Rasmus Bramstoft, SuperP2G, 30/03/2023

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European hydrogen analysis North vs. South
using the Balmorel model

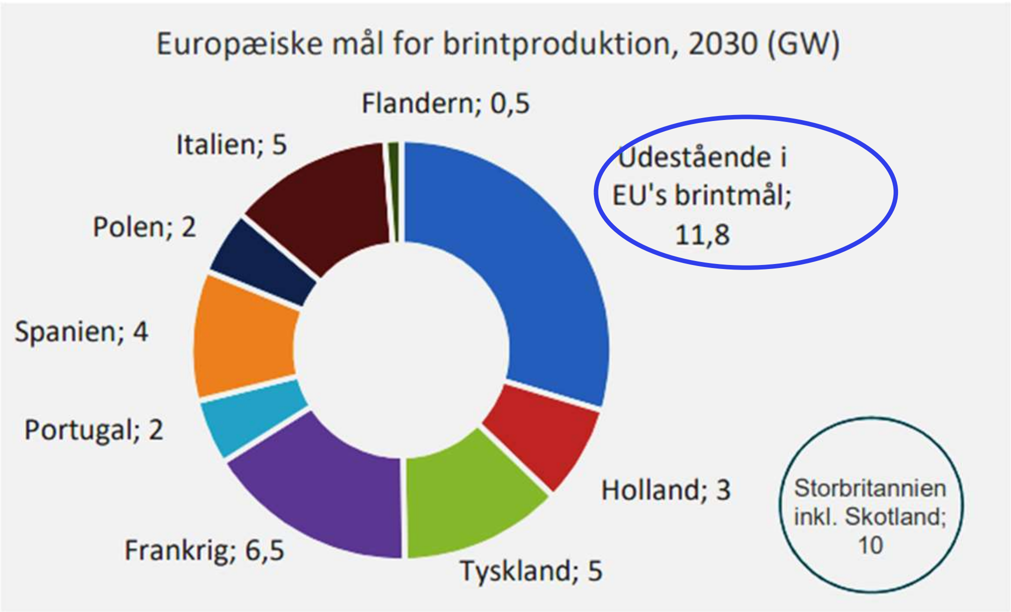
Agenda

Hydrogen Production in a European Energy System Perspective

- Motivation: EU targets
- Data: Hydrogen backbone
- Results: Hydrogen infrastructure, Capacities
- Conclusions

Motivation:

Fit 55 package, by 2030 ***40GW***, December 2021



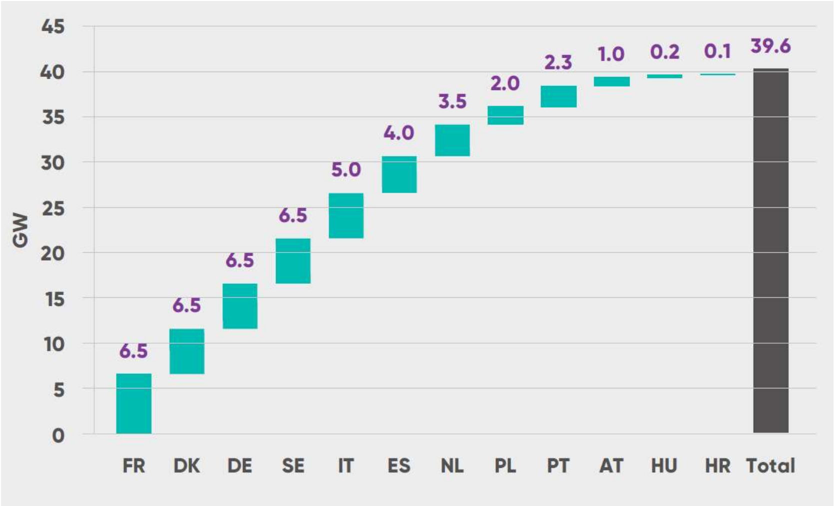
Source: Regeringens Strategi for POWER-TO-X, 2021

REPowerEU by 2030, March 2022

- **10 Mt** of annual domestic production and
- **10 Mt** of imports of renewable hydrogen
- Requires ***64 GW*** EU Electrolysis installed capacity

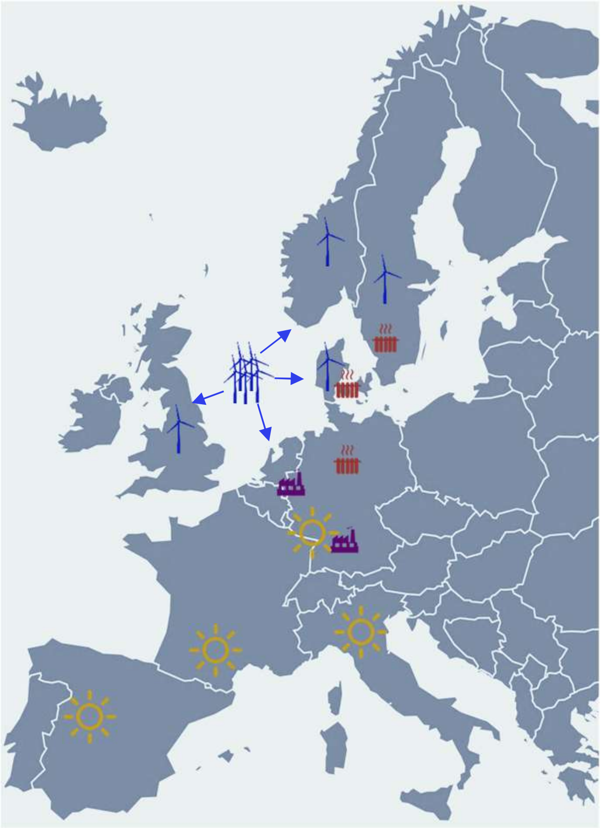
More and more ambitious targets!

Committed electrolyser capacity from EU national strategies by 2030 in the EU



Source: Clean Hydrogen monitor, 2022

Main investigation: Where/When to produce hydrogen (and electrofuels) in the future?



North European countries

- Large potentials for offshore and Cheap onshore wind
- District heating for excess heat(?)

Central and south European countries

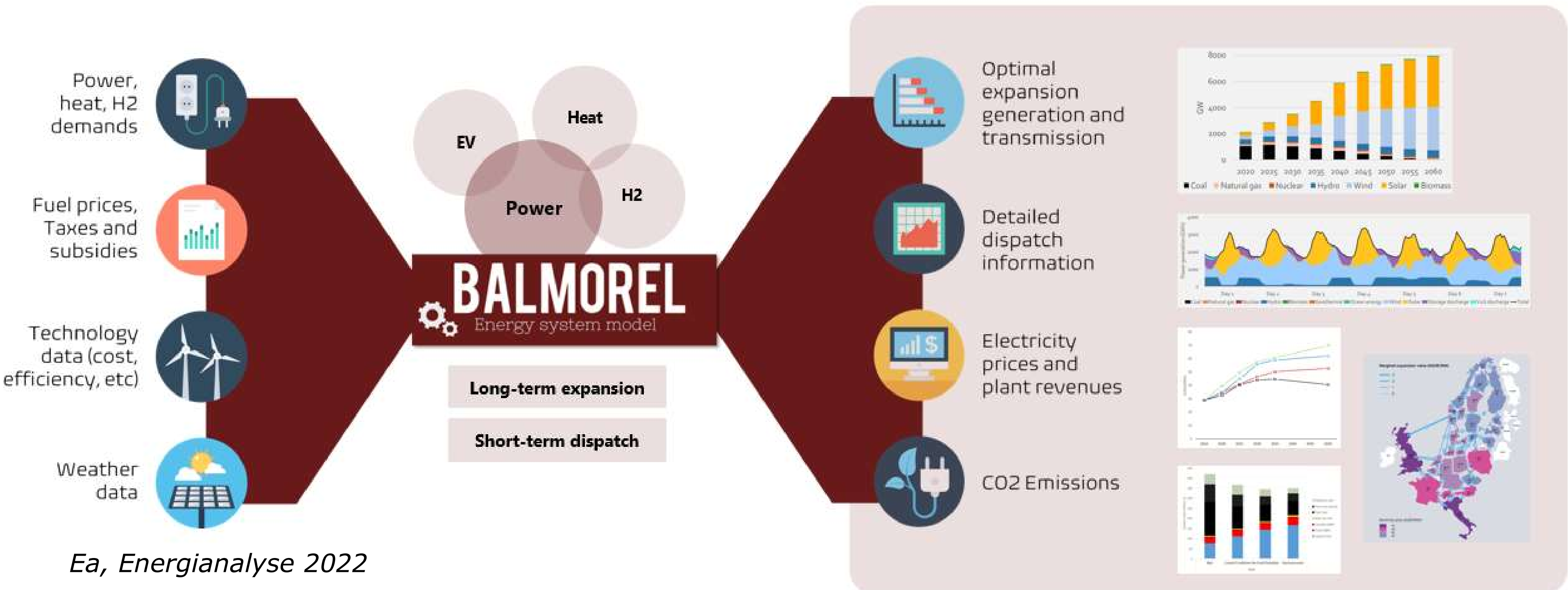
- Cheap solar PV
- Possible imports of H2 from MENA
- Repurpose and new grids (?)

