

# 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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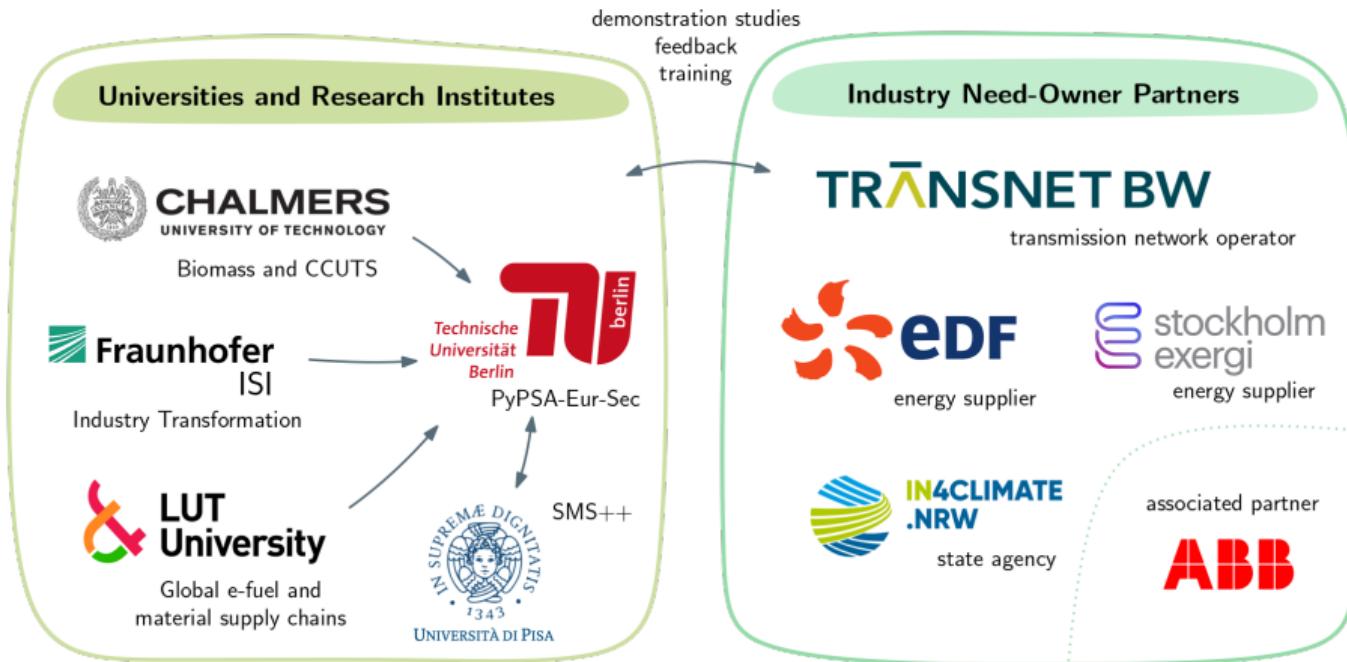
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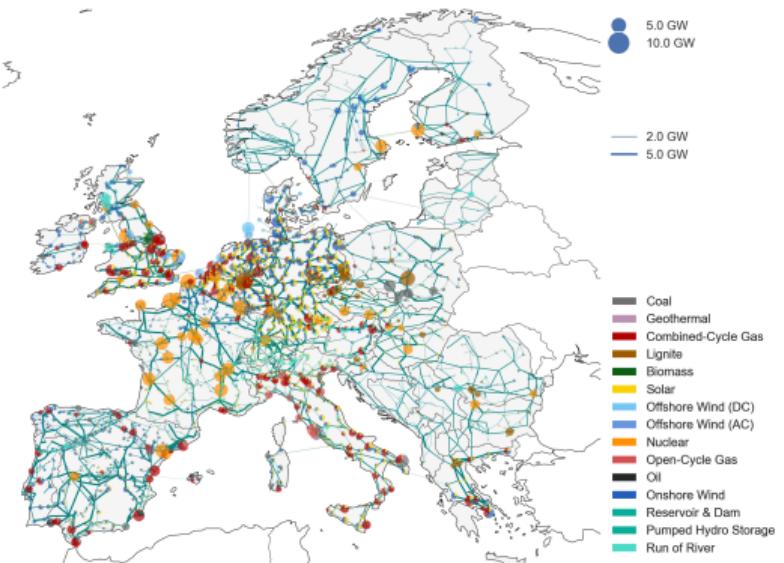
# RESILIENT project partners



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

# 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<sub>2</sub> network**
- **CO<sub>2</sub> 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.)

