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The Role of Projects of Common Interest in Reaching Europe's Energy Policy Targets

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Motivation: Recap 2030 policy targets

The EU has set ambitious targets for 2030, including the electricity, hydrogen and CO_2 infrastructure sector.

55 % emission reduction

- **Fit for 55**
- Translating to an emission allowance of ca. 2 bn. t CO_2 p.a. in 2030
- Covering the electricity, heat, industry, transport, buildings and agriculture sectors

10 Mt p.a. green H_2 production

- **REPowerEU**
- Accelerating the transition away from fossil fuels (esp. Russian gas), enhancing energy security through renewables
- Aligns with European Green Deal and targets scaling up renewable H_2 in hard-to-electrify-sectors

50 Mt p.a. CO_2 sequestration

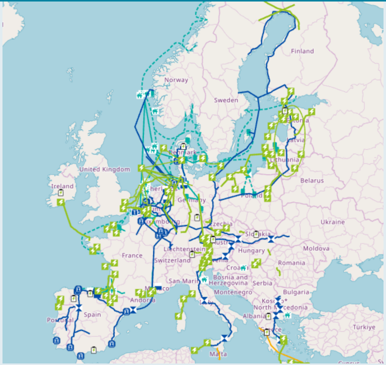
- **Net-Zero Industry Act**
- Essential component in helping industries to reduce their net emissions
- Provides means to capture unavoidable emissions from hard-to-abate sectors like cement, steel, chemicals, etc.

Motivation: PCI-PMI projects

What are PCI-PMI projects?

- Projects of Common Interest (PCIs) are key **cross-border infrastructure projects** that link the energy systems of EU countries
- Projects of Mutual Interest (PMIs) include cooperations with countries outside the EU
- Intend “to help the EU achieve its **energy policy and climate objectives**: affordable, secure and sustainable energy for all citizens and the long-term decarbonisation of the economy in accordance with the **Paris Agreement**”
- “Potential overall benefits of the project must outweigh its costs”
- Given their **lighthouse character**, these projects are highly likely to be implemented.
- Large infrastructure projects (incl. PCI-PMI) are however commonly facing delays due to permitting, procurement bottlenecks, etc.

Project map

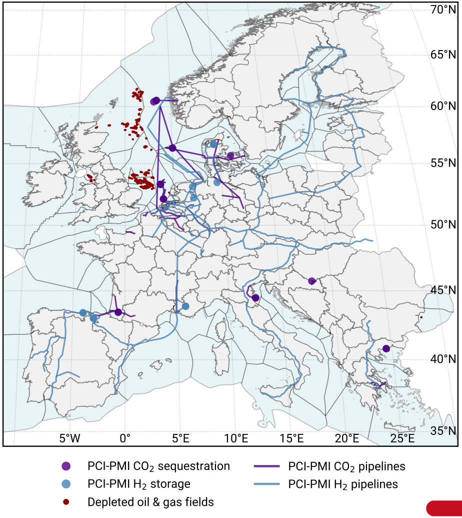


1. What is the impact of delay in PCI-PMI projects’ realisation on the EU’s policy targets for 2030?
2. What are the costs associated with adhering to the EU policy targets, even if PCI-PMI projects are delayed?

Source: https://energy.ec.europa.eu/topics/infrastructure_en and https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer

Model setup

- Including sectors **power, heat, transport, industry, feedstock** and **agriculture**
- **Myopic optimisation** for 2030, 2040 and 2050
- **Co-optimising** generation, transmission, storage, and power-to-X conversion
- Resolving 34 countries to **99 regions** (NUTS mix) at **4-hourly** temporal resolution on avg. (using tsam).
- Implementing **PCI-PMI** HVAC, HVDC, hydrogen and carbon infrastructure projects as well as key GHG, H_2 production, electrolyser capacity, and CO_2 sequestration targets (next slide). Additional sequestration potential from **depleted oil and gas fields** [6]
- **Regret analysis** approach based on 5 long-term scenario, 3 short-term scenarios, in total 60 model runs



