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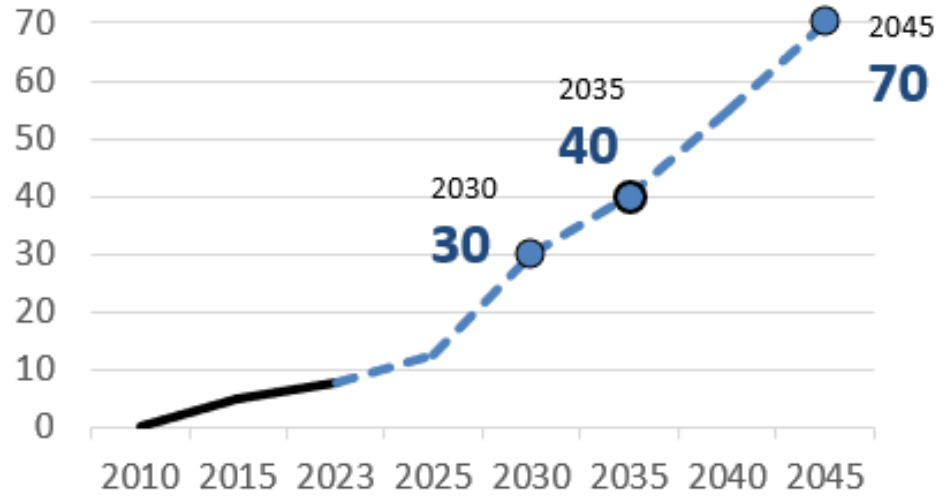
Enno Wiebrow, *Jonathan Hanto, Nikita Moskalenko, Yannick Schönmeier,*
Konstantin Löffler, Karlo Hainsch

Generation options & effects of sustainable hydrogen from offshore wind energy on the German energy system

Motivation