# Case study: Motivation and research questions

The EU has set ambitious targets for 2030, including the electricity, hydrogen and CO<sub>2</sub> infrastructure sector.

## 55 % emission reduction

- Fit for 55
- Translating to an emission allowance of ca. 2 bn. t CO<sub>2</sub> in 2030
- Covering the electricity, heat, industry, transport, buildings and agriculture sectors

## 10 Mt p.a. H<sub>2</sub> 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<sub>2</sub> in hard-to-electrify-sectors

## 50 Mt p.a. CO<sub>2</sub> 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.

## Case study: Motivation and research questions

## 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 likely to be implemented

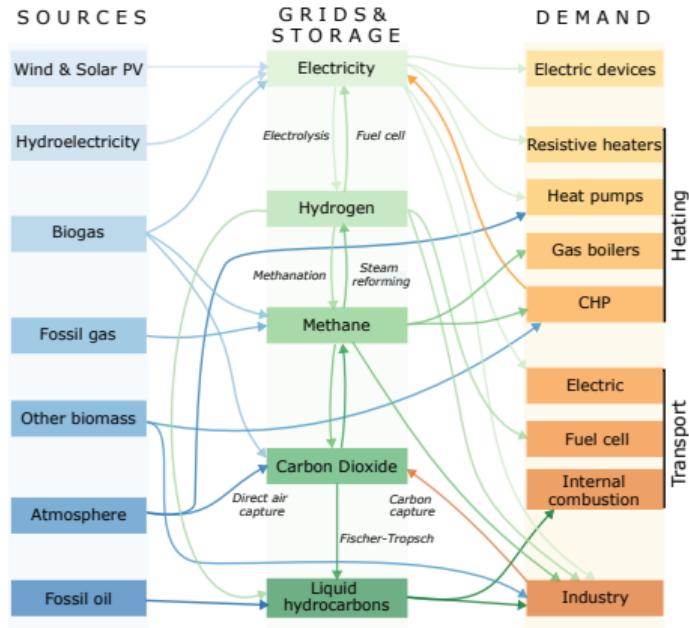
## Map of projects



- 1 At what cost do we stick to the targets? How does a delay of PCI-PMI projects affect the system?
  - 2 What is the impact of missing the EU 2030 policy targets for CO<sub>2</sub> sequestration and H<sub>2</sub> production?

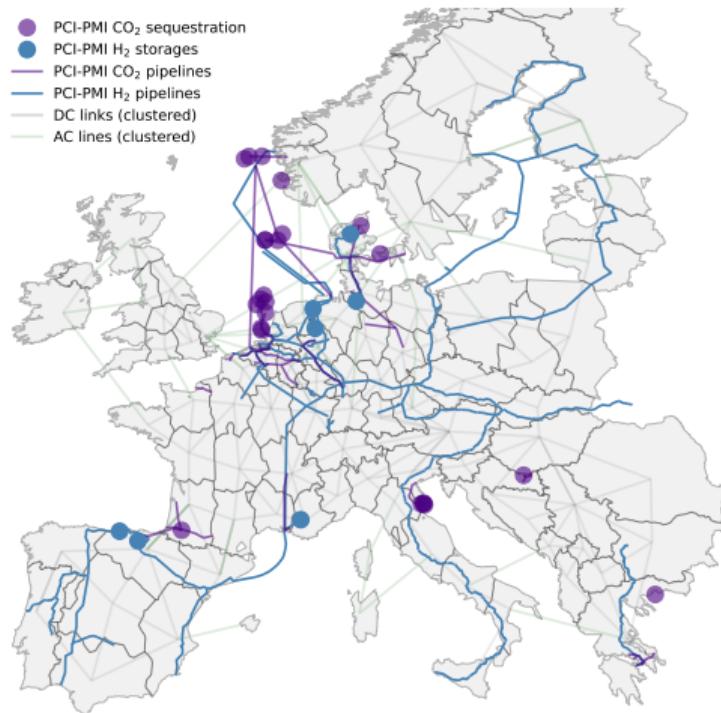
# Case study: Model setup

- Including sectors **power, heat, transport, industry, feedstock** and **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 **policy targets**:
  - 55 % emission reduction (**Fit for 55**)
  - 10 Mt p.a. production of hydrogen (**REPowerEU**)
  - 50 Mt p.a. of CO<sub>2</sub> sequestration (**Net-Zero Industry Act**)