Hydrogen infrastructure in the future?

What is the competition between blue and green hydrogen?

Required capacities for Self-sufficient EU?

Sector coupled energy systems analysis - Balmorel



Ea, Energianalyse 2022

Open source (GAMS based) * DTU course in June * www.balmorel.com

Scenarios

Base

H_2 production pathways:

H2 Import

Green H2 Europe

H_2 production pathways:

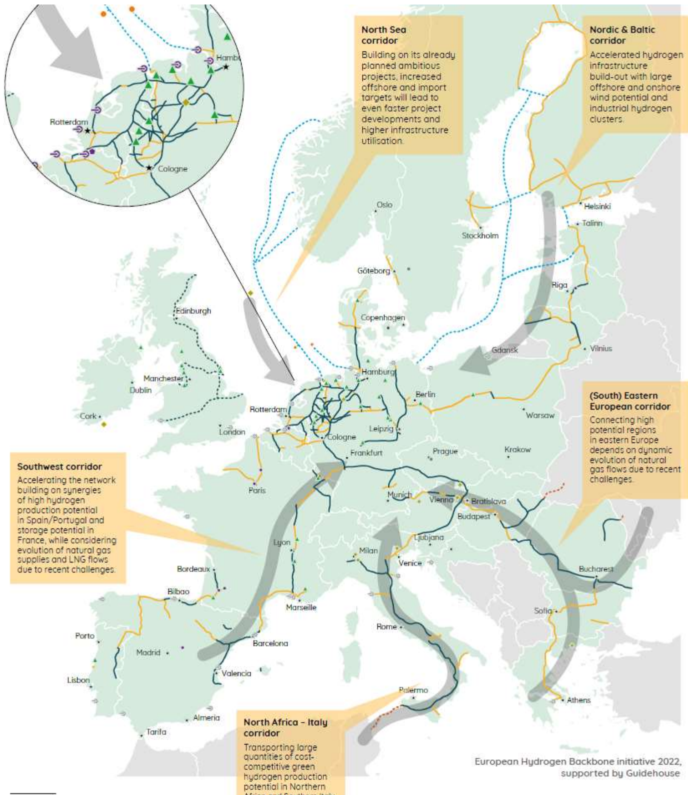
H2 Import

Self Sufficient EU

H_2 production pathways:

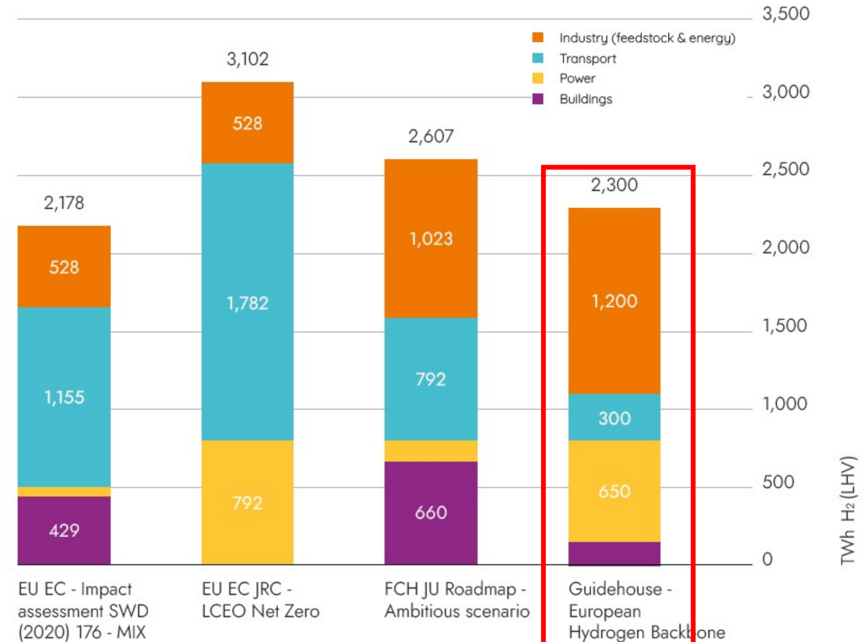
DATA: European Hydrogen BackBone (EHB) – 28 Gas TSOs

5 main corridors



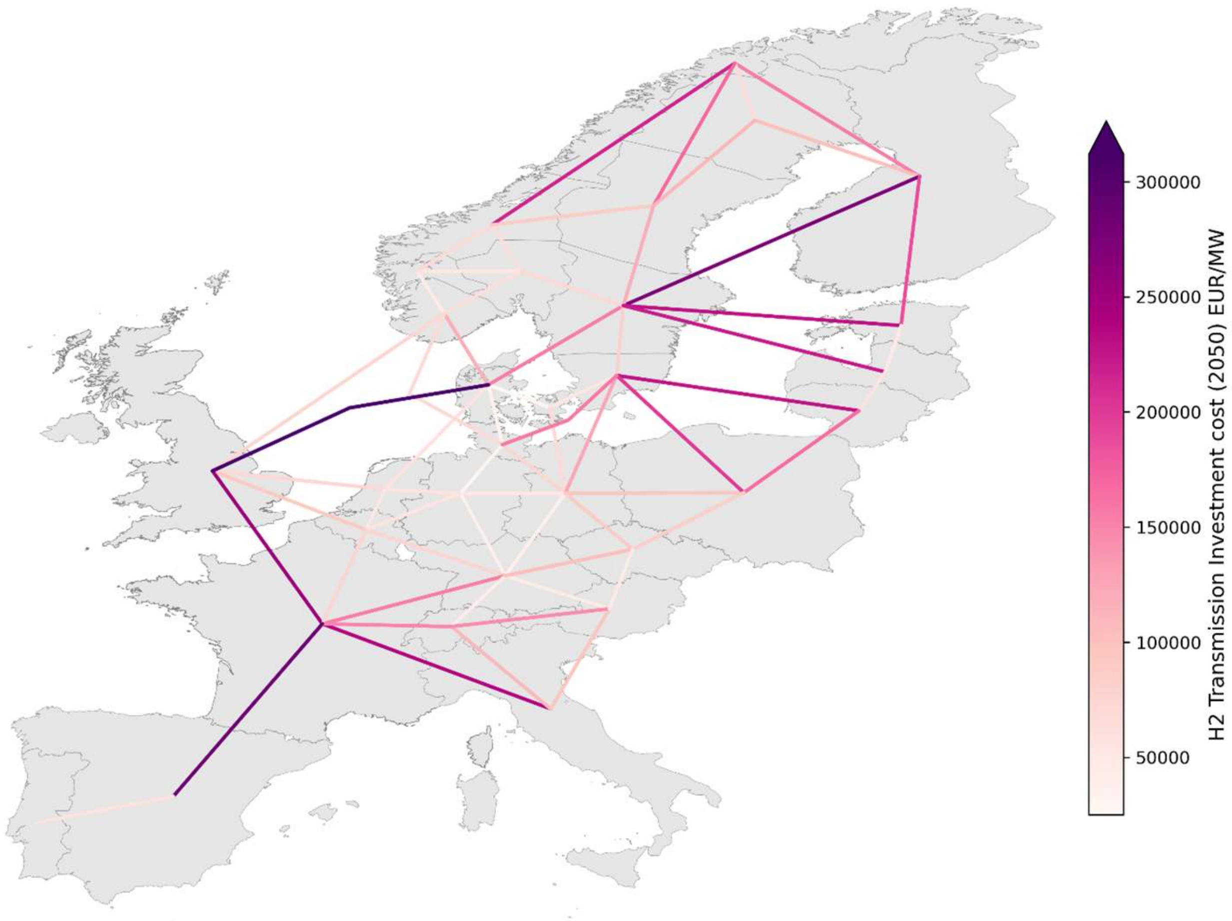
Source: A European Hydrogen infrastructure vision covering 28 countries, April 2022