- Greenhouse gas neutrality target by 2045 & coal phase-out by 2038 at the latest.
- Easter package: 115 GW onshore wind & 215 GW PV by 2030.
- Offshore wind expansion targets:
  - 30 GW installed capacity by 2030
  - 40 GW installed capacity by 2035
  - 70 GW installed capacity by 2045



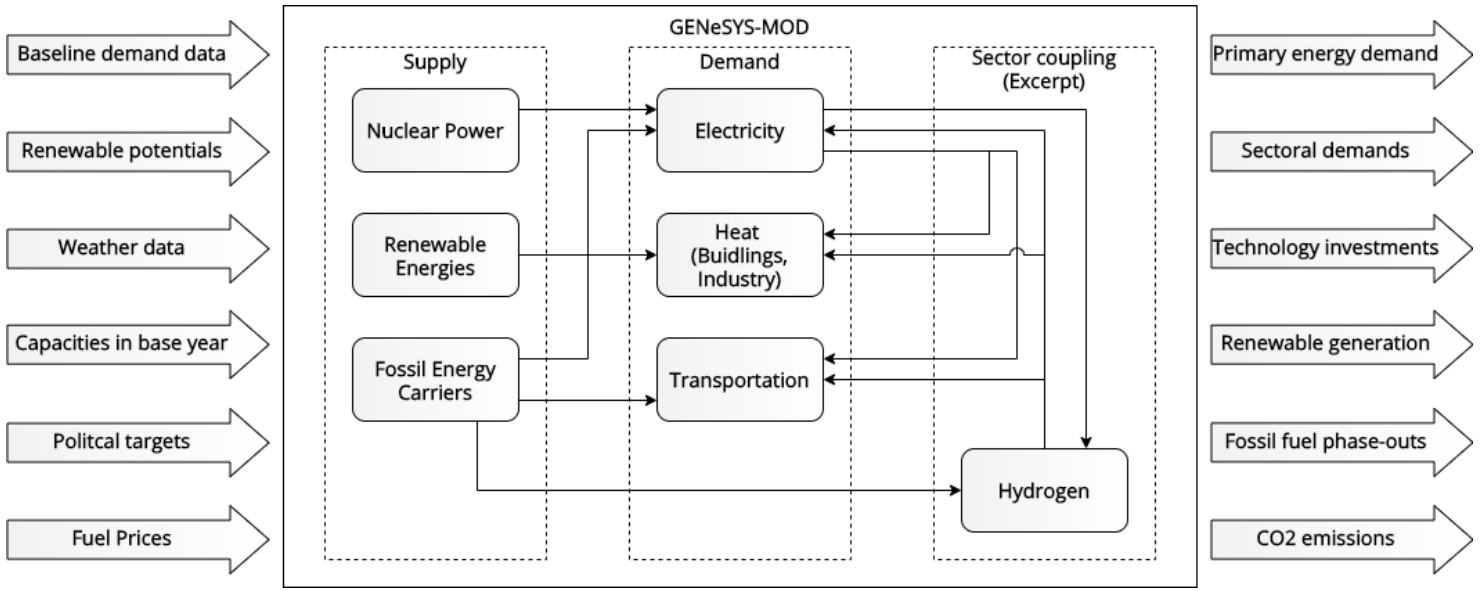
→ Electrification & deployment of sector coupling technologies