# Case study: Overview of PCI-PMI H<sub>2</sub> and CO<sub>2</sub> infrastructure

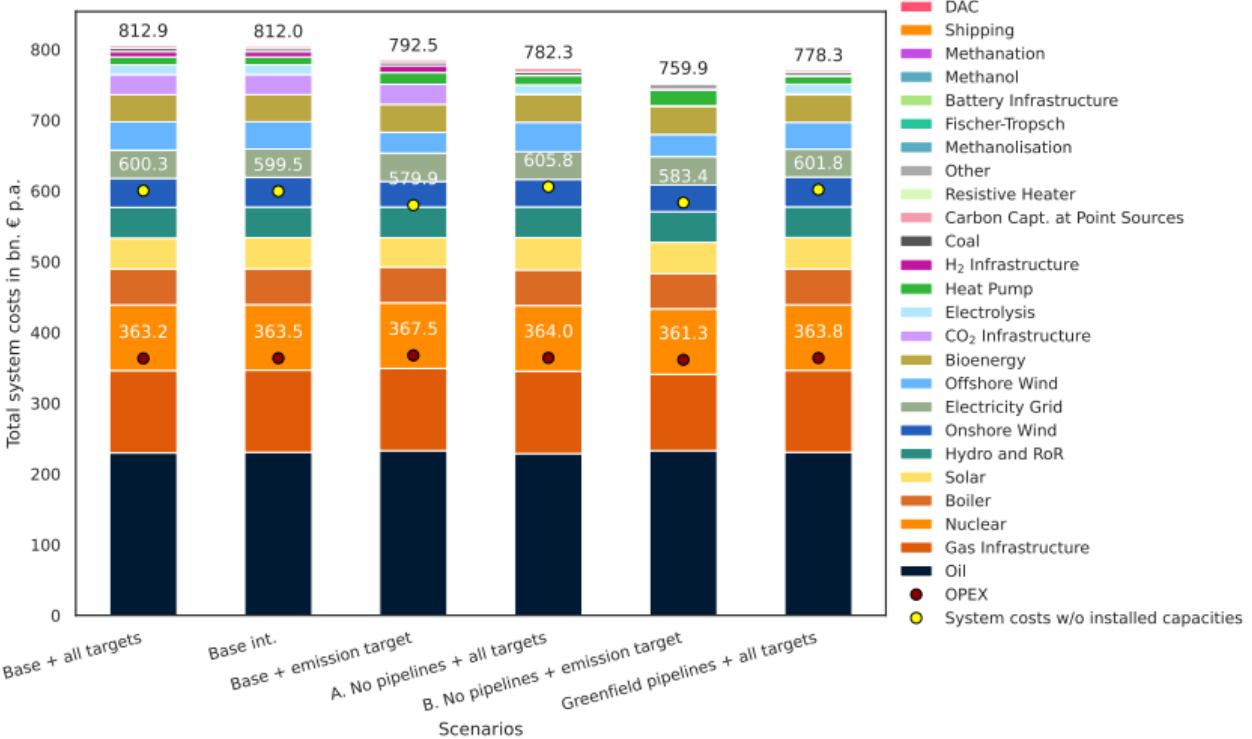
- Baseline scenario incorporates **PCI-PMI** projects for H<sub>2</sub> and CO<sub>2</sub> infrastructure, including pipelines, storages (H<sub>2</sub>) and sequestration sites (CO<sub>2</sub>), commissioned by 2030
- Total CO<sub>2</sub> sequestration capacity sums up to **75 Mt p.a.**, mostly located in the North Sea
- Total H<sub>2</sub> storage capacity sums up to **977 GWh<sub>H2</sub> p.a.**



Source: Own illustration based on data extracted from  
[https://ec.europa.eu/energy/infrastructure/transparency\\_platform/map-viewer](https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer)

