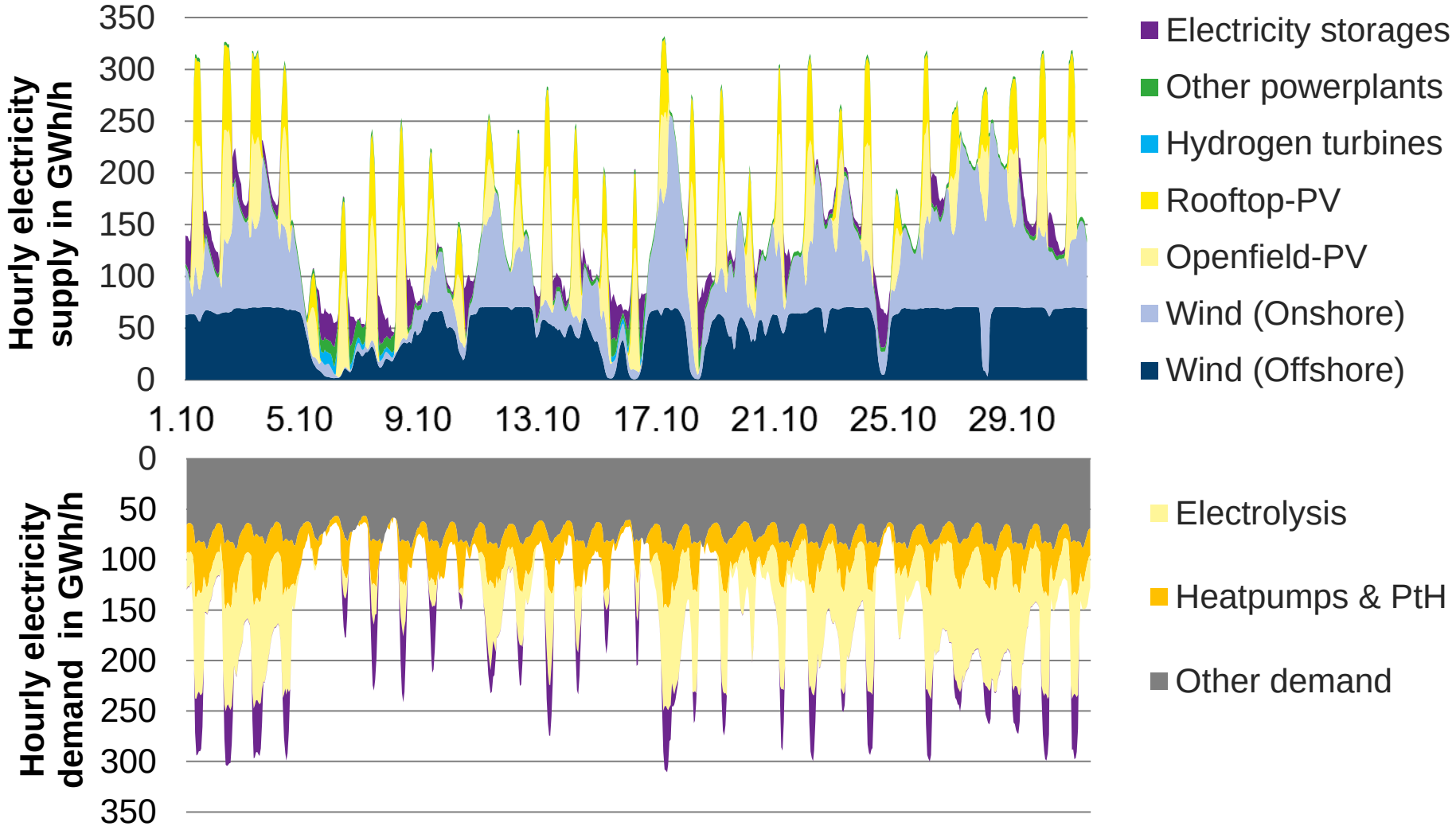


➢ Heat storages enable flexible operation of heatpumps and PtH-applications

PtH – Power-to-Heat

3 Results: Impact on electricity supply and demand

Impact on Electricity Supply and Demand in October 2045



➢ Hydrogen and heat storages are crucial flexibility sources in a greenhouse gas-neutral German energy system

Conclusion

- About 2.8 TWh of heat and about 35 TWh of hydrogen storage capacity required for security of supply in the year 2045
- Robust system design doubles the required H_2 storage capacity
- Hydrogen storages needed for flexible operation of electrolyzers
- Heat storages used as seasonal and short-term storages
- Hydrogen and heat storages crucial for an energy system based on renewable energies

Thank you!

Institute of Energy and Climate Research

Techno-economic Systems Analysis (IEK-3)

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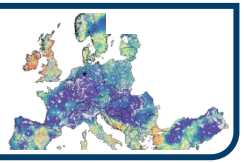
Backup

ETHOS: Energy Transformation PatHway Optimization Suite

Renewable Energy Resources



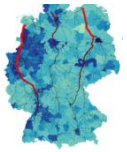
Electricity transmission & distribution grids

Societal feasibility

Gas transmission grid

Technology Database

H_2 and PtX Infrastructure



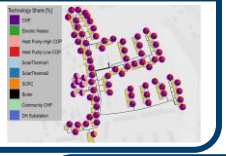
Macro-economics*

Life Cycle Assessment*

Buildings

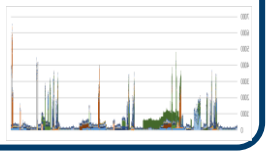
H_2 global

Districts

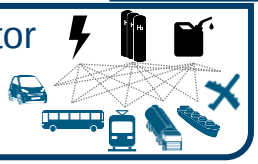


Activity-based transport demand

From demand to load profile

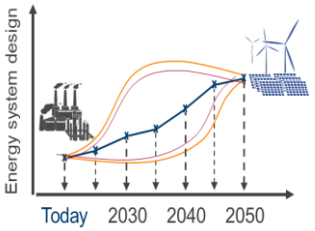


Transport sector
– Passenger
– Freight



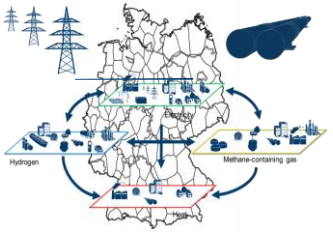
Integrated Hourly Optimization

Single-node



Cost optimized energy systems

< 400 nodes



Regionalized via **local demand and infrastructure**

*with IEK-STE