2050 allocation



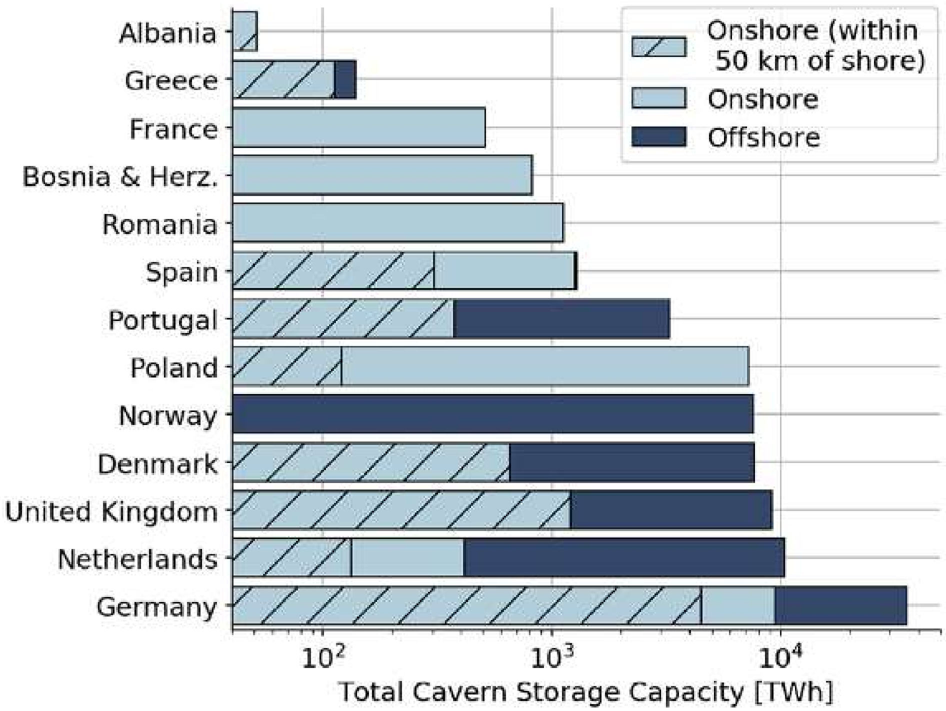
Source: Analysing future demand, supply, and transport of hydrogen, June 2021

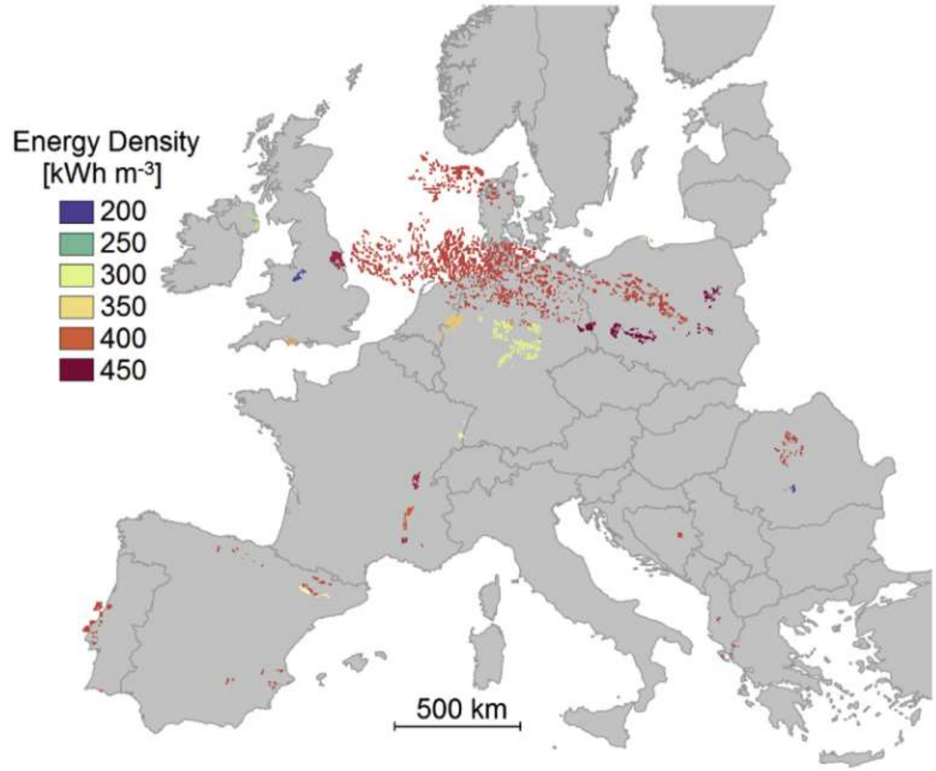
DATA: Hydrogen backbone report into Balmorel (2050)



- Costs for hydrogen transmission grids vary from 50,000 €/MW to 300,000 €/MW
- Depends on the length, status (off- or onshore), new or repurposed

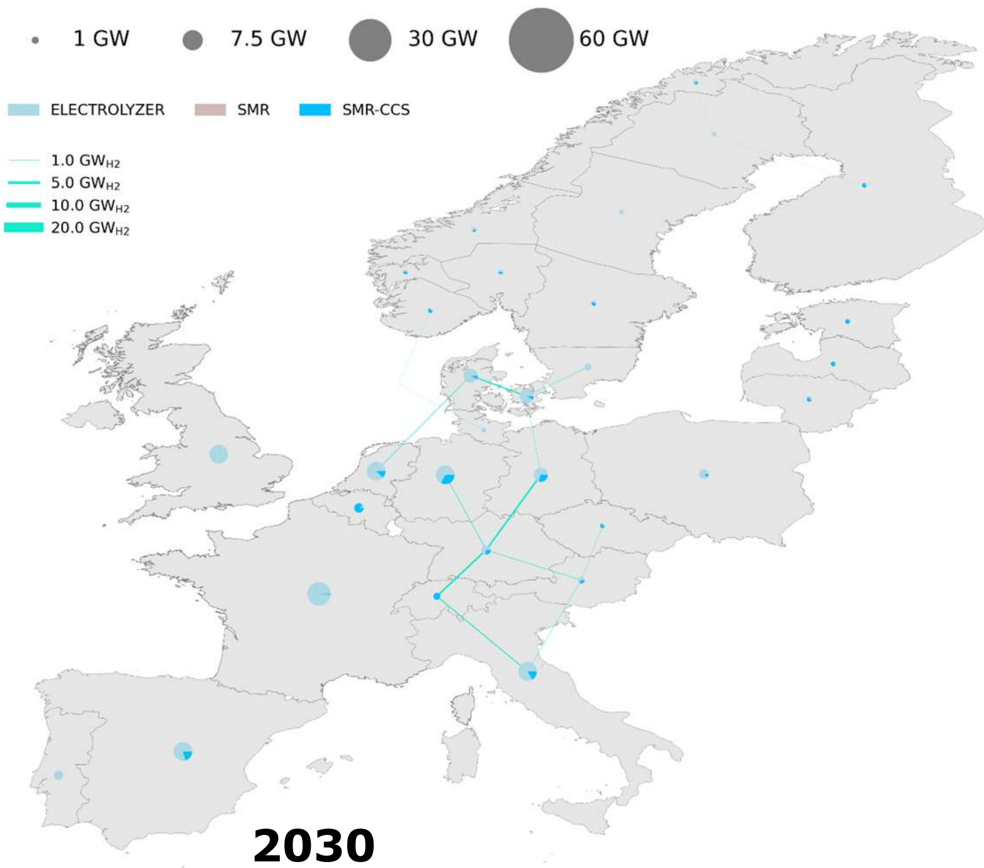
Caverns – spatial allocation and potential