# Case study: First results – Total system costs

■ test



Source: Own illustration based on first results

# Case study: First takeaways for modelling year 2030

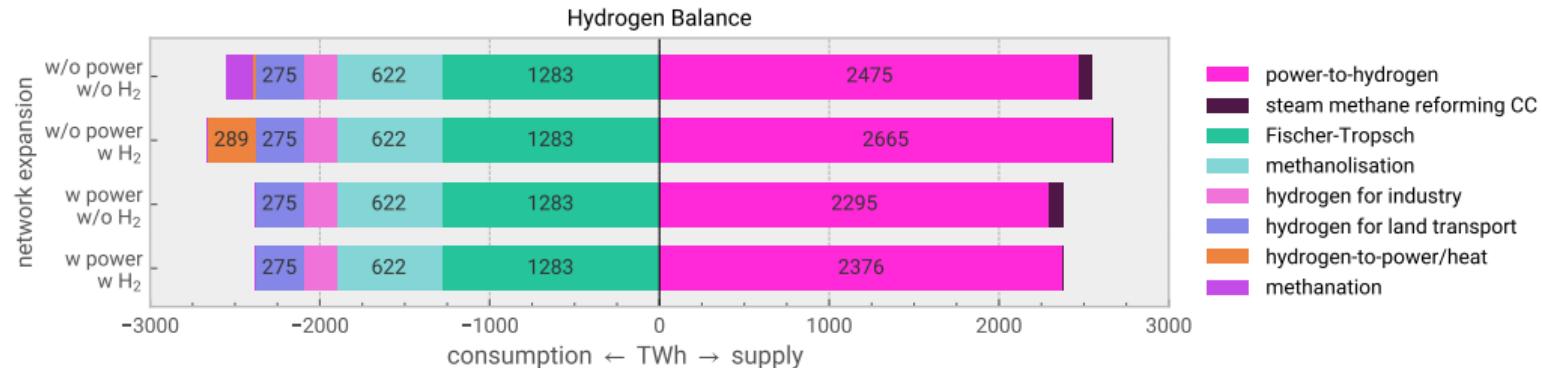
- 1 Reaching the 2030 EU targets translates into around 20 bn. € p.a. in total system costs for all included sectors
- 2 By omitting a H<sub>2</sub> target, almost no electrolyzers are installed and hydrogen is produced. Industrial hydrogen demand is then met by decentral steam methane reforming (SMR).
- 3 With a potential delay of all planned PCI-PMI H<sub>2</sub> and CO<sub>2</sub> infrastructure projects, all three **EU policy targets for 2030 can still be achieved**, however with some implications
- 4 PCI-PMI H<sub>2</sub> pipelines help distribute more **affordable green hydrogen** from northern and south-western Europe to high-demand regions central Europe

# Outlook

- Add all PCI-PMI projects, including hybrid offshore interconnection projects (energy islands), electricity storages, etc.
- Look at the long-term role of PCI-PMI projects in the European energy system.

# Appendix

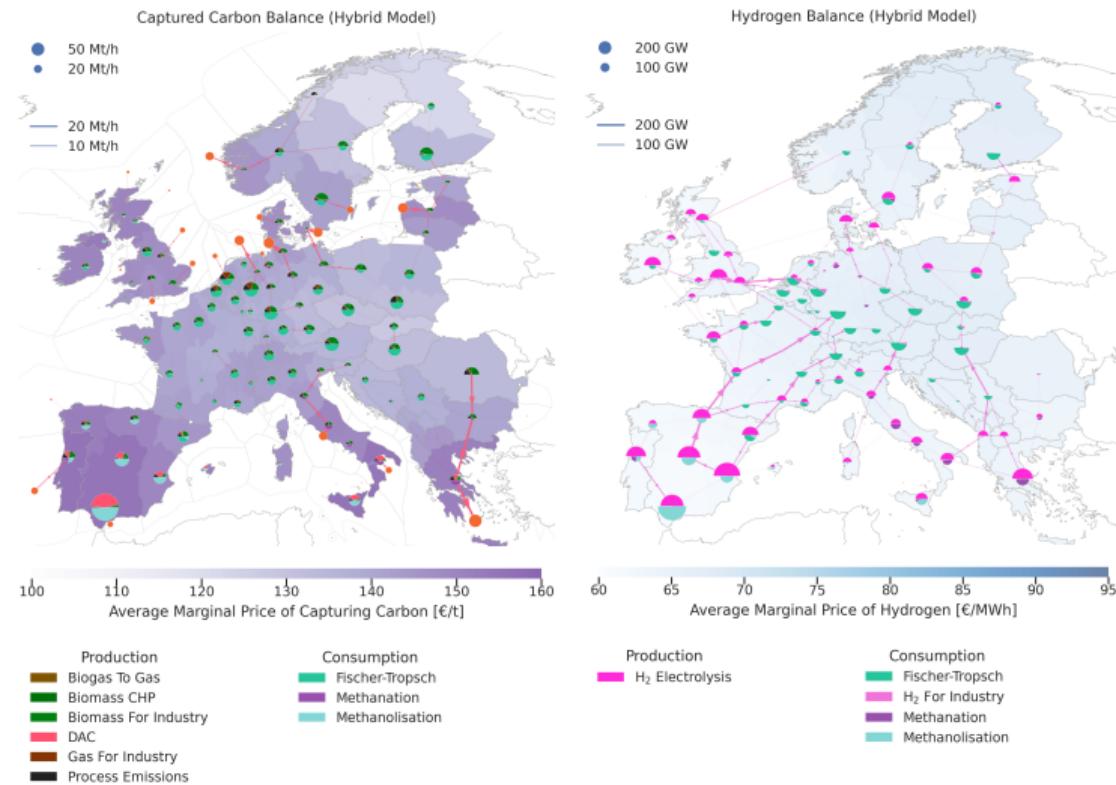
# Why H<sub>2</sub>? Most H<sub>2</sub> is used for derivative fuels and chemicals!