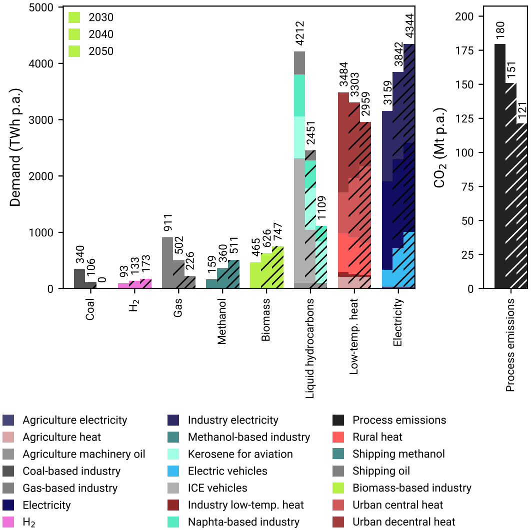
Source: Own illustration based on data extracted from https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer

Pathway for implemented long-term (LT) targets

Planning horizon	2030	2040	2050
Targets			
GHG emission reduction	−55 %	−90 %	−100 %
CO_2 sequestration	50 Mt p.a.	150 Mt p.a.	250 Mt p.a.
Electrolytic H_2 production	10 Mt p.a.	27.5 Mt p.a.	45 Mt p.a.
H_2 electrolyser capacity	40 GW	110 GW	180 GW

Model targets based on [1–5]

Exogenous demand



Long-term scenarios

Long-term scenarios	DI	PCI	PCI-n	PCI-in	CP
CO_2 sequestration					
Depleted oil & gas fields*	■	■	■	■	■
PCI-PMI seq. sites**	–	■	■	■	■
H_2 storage					
Endogenous build-out	■	■	■	■	■
PCI-PMI storage sites	–	■	■	■	■
CO_2 pipelines					
to depleted oil & gas fields	■	■	■	■	■
to PCI-PMI seq. sites	–	■	■	■	■
CO_2 and H_2 pipelines					
PCI-PMI	–	■	■	■	■
National build-out	–	■	■	■	■
International build-out	–	–	–	■	■
PCI-PMI extendable	–	–	–	–	■

■ enabled – disabled * approx. 286 Mt p.a. ** approx. 114 Mt p.a.

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Regret-matrix setup

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

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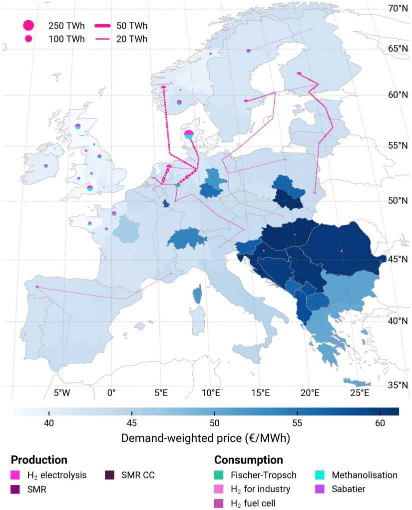
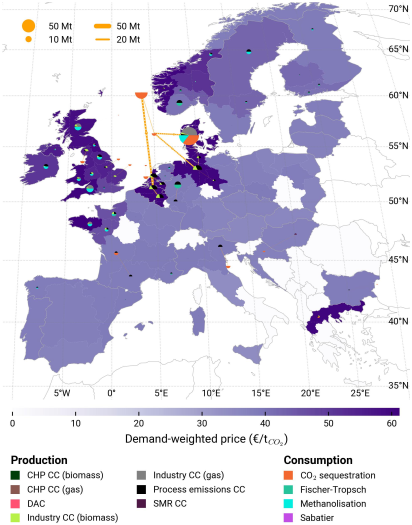
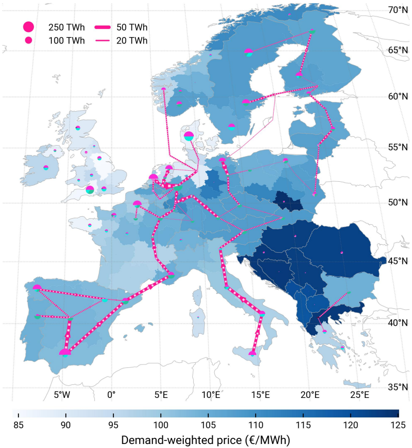
LT — PCI: 2030 regional H_2, CO_2 balances and transport





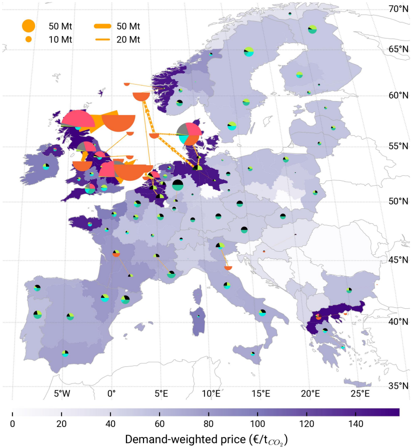
Source: Own illustration.