→ What will the German energy system look like by 2050?

The Global Energy System Model (GENeSYS-MOD) - Overview

- …is based on the Open-Source Energy Modeling System (OSeMOSYS) and enhances the framework with multiple additional features.
- …is a **linear program** which optimizes the net present value of a future energy system based on the given assumptions and bounds (cost-optimizing).
- …includes **all the main energy sectors**: Power, Heat (Buildings, Industry) and Transportation (frgt & psng)
- …is **publicly available** to the community with both code and model data.

(https://git.tu-berlin.de/genesysmod/genesys-mod-public/-/releases/genesysmod3.0)

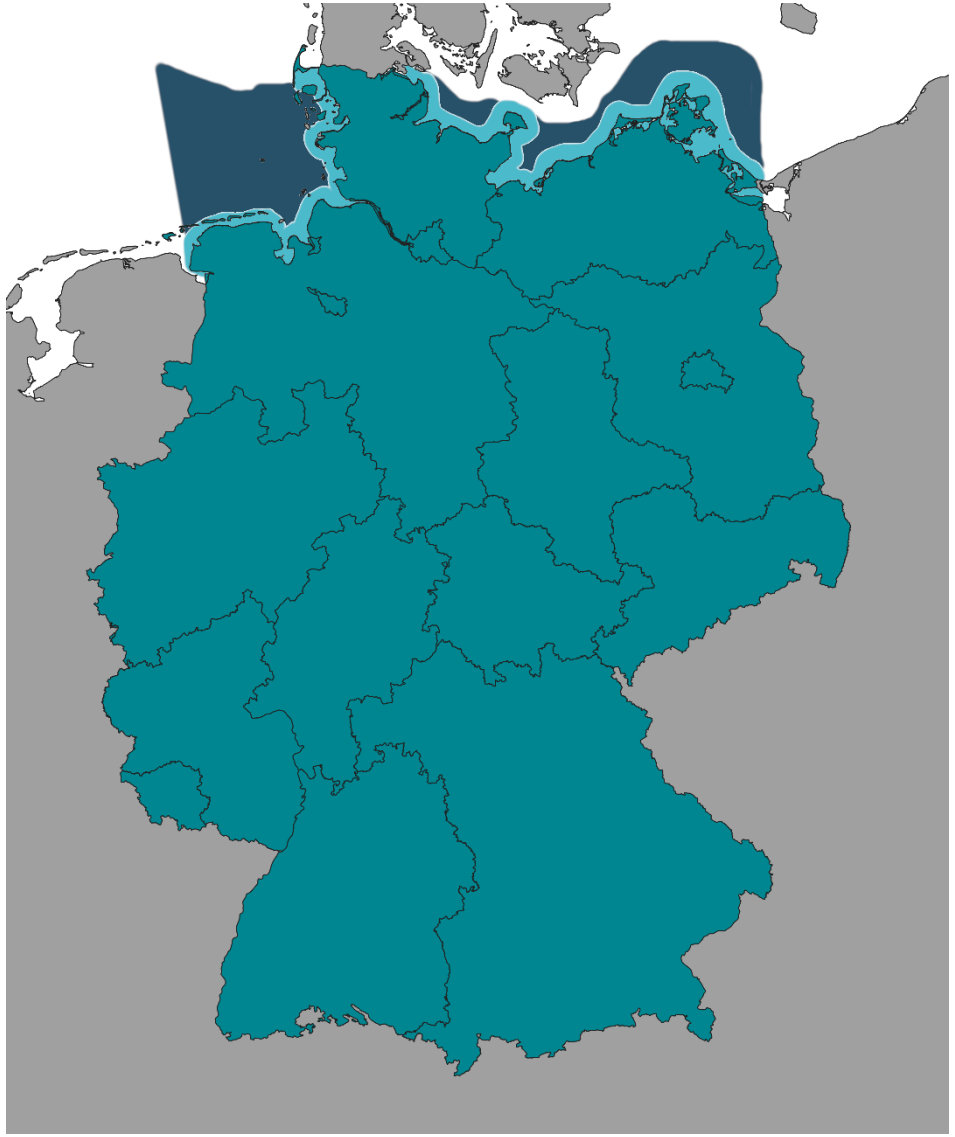


Spatial and temporal resolution

- Germany is divided in its 16 federal states
- Neighbouring countries included (but at lower resolution)
  - To enable trade of electricity/Hydrogen
- Hourly time-series for renewable potentials and demands
  - Reduced by time-series clustering algorithm
  - Results in temporal resolution of every 244th hour (35 time slices p.a)
- Modeling until 2050 in 5 year steps

Model updates to improve hydrogen representation

- Added North Sea and Baltic Sea regions as offshore wind hubs
  - Can only use offshore wind and produce hydrogen
  - Trade with the adjacent regions allowed
- Added different electrolysis technologies
  - Alkaline, PEM, SOEC
- More accurate weather time series