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

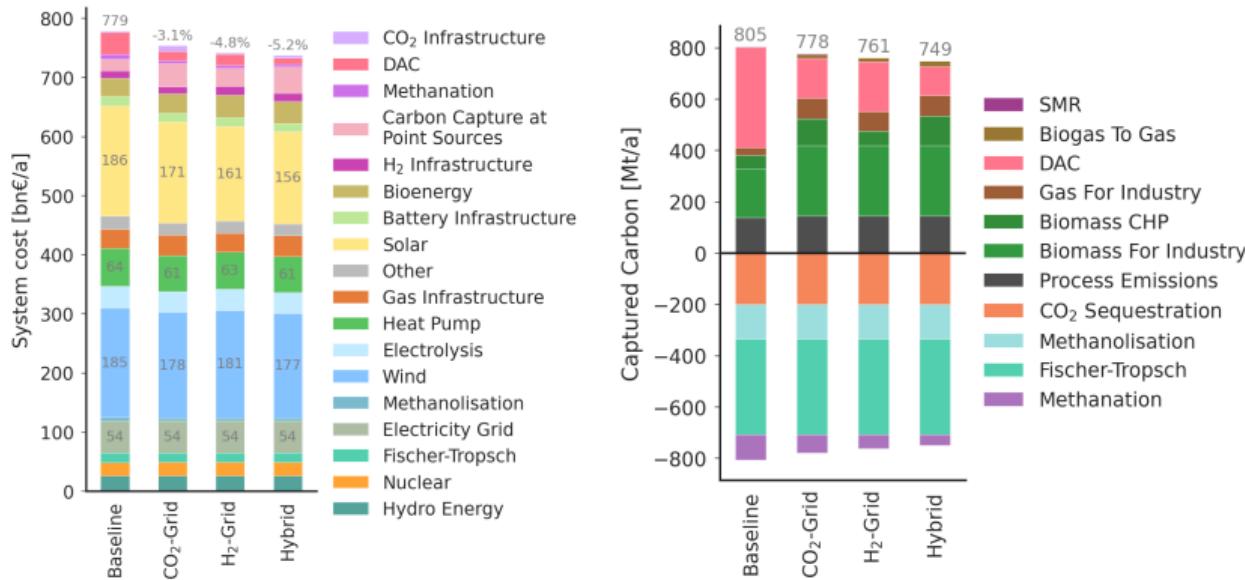
- ammonia for fertilizers
- direct reduced iron for steelmaking
- shipping and aviation fuels
- precursor to high-value chemicals
- backup heat and power supply
- some heavy duty land transport

# Transporting CO<sub>2</sub> to H<sub>2</sub> or transporting H<sub>2</sub> to CO<sub>2</sub>?



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

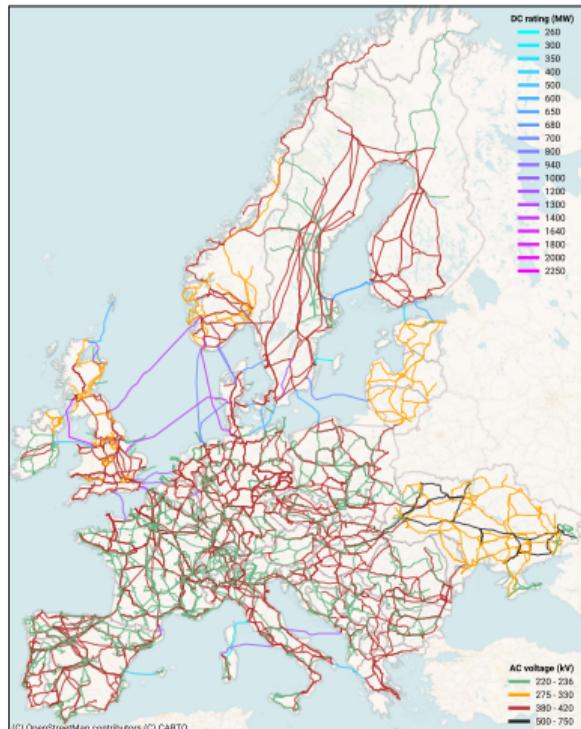
# Carbon management: Capture, use, transport and sequestration



- 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)

# 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 from  
[https://ec.europa.eu/energy/infrastructure/transparency\\_platform/map-viewer](https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer)