Technische Universität Berlin

EN SYS Digital Transformation in Energy Systems

Supported by: Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

The Role of PCI-PMI Infrastructure in Reaching Europe's Energy Policy Targets

resilient-project.github.io · pypsa.org · github.com/PyPSA/pypsa-eur · github.com/bobbyxng

Motivation

EU targets and PCI-PMI projects

The European Union (EU) aims to achieve climate-neutrality by 2050, with ambitious domestic H_2 production and CO_2 sequestration targets next to a net-zero transition. The European Commission selects so-called Projects of Common Interest (PCI) and Projects of Mutual Interest (PMI) (Figure 1) — large infrastructure projects for electricity, hydrogen and CO_2 transport, and storage — that are of transnational importance as they link the energy systems of European countries.

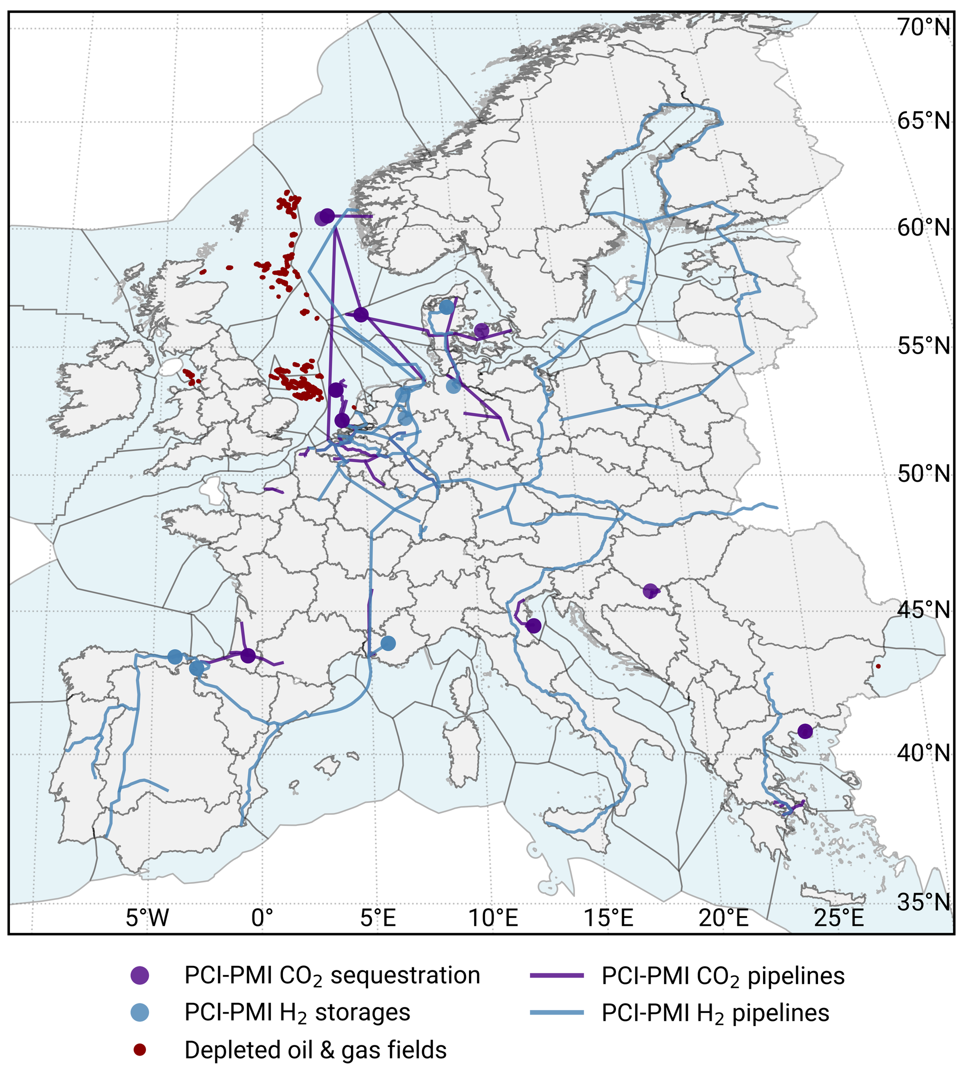


Figure 1: Map of the regional scope including clustered onshore (grey) and offshore regions (blue), as well as PCI-PMI CO_2 and H_2 pipelines, storage and sequestration sites. Depleted offshore oil and gas fields (red) provide additional CO_2 sequestration potential [1].

In this work, we evaluate the impact of PCI-PMI projects for the European energy system and EU energy policies using a **regret-analysis** approach (Table 1) using the open-source sector-coupled energy system model PyPSA-Eur [1, 2, 3]. More specifically, we run five long-term scenarios varying in the degree of CO_2 and H_2 infrastructure deployment, including the on-time commissioning of PCI-PMI projects. In a second step, we evaluate the performance of these long-term scenarios in a short-term scenario (potential realisation), i.e. (i) reduced policy targets, (ii) delay of PCI-PMI, or (iii) no pipelines at all. In total, 60 optimisations are run at 2190 snapshots (on avg. 4h resolution) for 99 NUTS regions.

Table 1: Regret matrix setup: Long-term and short-term scenarios.

Short-term	Reduced targets	Delayed pipelines	No pipelines
Long-term scenarios			
Decentral Islands (**DI**)	■	–	–
PCI-PMI (**PCI**)	■	■	■
PCI-PMI nat. (**PCI-n**)	■	■	■
PCI-PMI internat. (**PCI-in**)	■	■	■
Central Planning (**CP**)	■	■	■
Targets			
GHG emission reduction	■	■	■
CO_2 sequestration	–	■	■
Electrolytic H_2 production	–	■	■
H_2 electrolysers	–	■	■
CO_2 + H_2 infrastructure			
CO_2 sequestration sites	■	■	■
CO_2 pipelines to seq. site	■	■	■
CO_2 pipelines	■	□	–
H_2 pipelines	■	□	–

■ enabled □ delayed by one period – disabled

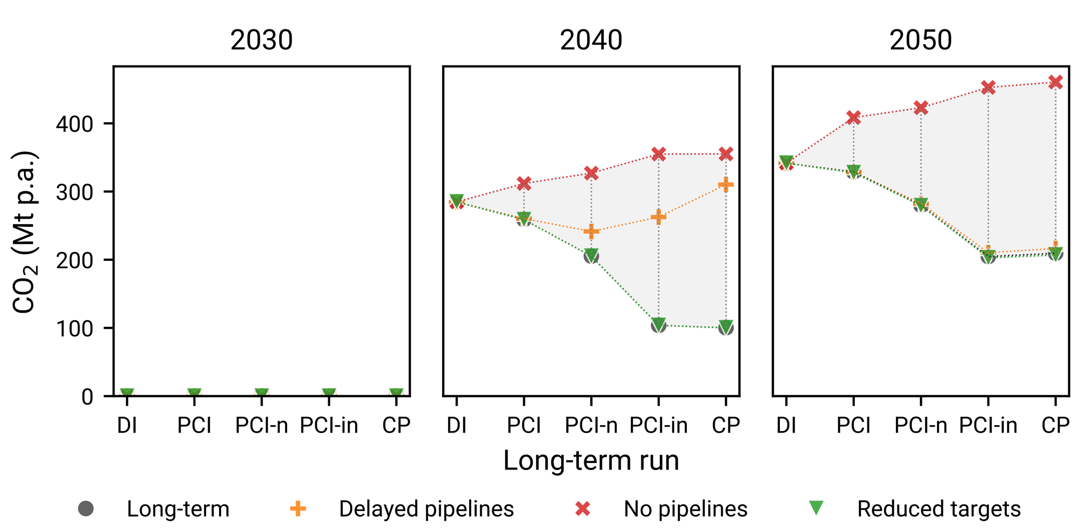


Figure 2: DAC utilisation

Key results

Pipelines vs. DAC

In the *PCI* scenario, **CO_2 pipelines** transport CO_2 from biomass-based industry process and point sources equipped with carbon capture in north-western Europe to sequestration sites in the North Sea (Figure 3). These include PCI-PMI projects (around 114 Mt p.a.) and up to 286 Mt p.a. of additional potential from depleted oil and gas fields.