Scenarios

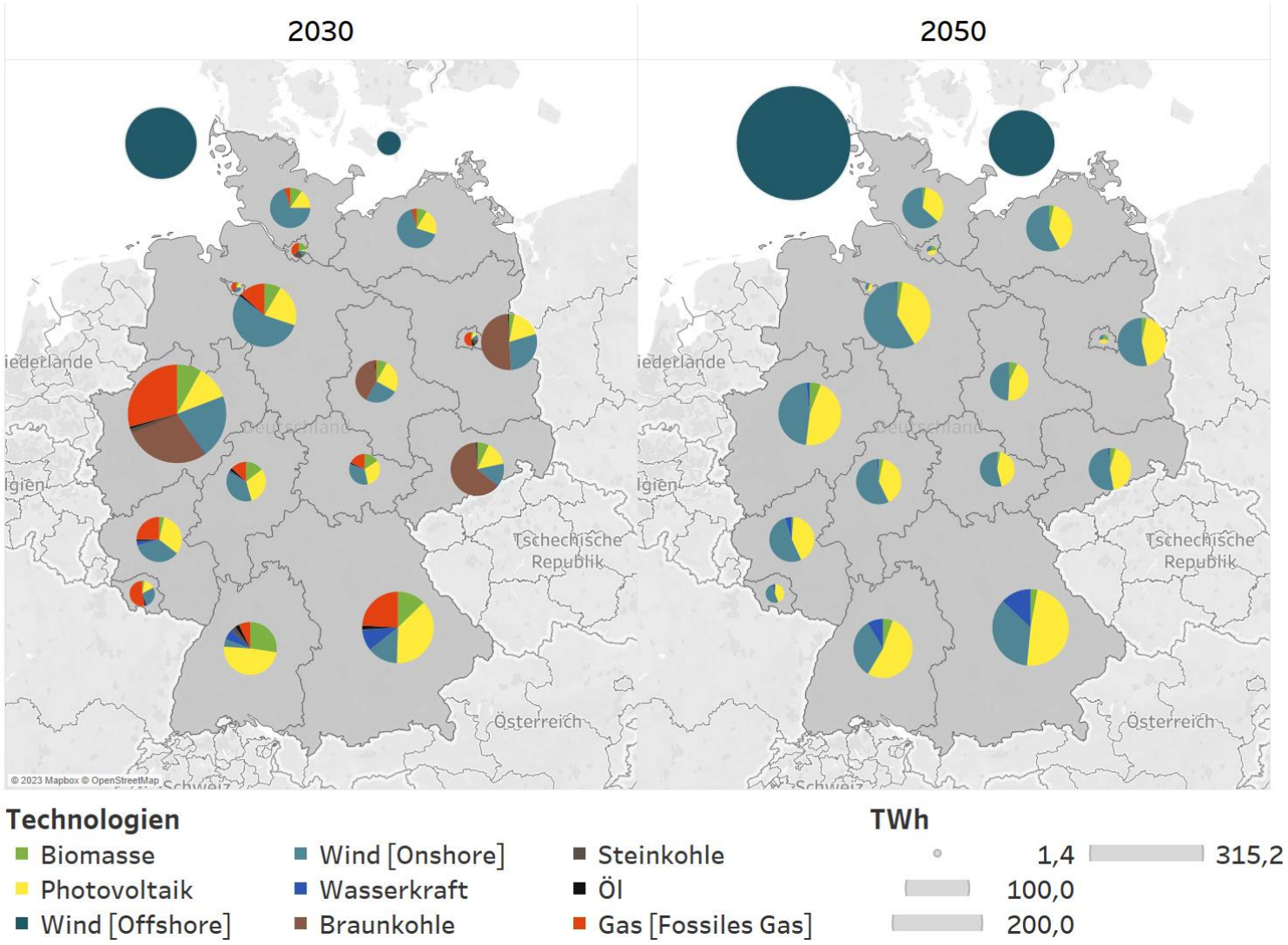
- Ambitious scenario in line with a **2°C climate goal** (Net-zero 2045)
  - Transition driven by carbon budget
- Reaches targets through **equal inclusion** of **societal, industry, and policy action**
- **Balanced in its ambitions**, helps the model include constraints and limitations more easily

Policy Scenario

• Current political targets (Easter Package)
  • Expansion of renewables
  • Coal phase-out by 2038