LT — PCI: 2040 regional H_2, CO_2 balances and transport



Production
- H_2 electrolysis
- SMR
- SMR CC

Consumption
- Fischer-Tropsch
- H_2 for industry
- H_2 fuel cell
- Methanolisation
- Sabatier

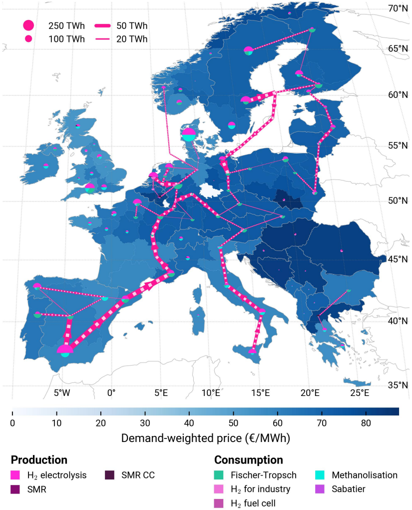


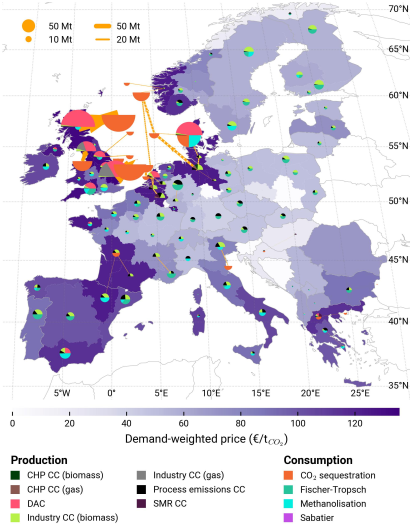
Production
- CHP CC (biomass)
- CHP CC (gas)
- DAC
- Industry CC (biomass)
- Industry CC (gas)
- Process emissions CC
- SMR CC

Consumption
- CO_2 sequestration
- Fischer-Tropsch
- Methanolisation
- Sabatier

Source: Own illustration.

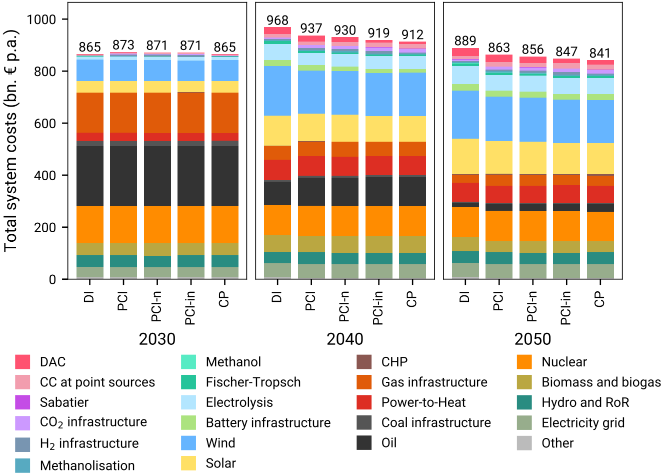
LT — PCI: 2050 regional H_2, CO_2 balances and transport



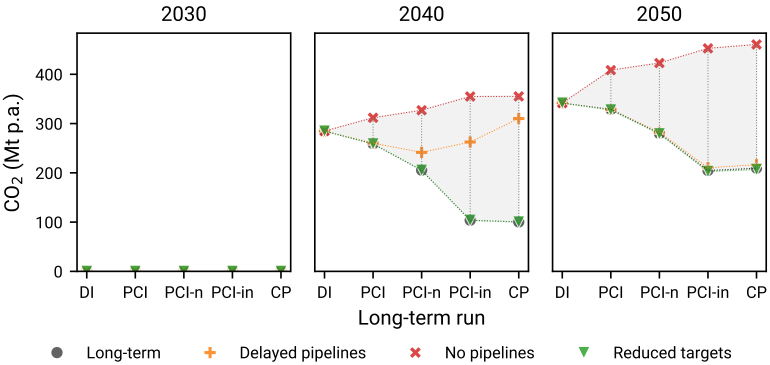


Source: Own illustration.