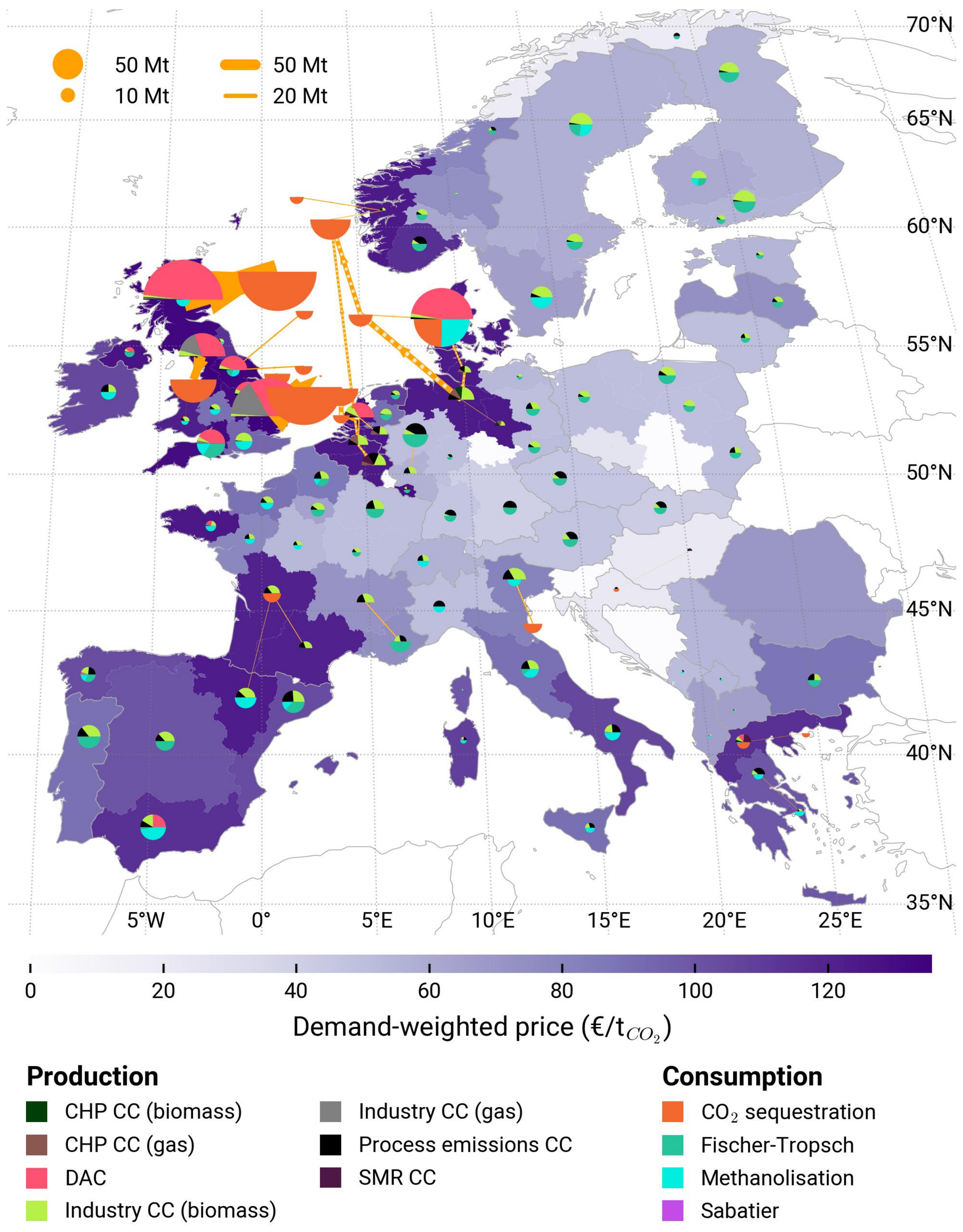


Figure 3: *PCI* long-term scenario (2050) — CO_2 balances and distribution

Results show that a build-out of CO_2 pipelines **reduces the reliance on expensive DAC technology** (Figure 2). Seeing a delay in the commissioning of pipeline projects leads to a significant increase in the use of DAC, most visible in the year 2040. In the most extreme case, DAC utilisation in pipeline scenarios by up to 300 Mt p.a. if the pipelines are not built at all, and the system has to react on short notice through additional investments or higher utilisation of existing assets.