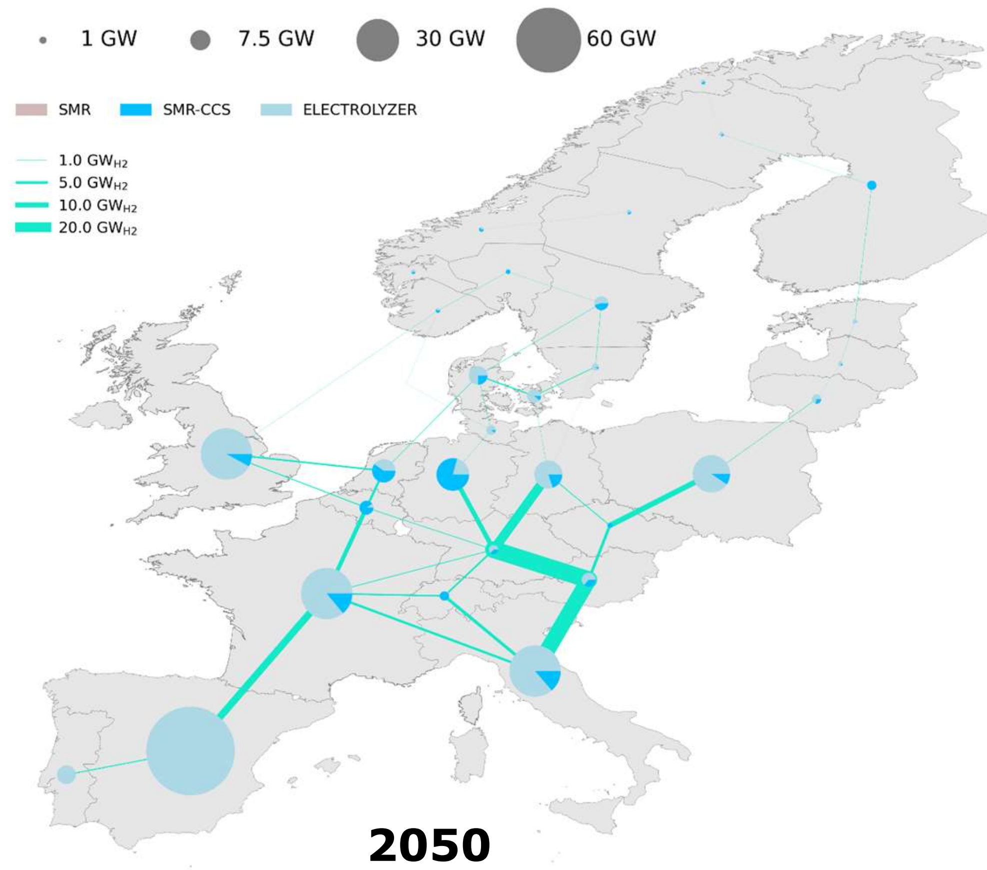


Caglayan et al. (2020)

Results: BASE - Where, when and how to produce H2?

