ISEASA
1st International Symposium on Energy System Analysis

Resilient strategies for the European energy system
A case study on 2030 EU policy targets

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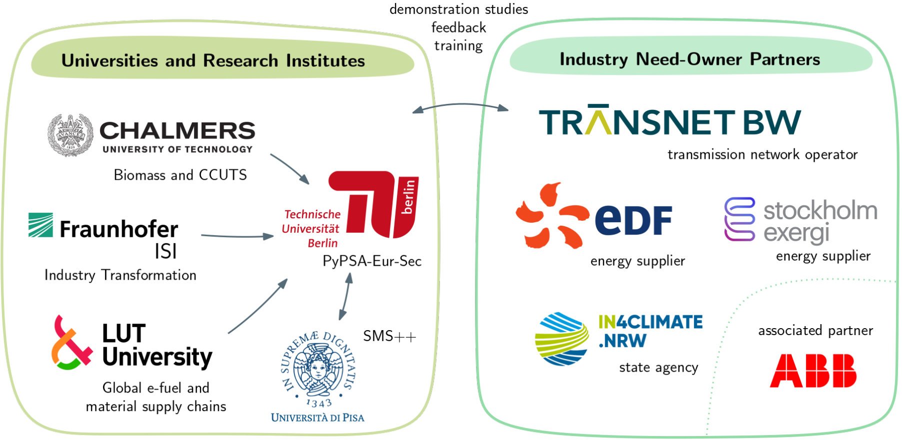
RESILIENT project partners



Funded via **CETPartnership 2022** Call – **BMWK** for all German partners.

Source: https://resilient-project.github.io/

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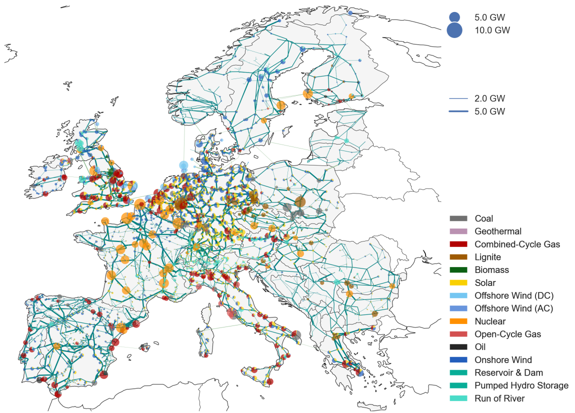
PyPSA-Eur: An open-source, sector-coupled model for Europe

- Spatially and temporally highly linear optimisation model that covers the European continent,
- Built on top of the open-source toolbox PyPSA,
- Includes stock of existing power plants, renewable potentials, availability time series,
- Covers the electricity high-voltage grid from AC 220 kV to 750 kV (UA) and DC 150 kV upwards, option to include planned transmission projects (TYNDP and German NEP),
- Maintained by the Department of Digital Transformation in Energy Systems at TU Berlin.



Source: https://pypsa-eur.readthedocs.io

Selection of planned model developments

Computational methods for uncertainties

- decomposition techniques
- large-scale stochastic optimisation
- **test robustness of system**
- using SMS++ framework

Carbon management and biomass usage

- **CO_2 network**
- **CO_2 sequestration potentials**
- circular carbon economy and recycling
- biomass usage options

Industry transformation (FORECAST)

- fuel and process switching
- industry relocation
- carbon sources and feedstocks
- data on stock & investment cycles
- new technologies (oxyfuel cement, etc.)

Global green fuel and material markets

- **imports of green energy and materials**
- **effects on European infrastructure**
- restructuring of value chains
- risks (geopolitical, technological, etc.)