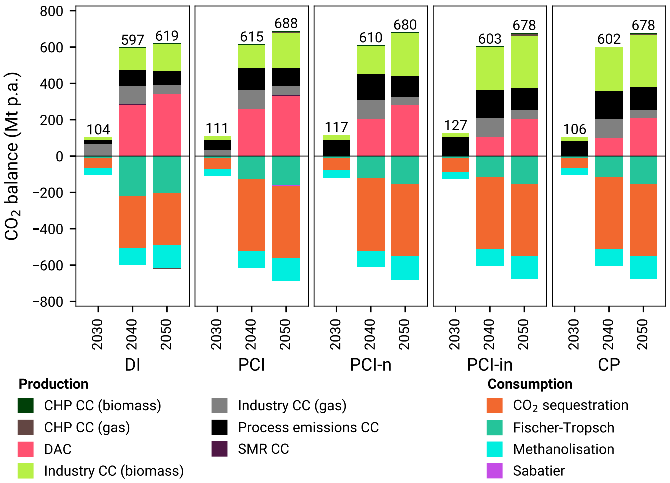
LT — Total system costs



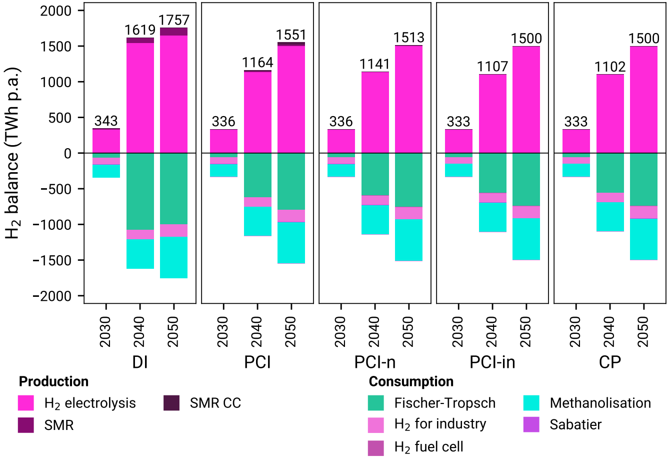
LT — CO_2 balances



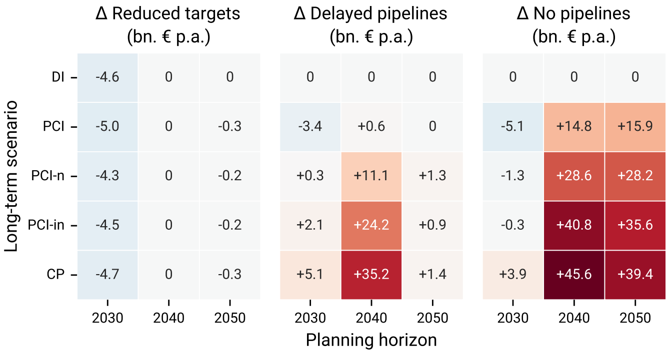
LT — CO_2 balances: Direct Air Capture (DAC) utilisation



LT — H_2 balances

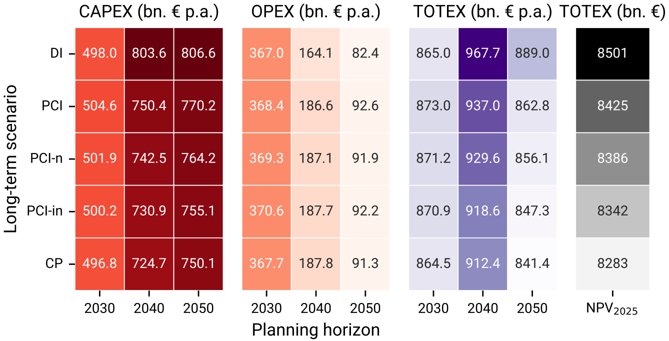


Regret matrix



Regret terms are calculated by subtracting system costs of long-term scenarios (rows) from short-term scenarios (columns).
Positive values reflect higher costs in the short-term scenarios compared to the long-term ones.

Value of PCI-PMI projects in the long run



Conclusion

1. PCI-PMI projects have a positive impact on total system costs and are likely a no-regret investment based on our results (though not perfectly cost-optimal compared to theoretical *CP* scenario).
2. Additional cost savings can be unlocked with single, strategically placed pipelines to connect additional H_2 production sites and CO_2 point sources to the pipeline network.
3. Further, the success of large-scale investment projects is largely driven by political support, public acceptance, which is especially given for PCI-PMI projects.
4. H_2 pipelines projects help distribute more affordable green H_2 from northern and south-western Europe to high-demand regions in central Europe; ii) CO_2 transport and storage projects help decarbonising the industry by connecting major industrial sites and their process emissions to offshore sequestration sites in the North Sea (Denmark, Norway, and the Netherlands).
5. Pipelines basically serve as a tool to hedge risks of overbuilding solar and wind generation capacities and reduce excessive reliance on single carbon capture technologies like DAC and carbon capture at point sources $\rightarrow$ confirms previous findings of [6].
6. Overall, PCI-PMI projects including additional pipeline build-outs allow a lower-cost and less technology-dependent transition towards a decarbonised system compared to a system without any pipeline infrastructure. They support achieving the EUs ambitious policy targets in the long run.

References (excerpt)

[1] European Commission. *'Fit for 55': Delivering the EU's 2030 Climate Target on the Way to Climate Neutrality. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2021) 550 Final, Brussels.* 2021. (Visited on 01/26/2025).

[2] European Commission. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Towards an Ambitious Industrial Carbon Management for the EU.* 2024. (Visited on 05/05/2025).

[3] European Commission. *REPowerEU Plan. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2022) 230 Final, Brussels.* 2022. (Visited on 01/26/2025).

[4] European Commission. Directorate General for Energy. and Fraunhofer Institute for Systems and Innovation Research. "METIS 3, Study S5: The Impact of Industry Transition on a CO2 Neutral European Energy System.". In: (2023). DOI: 10.2833/094502. (Visited on 05/05/2025).

[5] European Parliament and Council of the European Union. *Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on Establishing a Framework of Measures for Strengthening Europe's Net-Zero Technology Manufacturing Ecosystem and Amending Regulation (EU) 2018/1724 (Text with EEA Relevance).* June 2024. (Visited on 01/26/2025).

[6] Fabian Hofmann et al. "H2 and CO2 Network Strategies for the European Energy System". In: *Nature Energy* (Apr. 2025), pp. 1–10. ISSN: 2058-7546. DOI: 10.1038/s41560-025-01752-6. (Visited on 04/16/2025).

Thank you.

↪ github.com/pypsa/pypsa-eur

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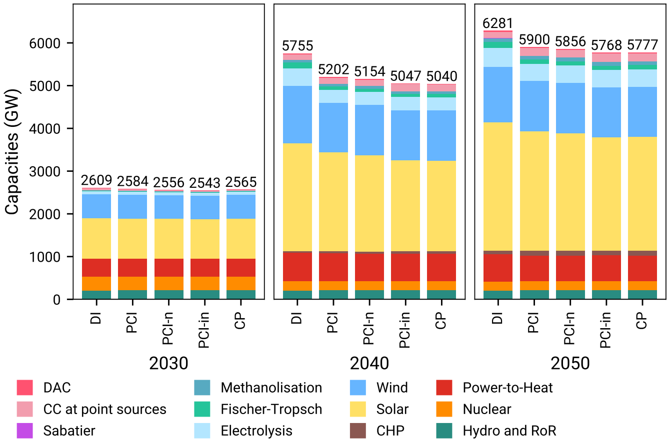
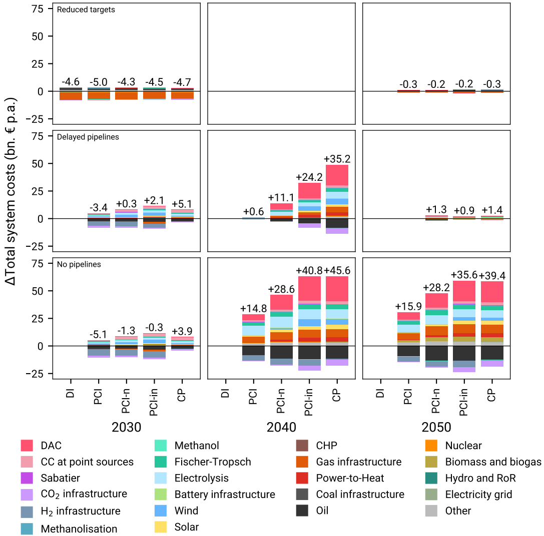
Appendix