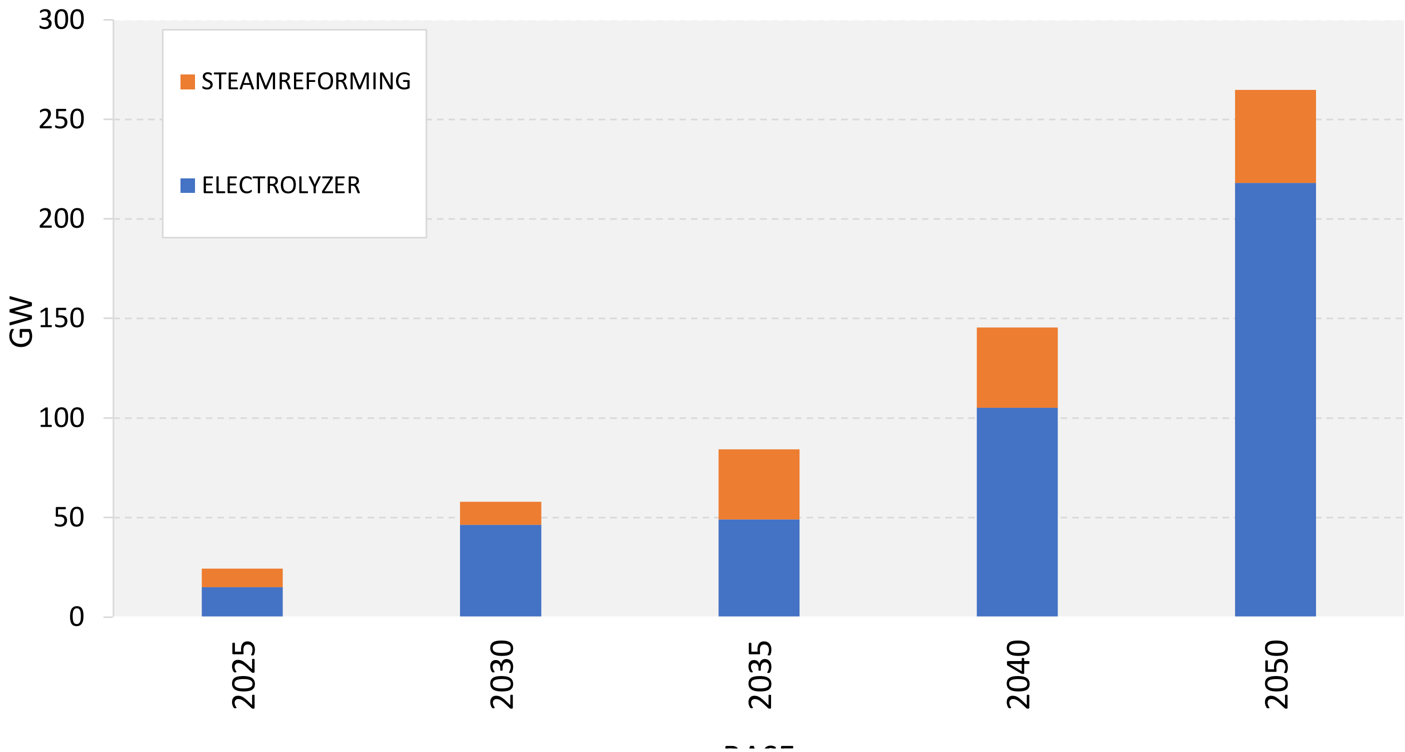


Demand: 337 TWh



1418 TWh

BASE: Hydrogen capacities - Electrolysis vs SMR-CCS

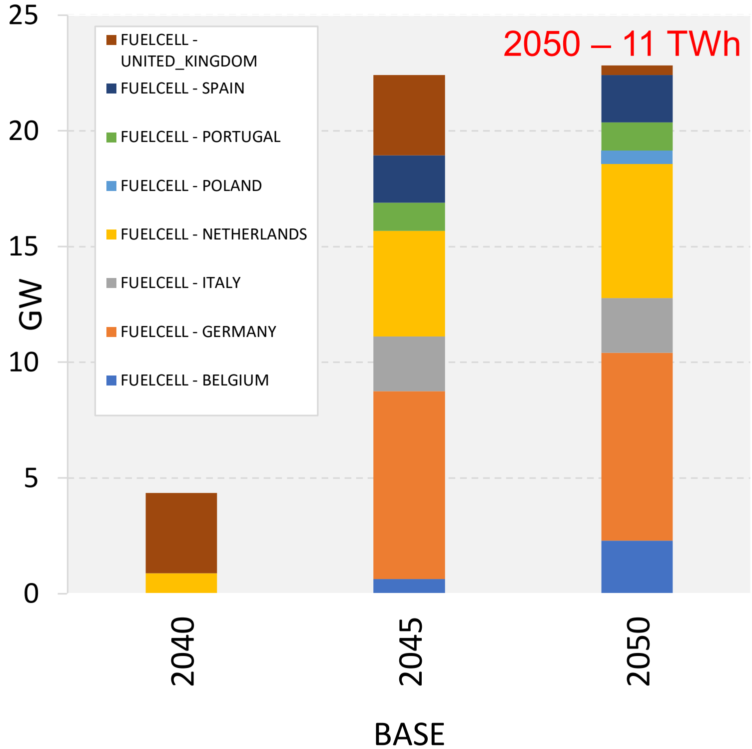


A large deployment of electrolysis capacities,

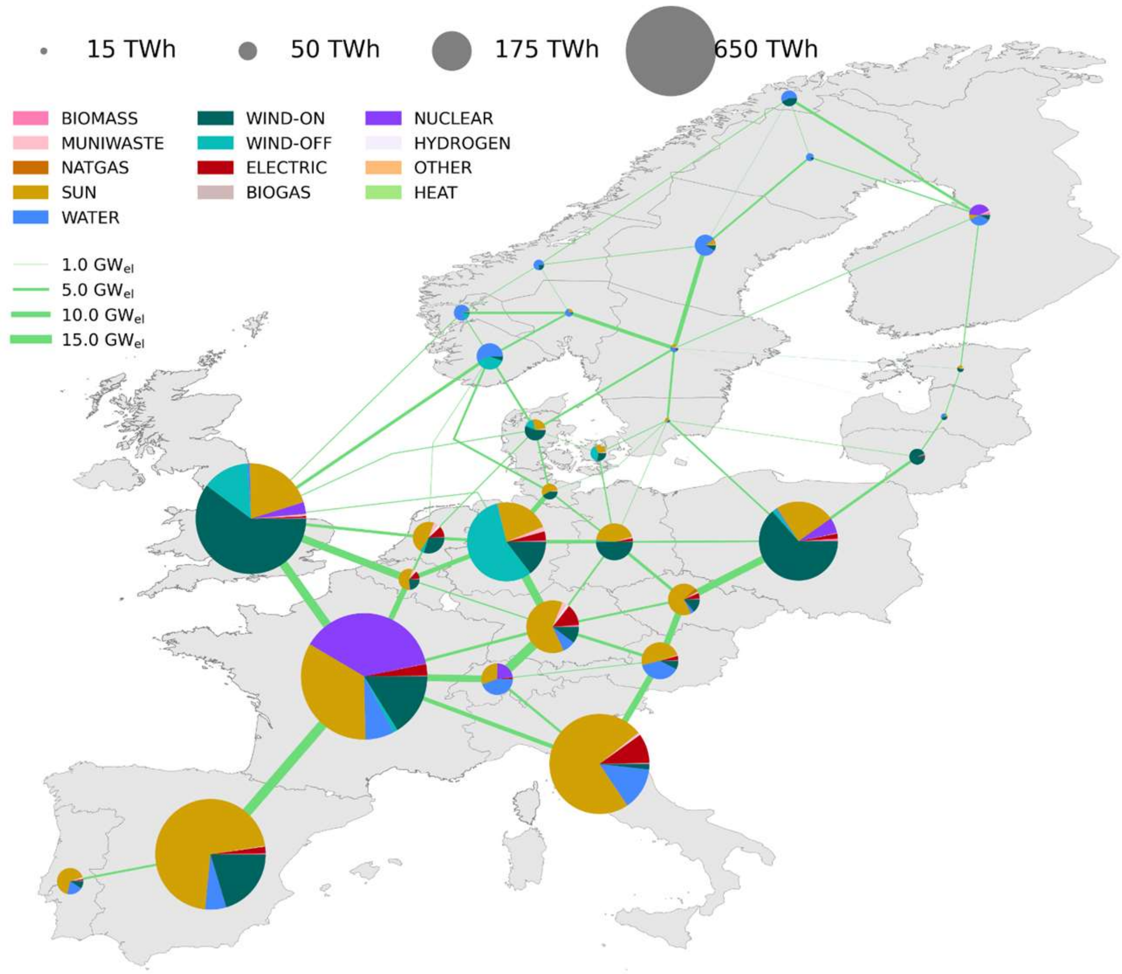
But: lock-in effects also into Steam methan reforming with CCS (blue hydrogen), especially from 2035 on

Strong demand for hydrogen and electrification from 2030 on, but: some of the renewable electricity production (less good locations) is not competitive with lower natural gas prices and SMR

Hydrogen to Power?

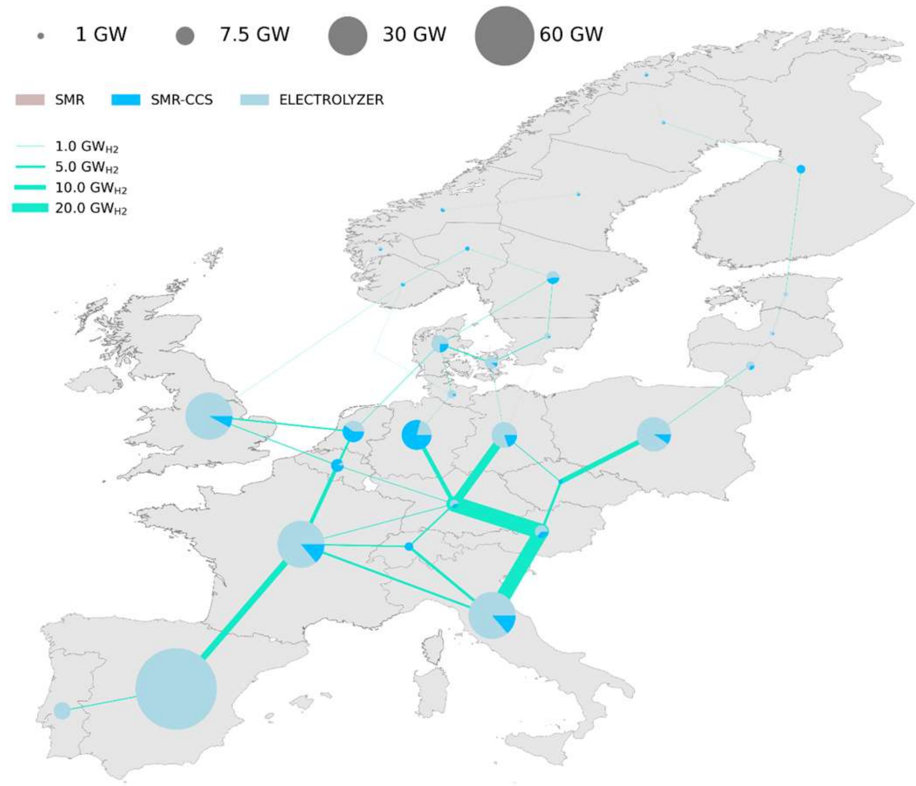


Electricity production mix (2050)