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Case study: Motivation

Blabla

- target 1

Source: Neumann, Zeyen, Victoria, Brown, 2023; https://doi.org/10.1016/j.joule.2023.06.016

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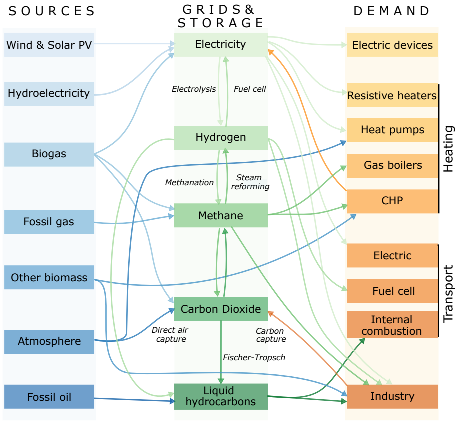
Case study: Model setup

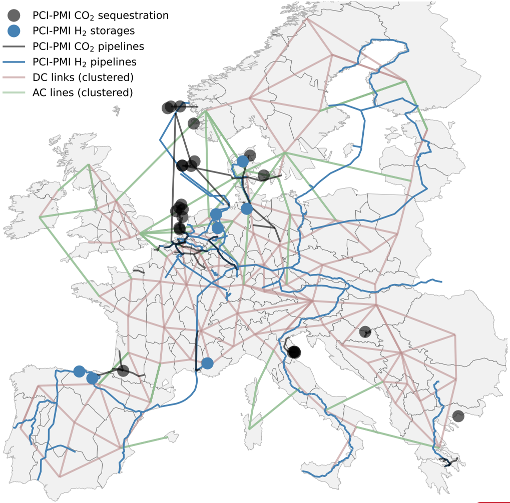
- Including sectors **power, heat, transport, industry, agriculture**
- Minimising **total system costs** (investment and operation) for the target
- **Co-optimising** generation, transmission, storage, and power-to-X conversion
- Resolving 34 countries to **90 regions** at **3-hourly** temporal resolution
- Implementing **PCI/PMI** hydrogen and carbon infrastructure projects as well as key **2030 targets**:
  - 55 % emission reduction (**Fit for 55**)
  - 10 Mt p.a. production of hydrogen (**REPowerEU**)
  - 50 Mt p.a. of CO_2 sequestration (**Net-Zero Industry Act**)



Source: https://pypsa-eur.readthedocs.io

Case study: Overview of PCI-PMI H_2 and CO_2 infrastructure

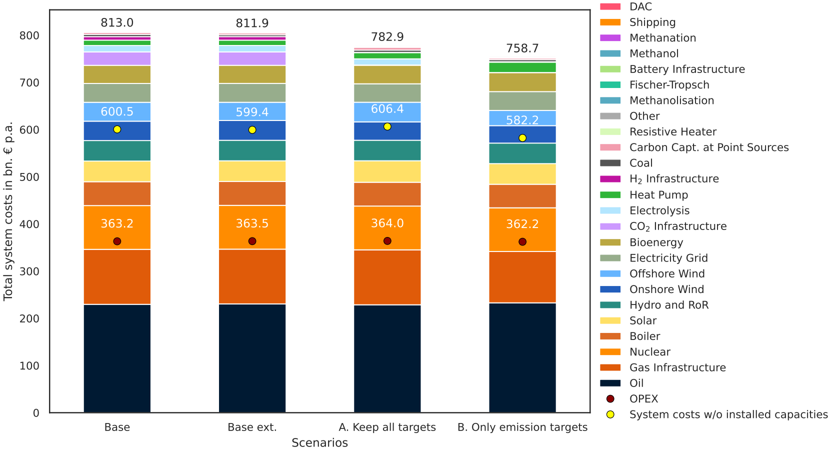
- Baseline scenario incorporates **PCI/PMI** projects for **H_2** and **CO_2** infrastructure, including pipelines, storages (H_2) and sequestration sites (CO_2), commissioned by 2030
- Total CO_2 sequestration potential sums up to **75 Mt p.a.**, mostly located in the North Sea
- Total H_2 storage capacity sums up to **977 GWh**



Source: Own illustration based on data extracted from
https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer

First results

- test



Source: Own illustration based on first results

Case study: First takeaways

1. Imports of green energy could reduce cost of European net-zero system **by 1-14%**.
2. **Diminishing returns** for larger import volumes; **preference** for steel, MeOH and H_2.
3. Infrastructure policy needs **coordination** with import strategy & carbon management.
4. Protect against interannual weather variability, e.g. with **(green) fuel reserves**.
5. Maneuvering space to accommodate non-cost factors: **geopolitics**, **reuse** of infrastructure, **resilience** of supply chains, diversification, and reduced land usage..