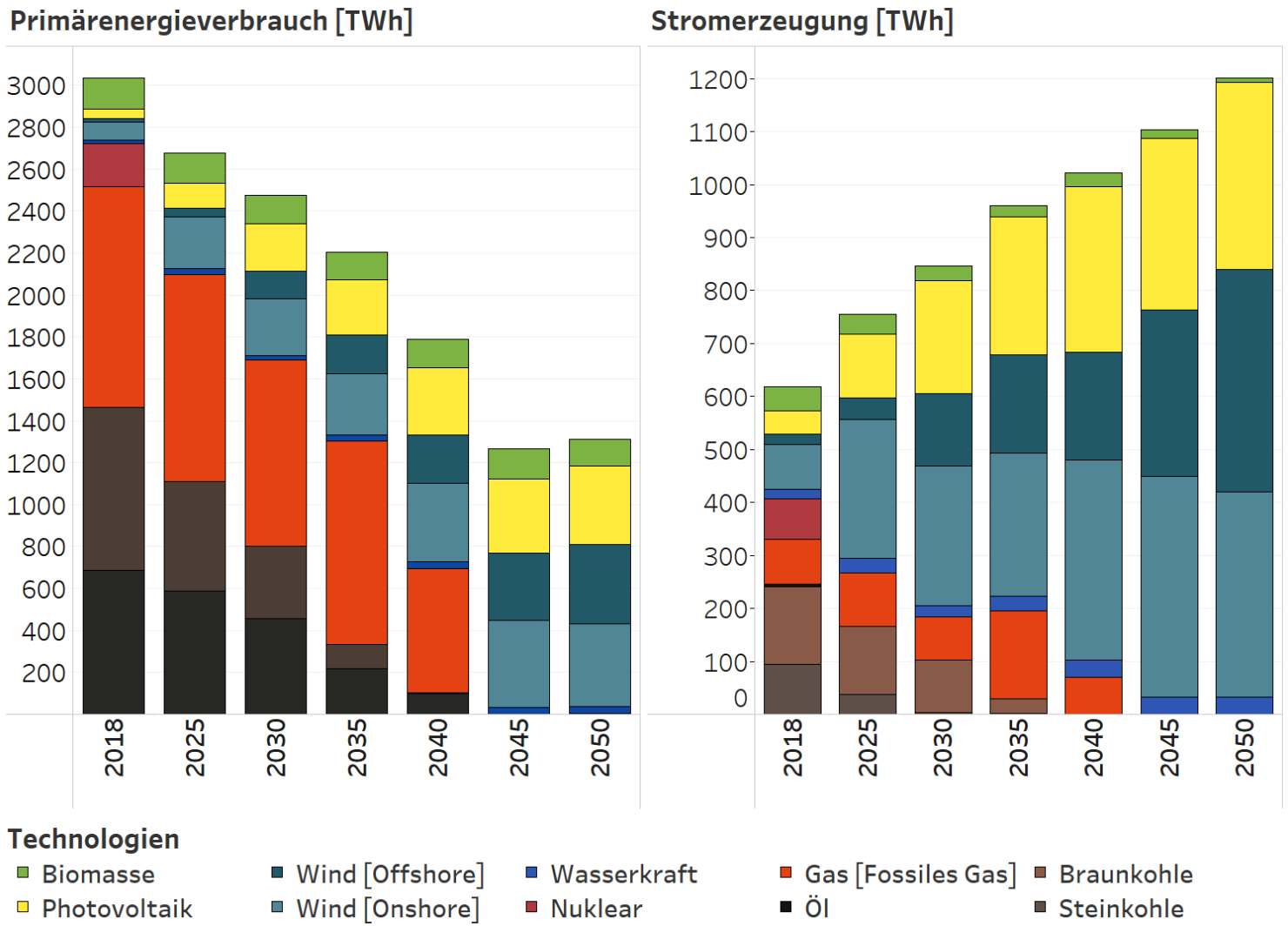
Open Scenario
• Reference scenario to compare with current policies • No restrictions for political goals • Only CO_2 target