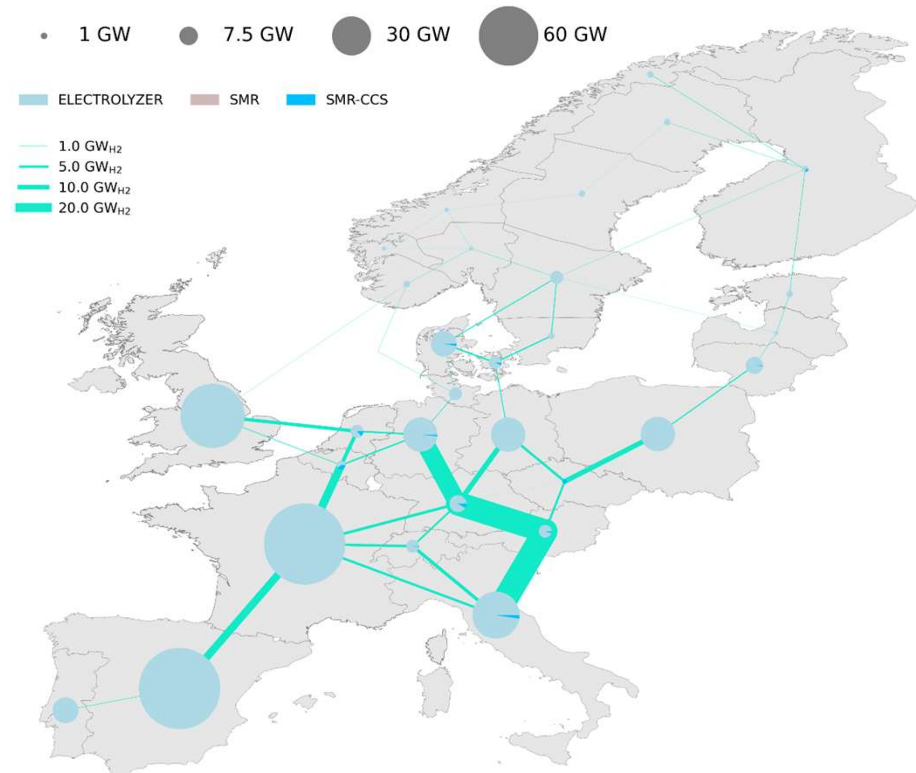


How could the energy system look without Hydrogen from SMR-CC? (2050)

Scenario: Base



Scenario: Green H2 Europe



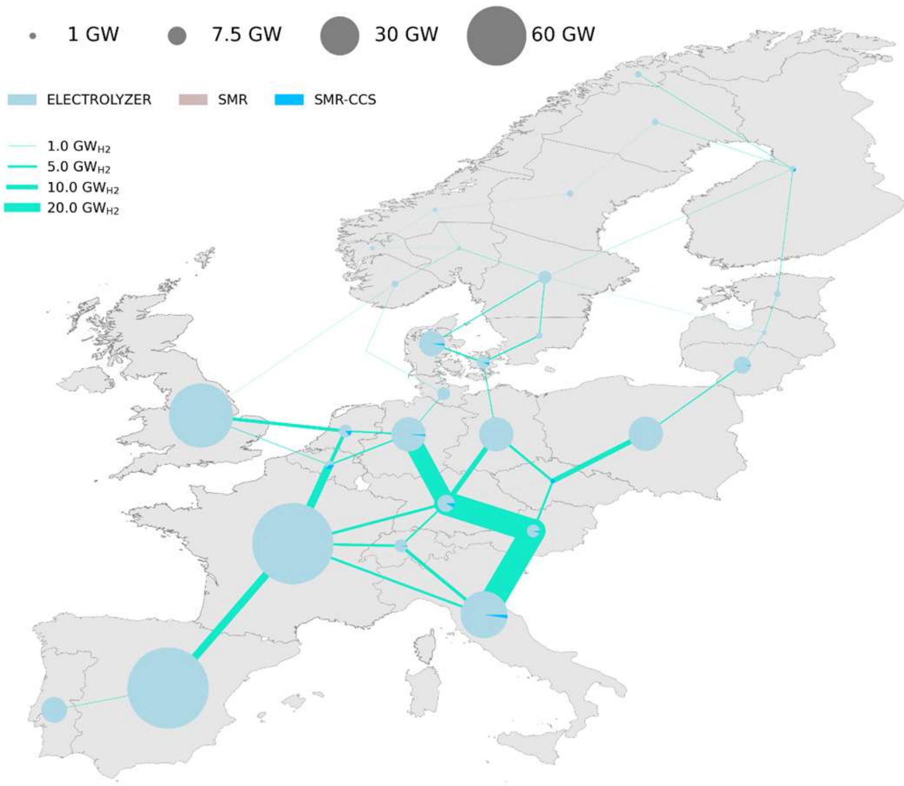
217 GW to 368 GW electrolysis for the same demand

Larger corridors, especially from Italy to Central Europe

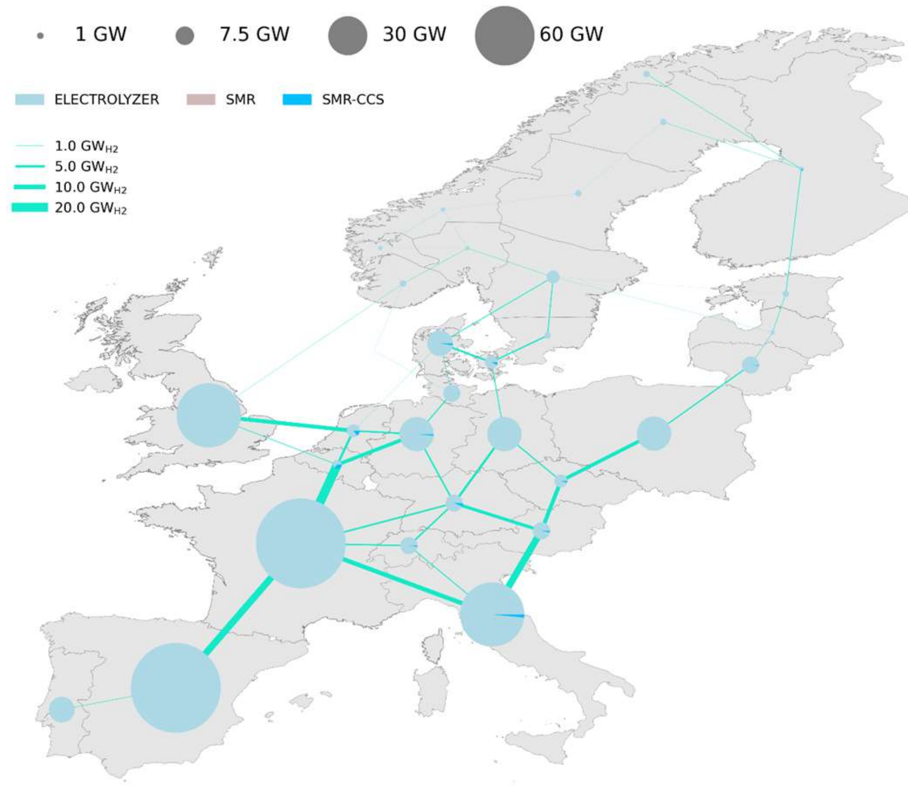
What could be the effect if not importing ? (2050)