H_2 pipelines connect production sites at locations with high renewable energy potential to demand sites, e.g. for methanol and Fischer-Trosch synthesis or direct use in the industry (Figure 4).

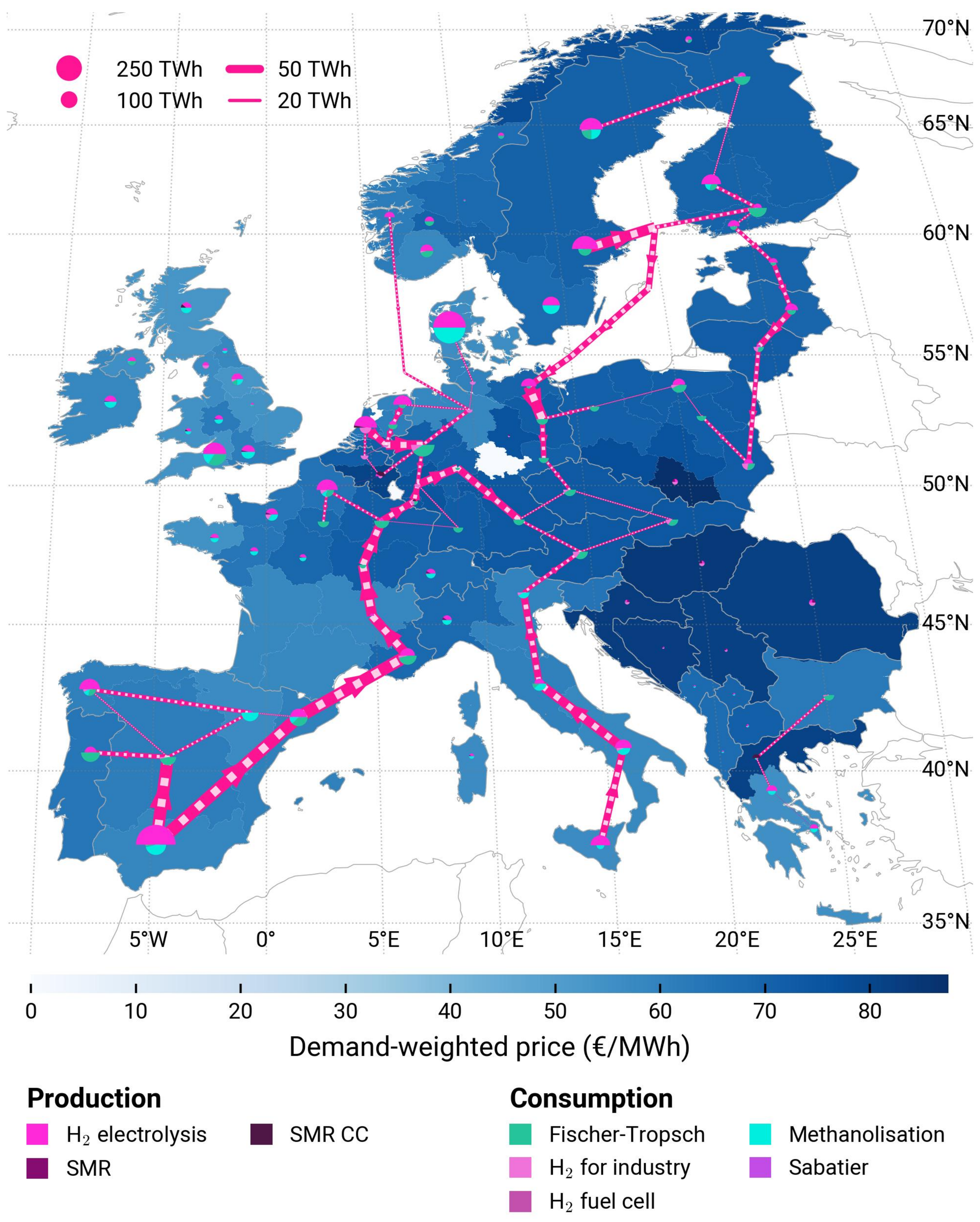


Figure 4: *PCI* long-term scenario (2050) — H_2 balances and distribution

Take-aways

Preliminary

- PCI-PMI CO_2 and H_2 pipelines support reaching the European policy targets at lower costs, especially over the total lifetime of the assets (Figure 6).
- More pipeline investments unlock even higher system cost savings of additional 7-16 bn. € p.a. in 2050 by reducing the reliance on expensive DAC technology.
- Delays of projects in 2030 barely affect total system costs. However, delays of PCI projects in combination with endogenous pipeline investments can increase system costs by up to 35.2 bn € p.a. (Figure 5).