Preliminary Results 2: Regional Power Production



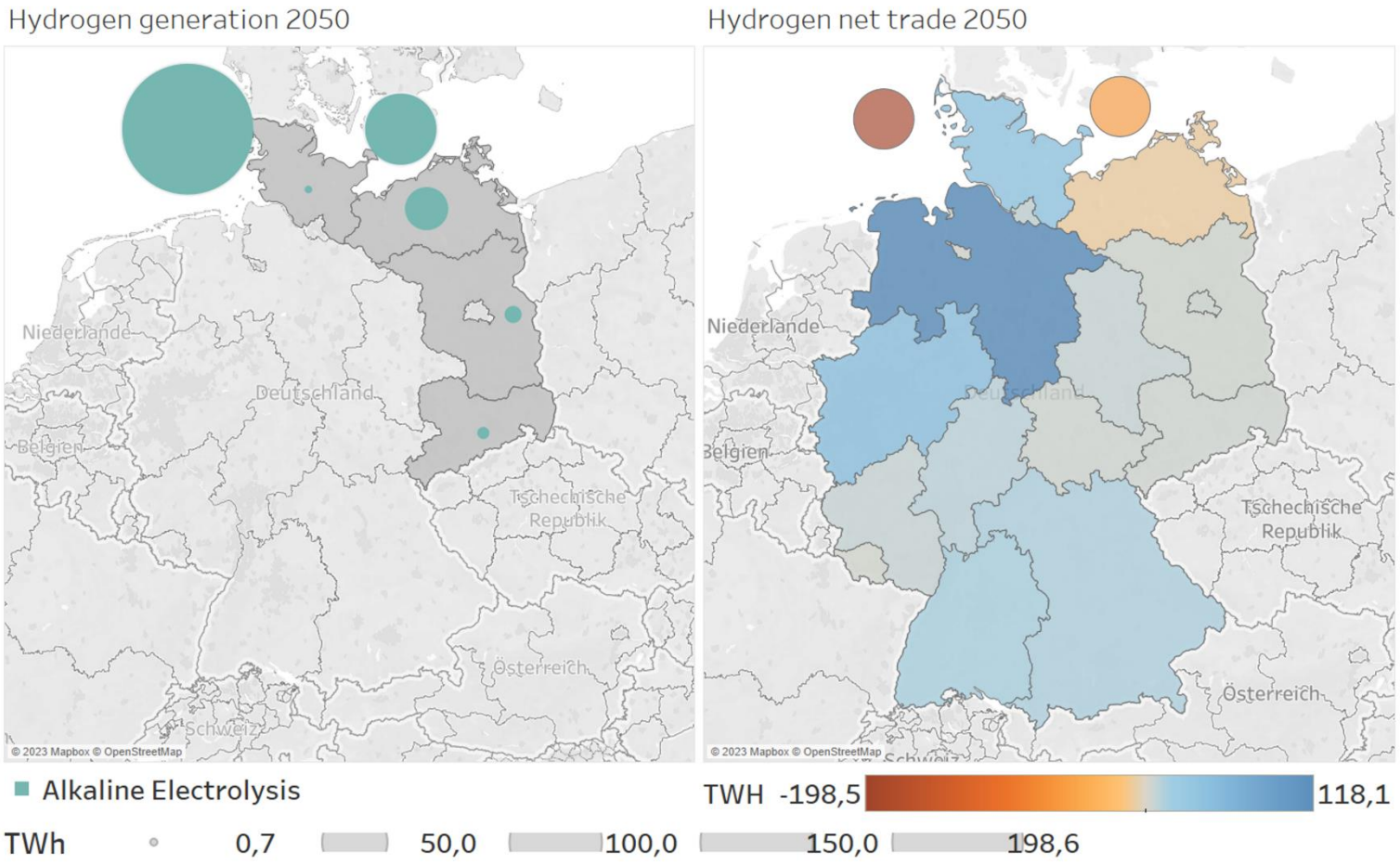
- Decarbonization in all German states to achieve greenhouse gas neutrality by 2045
- Increasing electricity production in North and Baltic Seas
- Wind and solar power meet most of GER's electricity demand

Preliminary Results 1: Primary energy & Electricity Production



- **Declining primary energy demand** by 2050 through **energy efficiency**
- Strong **increase in electricity** production by 2050 through electrification of all sectors
- **Renewable energy dominates** electricity production from 2030 onwards

Preliminary Results – Hydrogen Production and Export



- **Production dominated by the North and Baltic Sea**
- **Trading from the north-east into western regions**

Preliminary Results - Implications

- Cost comparison to other available technologies influences the result drastically
  - Cost developments of hydrogen technologies are to be assesed

- Transportation restrictions seem to be of lesser significance for hydrogen usage

- An increase of hydrogen into the current gas system seems to come with increased hydrogen exports from Norway, while gas exports from Türkiye might decline

Research Outlook

Represent the hydrogen transportation pathways within germany more accurate

Explore the possibility of using pipelines as a from of storage

Investigate sensitivities of centralized and decentralized production

Thank you for your Attention!