368 GW to 424 GW Electrolysis, EU strategy 450GW for 2050

Scenario: Green H2 Europe

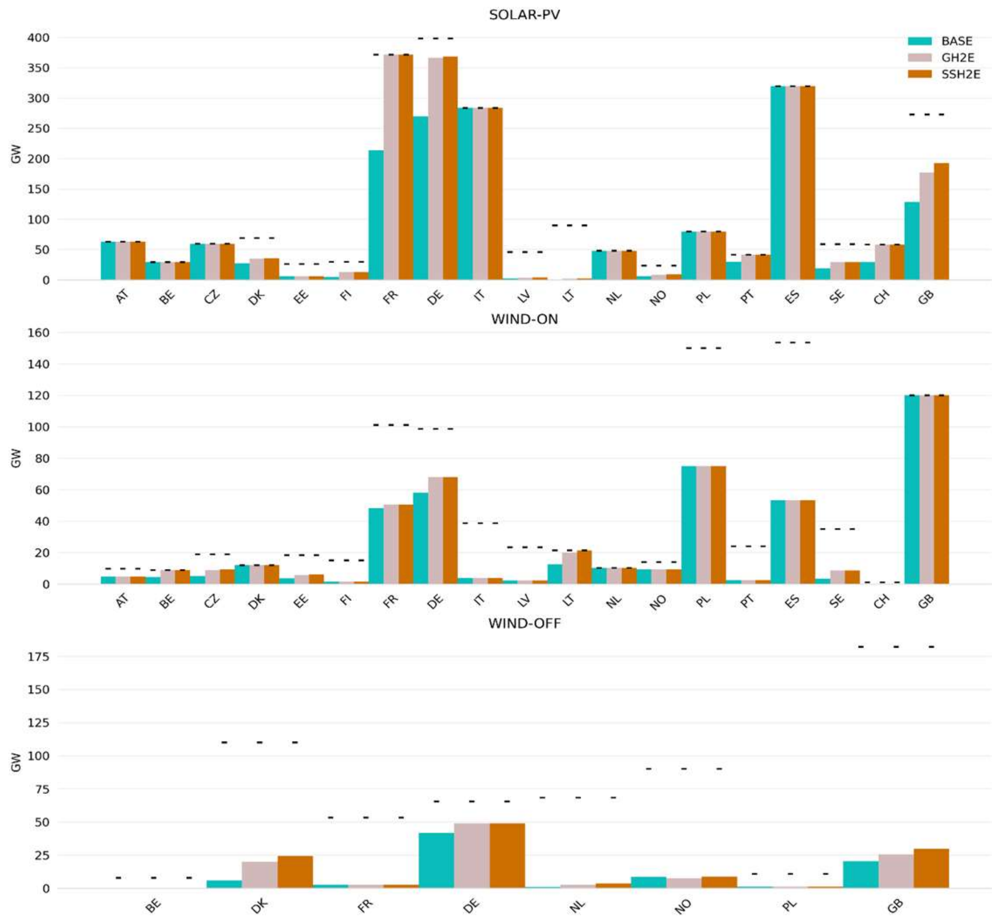


Scenario: Self-sufficient EU



Variable renewable investments (2050)

- Overall, our base scenario fully utilizes the good solar potentials. (ES, FR, IT).
- Integration of utility solar PV can heavily impact the future system.
- Ban of blue hydrogen heavily increases the deployment of offshore wind.



Conclusions

- **Large corridors from the South** to Central Europe, as solar power based hydrogen becomes very competitive, other corridors similar to the backbone report, except the Baltic

- Importing hydrogen from third countries leads to larger corridors from the South to Central, imports also cover peak demands
  Self-sufficient Europe: more **local production**, smaller corridors from the South needed

- Blue hydrogen can cause **lock-in effects** in the 2030ies and continue natural gas consumption

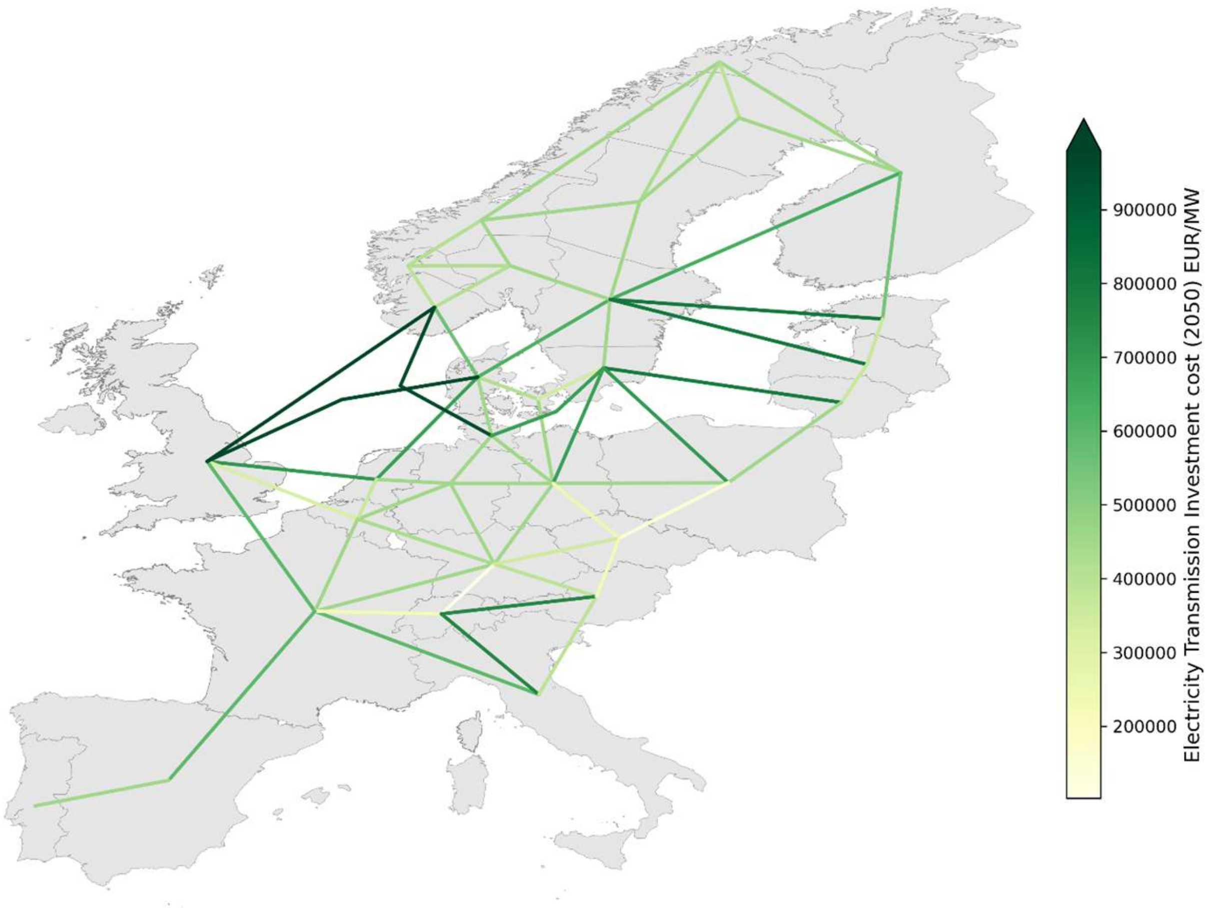
- **High hydrogen demands** to decarbonise the European energy system according to several hydrogen studies (EU Hydrogen backbone)

BACKUP

Scenarios

BASE	GH2E	SSH2E
- allows both, blue hydrogen and import of hydrogen - grey hydrogen is allowed, but exposed to high CO2 taxation/pricing CO2 price in 2030: 140 €/t, in 2050: 250 €/t (from WEO 2022 net-zero emissions scenario Natural gas price: 2025: 23 €/MWh 2050: 11 €/MWh	- Allows only green hydrogen deployment from 2030 on in EU and for imports - Other parameters the same as BASE	- Allows only green hydrogen deployment from 2030 on in EU + now imports allowed - Other parameters the same as BASE