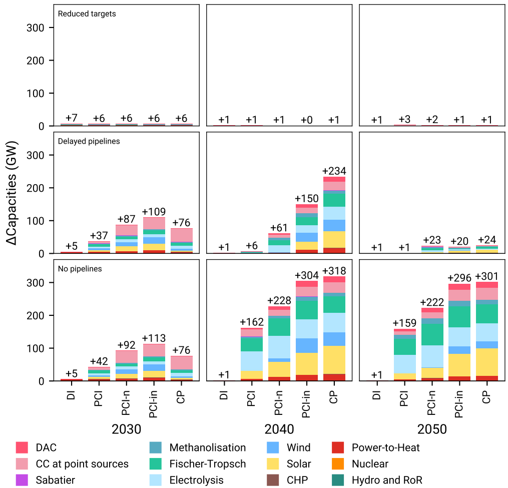
LT — Installed capacities



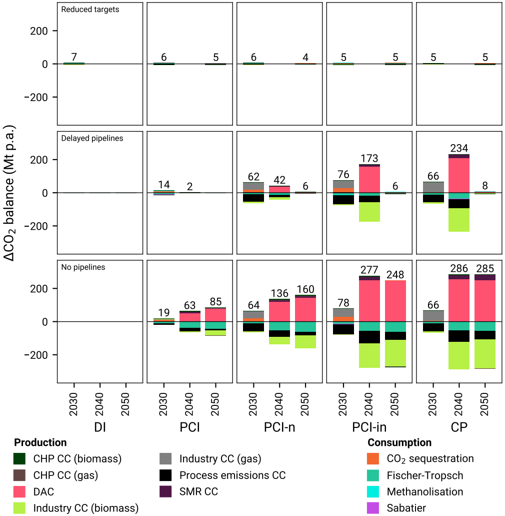
ST – Delta system costs



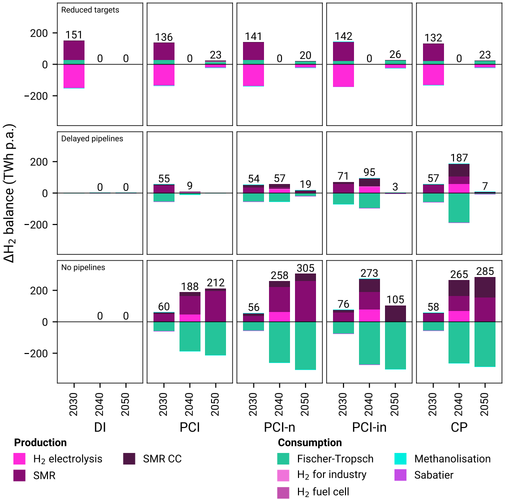
ST — Delta capacities



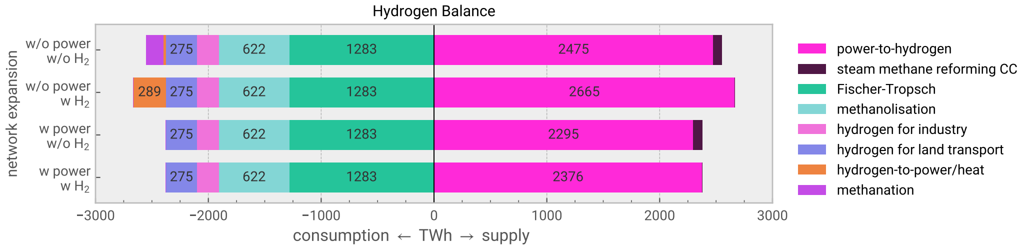
ST — Delta balances CO_2



ST — Delta balances H_2



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

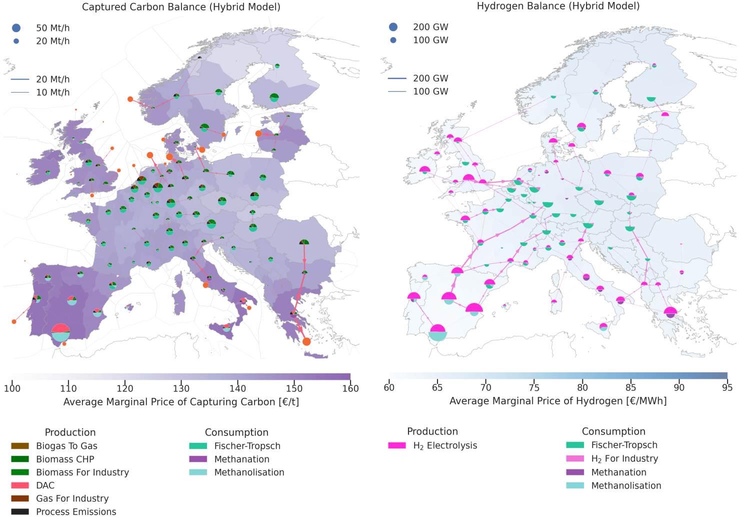


Mostly **green electrolytic hydrogen supply**. **Few direct uses of hydrogen** in the energy system, but it is used to synthesise other fuels and chemicals:

- 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

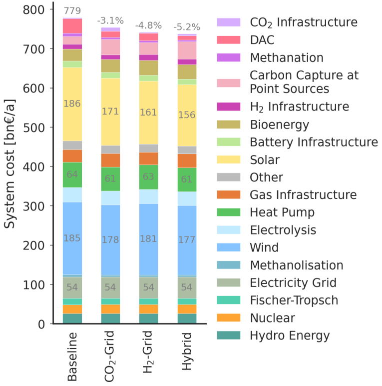
Source: Neumann, Zeyen, Victoria, Brown, 2023
https://doi.org/10.1016/j.joule.2023.06.016

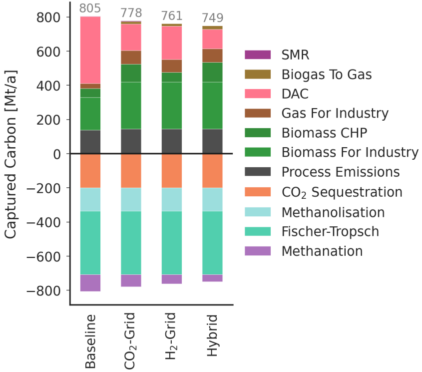
Transporting CO_2 to H_2 or transporting H_2 to CO_2?



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

Carbon management: Capture, use, transport and sequestration



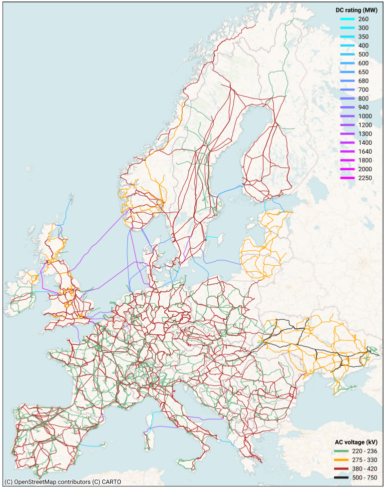


- **CCS** for process emissions (for instance, in cement industry)
- **CCU** for e-synfuels and e-chemicals (in particular, shipping, aviation, plastics)
- **CDR** for unabatable and negative emissions (to offset imperfect capture rates)

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

Electricity high-voltage grid based on OpenStreetMap (OSM)

- Dataset contains a topologically connected representation of the European high-voltage grid (220 kV to 750 kV) constructed using OpenStreetMap data
- Heuristic cleaning process was used to for lines and links where electrical parameters are incomplete, missing, or ambiguous
- Close substations within a radius of 500 m are aggregated to single buses
- Unique transformers are added for each voltage pair in a substation
- AC lines mapped using pandapower's standard line type library. In default version, nominal capacity is set to 70 % of the technical capacity to account for n-1 security approximation
- Includes all 38 European HVDC connections with their nominal rating that are commissioned as of 2024



Source: Own illustration based on data extracted using Overpass Turbo API
https://openstreetmap.org