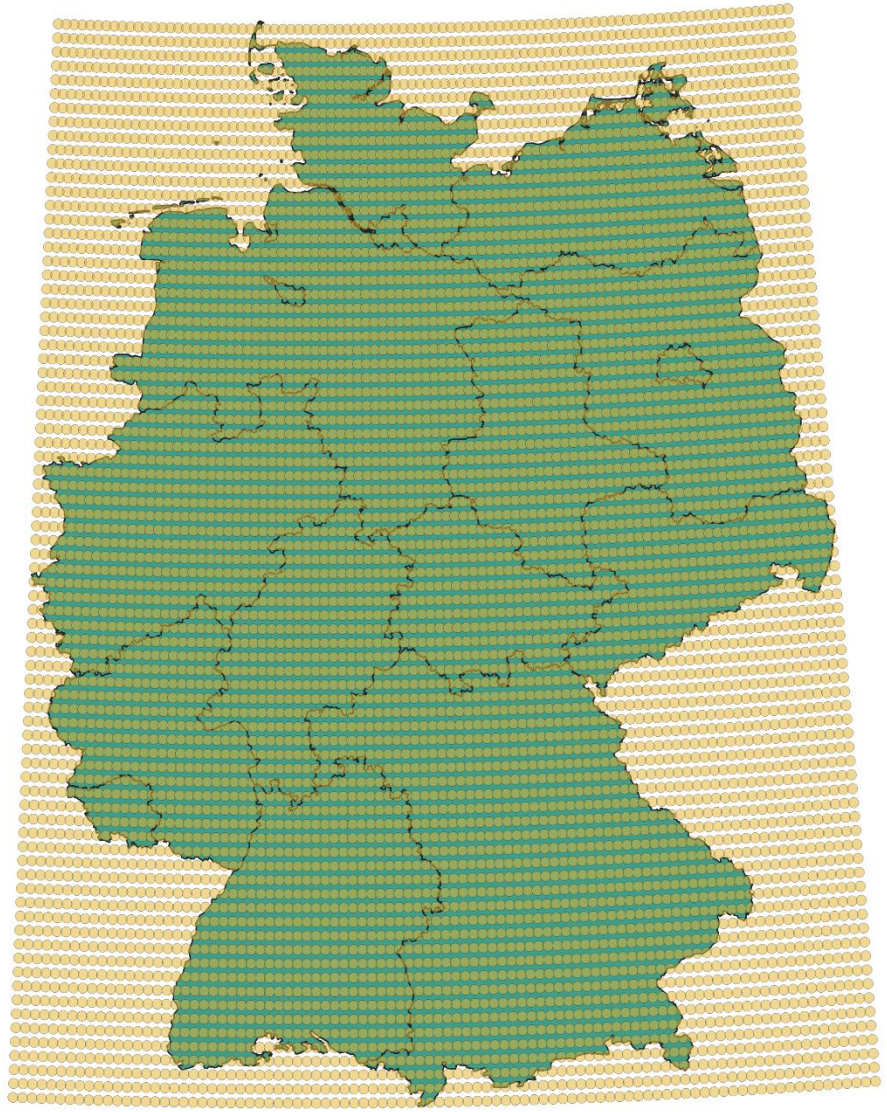
Jonathan Hanto – Research Associate
Technische Universität Berlin – joh@wip.tu-berlin.de
Europa-Universität Flensburg – jonathan.hanto@uni-flensburg.de

References

[1] Hainsch, K., Löffler, K., Burandt, T., Auer, H., Crespo del Granado, P., Pisciella, P., Zwickl-Bernhard, S., 2022. Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal? Energy 239, 122067. URL: https://www.sciencedirect.com/science/article/pii/S036054422102315X, doi:10.1016/j.energy.2021.122067.

[2] Auer, H., Crespo del Granado, P., Oei, P.Y., Hainsch, K., Löffler, K., Burandt, T., Huppmann, D., Grabaak, I., 2020b. Development and modelling of different decarbonization scenarios of the European energy system until 2050 as a contribution to achieving the ambitious 1.5° C climate target—establishment of open source/data modelling in the European H2020 project openENTRANCE. e & i Elektrotechnik und Informationstechnik 2020. doi:https://doi.org/10.1007/s00502-020-00832-7.

Availability mapping



Enno Wiebrow
Technische Universität Be