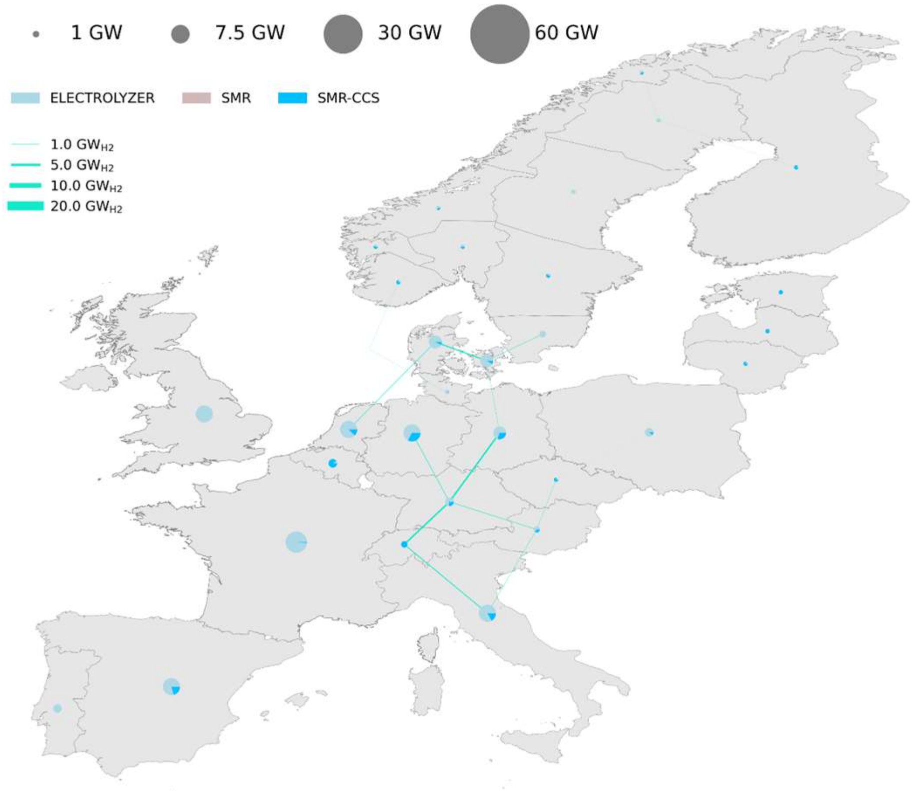
DATA: TNYDP projections into Balmorel (2050)



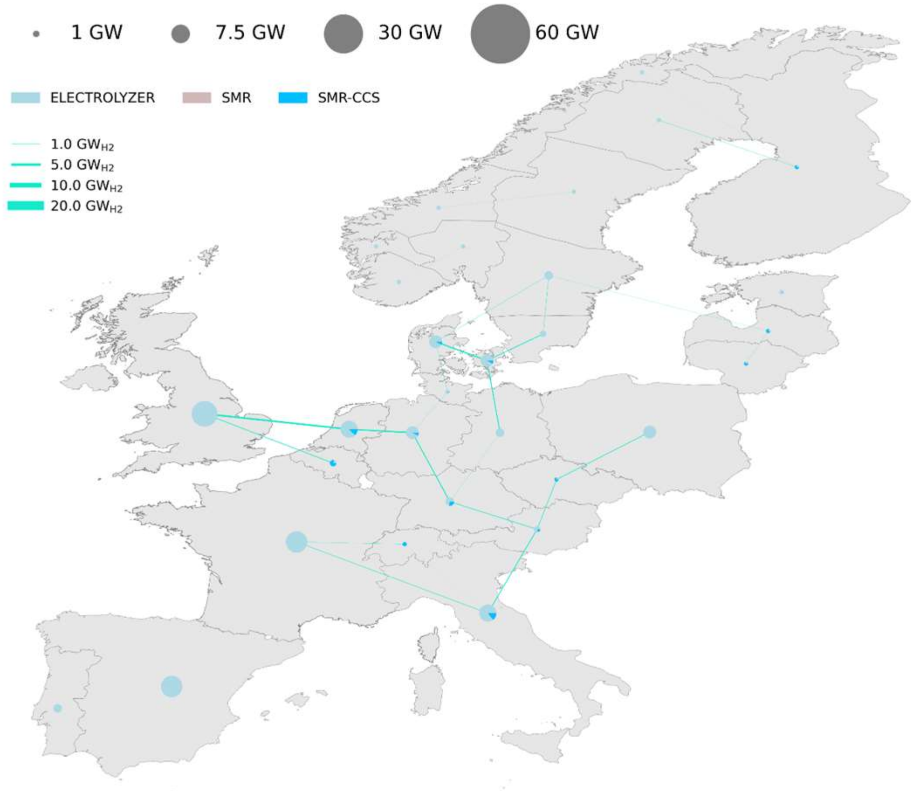
- Costs for hydrogen transmission grids vary from 200,000 €/MW to 900,000 €/MW
- Depends on the length, status (off- or onshore)

How could the energy system look without Hydrogen from SMR-CCS? (2030)

Scenario: Base

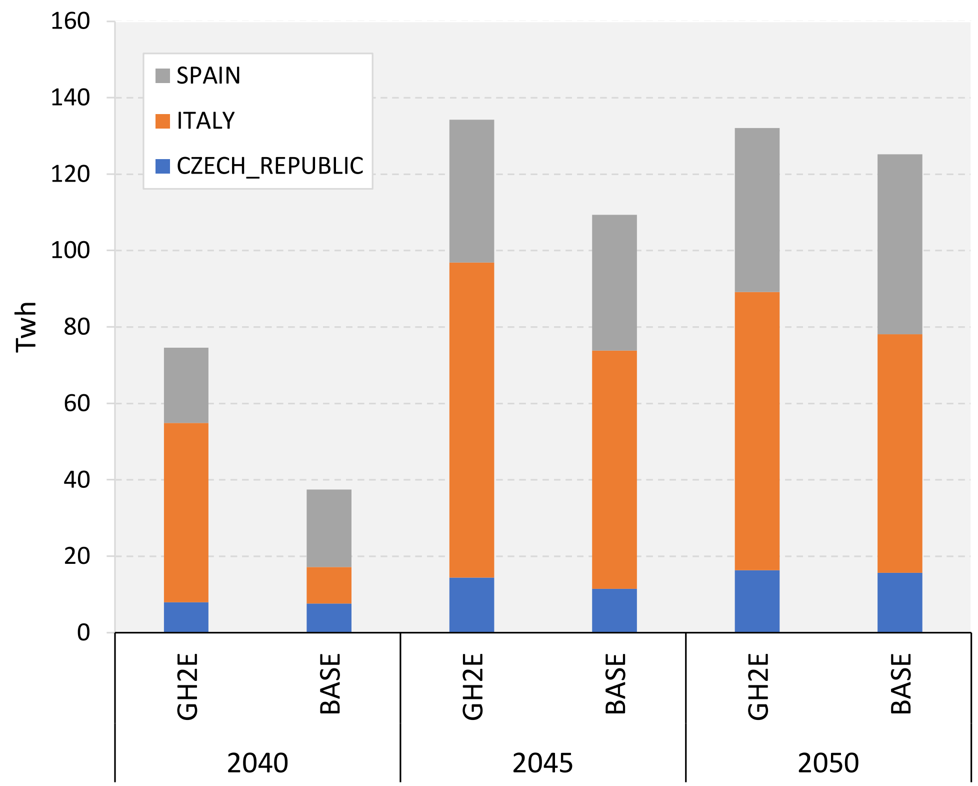


Scenario: GH2E



Imports from 3rd countries

1. The model uses a partial potential for importing. Sector coupling
2. Face out blue hydrogen leads to more importing.
3. Mainly imported from Italy for trading.
4. Imports from Spain balance are stored onsite and later traded.



Hydrogen Infrastructure across scenarios