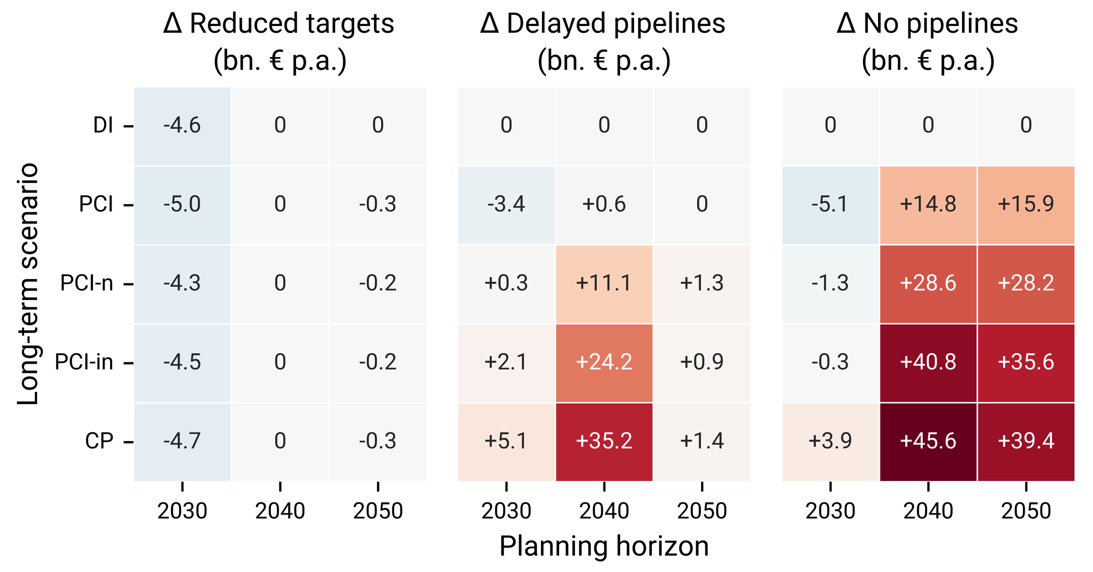


Figure 5: Regret matrix. Calculating regret terms by subtracting system costs of long-term scenarios (columns) from short-term scenarios (rows). Positive values reflect higher costs in the short-term scenarios compared to the long-term ones.