Outlook

- Add all PCI/PMI projects, including hybrid offshore interconnection projects (energy islands), electricity storages, etc.
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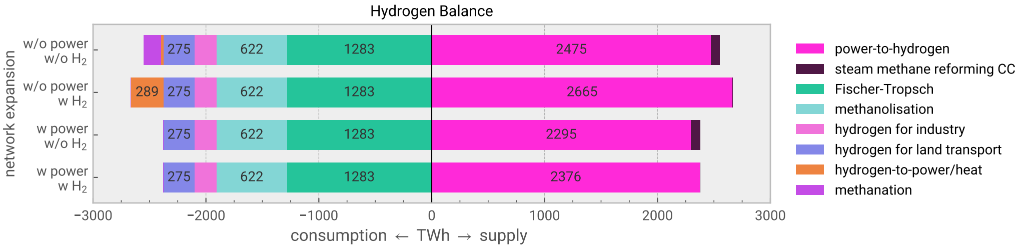
Appendix

Why H_2? Most H_2 is used for derivative fuels and chemicals!



Mostly **green electrolytic hydrogen supply**. **Few direct uses of hydrogen** in the energy system, but it is used to synthesise other fuels and chemicals:

- ammonia for fertilizers
- direct reduced iron for steelmaking
- shipping and aviation fuels
- precursor to high-value chemicals
- backup heat and power supply
- some heavy duty land transport

Source: Neumann, Zeyen, Victoria, Brown, 2023; https://doi.org/10.1016/j.joule.2023.06.016

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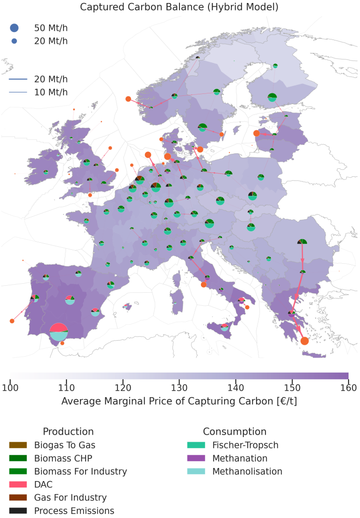
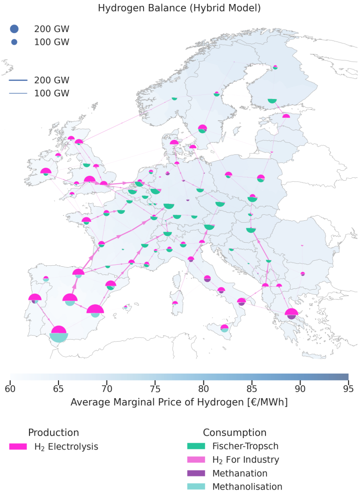
Transporting CO_2 to H_2 or transporting H_2 to CO_2?





Source: Hofmann, Tries, Neumann, Zeyen, Brown, 2024; https://arxiv.org/abs/2402.19042

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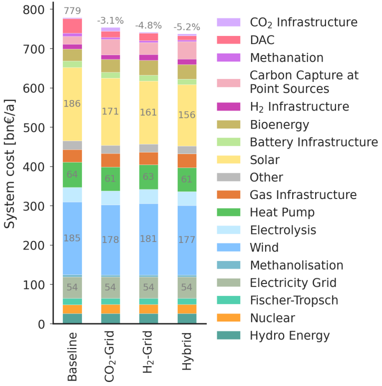
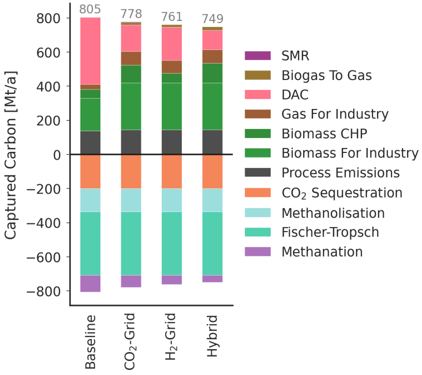
Carbon management: Capture, use, transport and sequestration





- **CCS** for process emissions (for instance, in cement industry)
- **CCU** for e-synfuels and e-chemicals (in particular, shipping, aviation, plastics)
- **CDR** for unabatable and negative emissions (to offset imperfect capture rates)

Source: Hofmann, Tries, Neumann, Zeyen, Brown, 2024; `https://arxiv.org/abs/2402.19042`