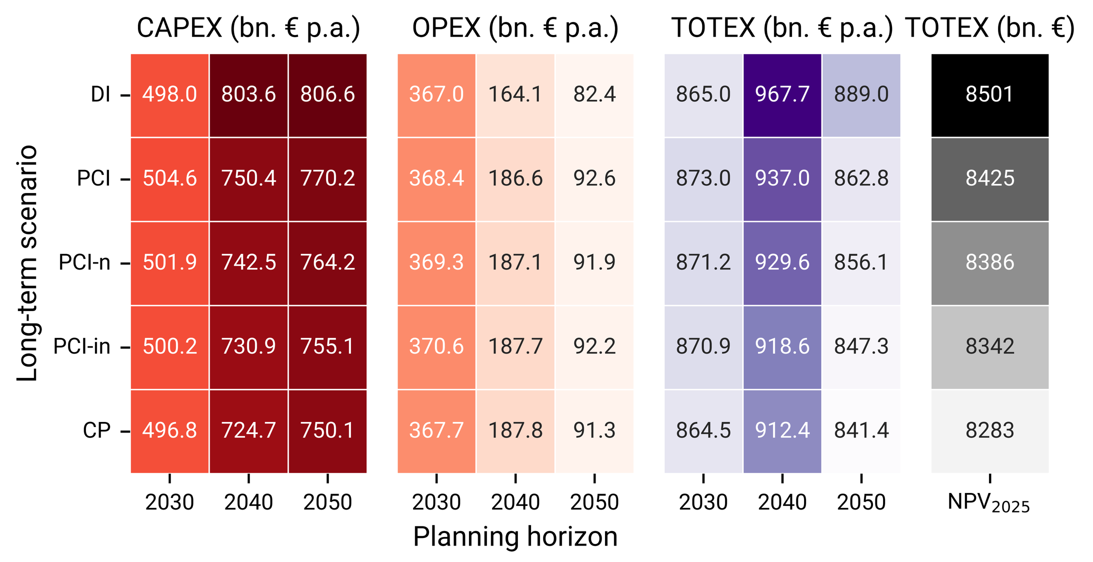
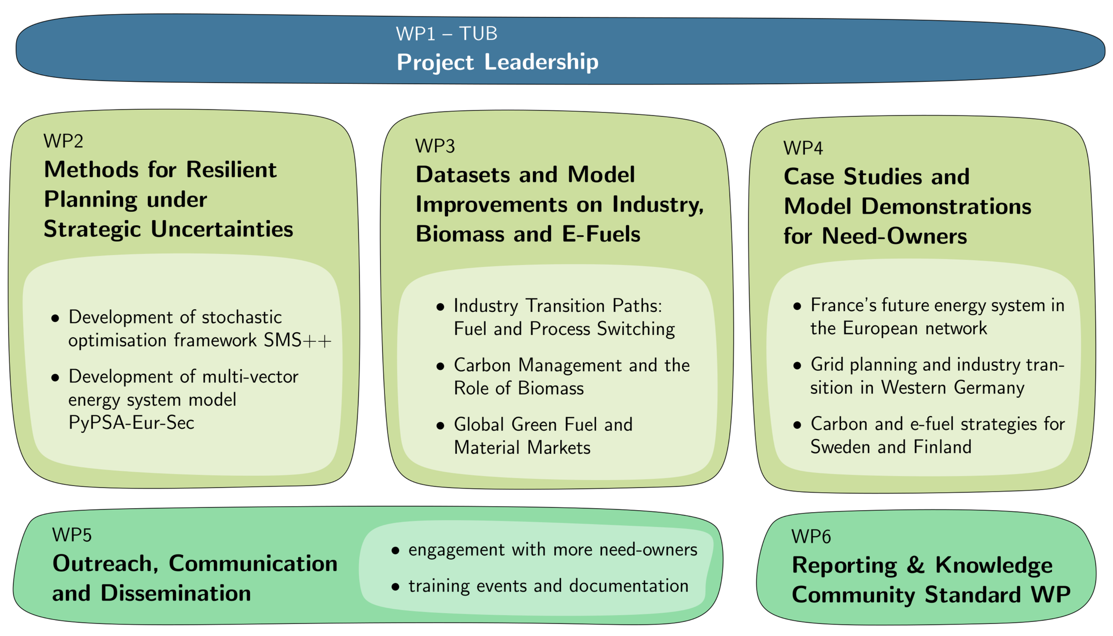


Figure 6: Total system costs

RESILIENT project



This work was supported by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) under Grant No. 03EI4083A (RESILIENT). This project has been funded by partners of the CETPartnership (https://cetpartnership.eu) through the Joint Call 2022. As such, this project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101069750.

References

[1] Fabian Hofmann, Christoph Tries, Fabian Neumann, Elisabeth Zeyen, and Tom Brown. H2 and CO2 network strategies for the European energy system. *Nature Energy*, pages 1–10, April 2025.

[2] Jonas Hörsch, Fabian Hofmann, David Schlachtberger, and Tom Brown. PyPSA-Eur: An open optimisation model of the European transmission system. *Energy Strategy Reviews*, 22:207–215, November 2018.

[3] Fabian Neumann, Elisabeth Zeyen, Marta Victoria, and Tom Brown. The potential role of a hydrogen network in Europe. *Joule*, 7(8):1793–1817, August 2023.

Contact: Bobby Xiong (xiong@tu-berlin.de)
Keywords: open-source · energy system modelling · policy targets · infrastructure · resilience · hydrogen · carbon · Europe