Can Norway save the European Union's hydrogen ambition for 2030?

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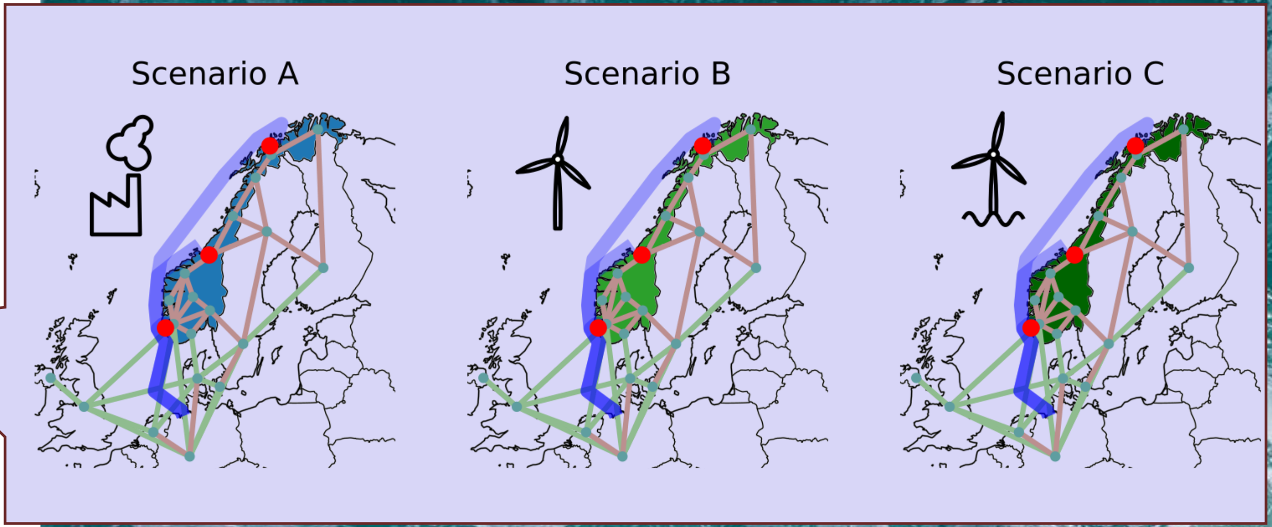
Why hydrogen from Norway for the EU?

The EU plans to import 10 million tons of (green) hydrogen by 2030 – next to producing 10 million tons themselves

- Norway currently exports 67% of its produced natural gas to the EU27
- Norway is ranked as one of the top ten potentially most competitive hydrogen exporters in the world
- Should Norway succeed in realising this potential, it would be able to maintain its economic growth despite a transition away from fossil fuel exports
- Potential pathways for upscaling hydrogen production in Norway
    - A: Business as usual – Blue hydrogen from Natural gas + SMR + CCS
    - B: Moderate onshore – Green hydrogen from onshore wind buildout
    - C: Accelerated offshore – Green hydrogen from offshore wind buildout



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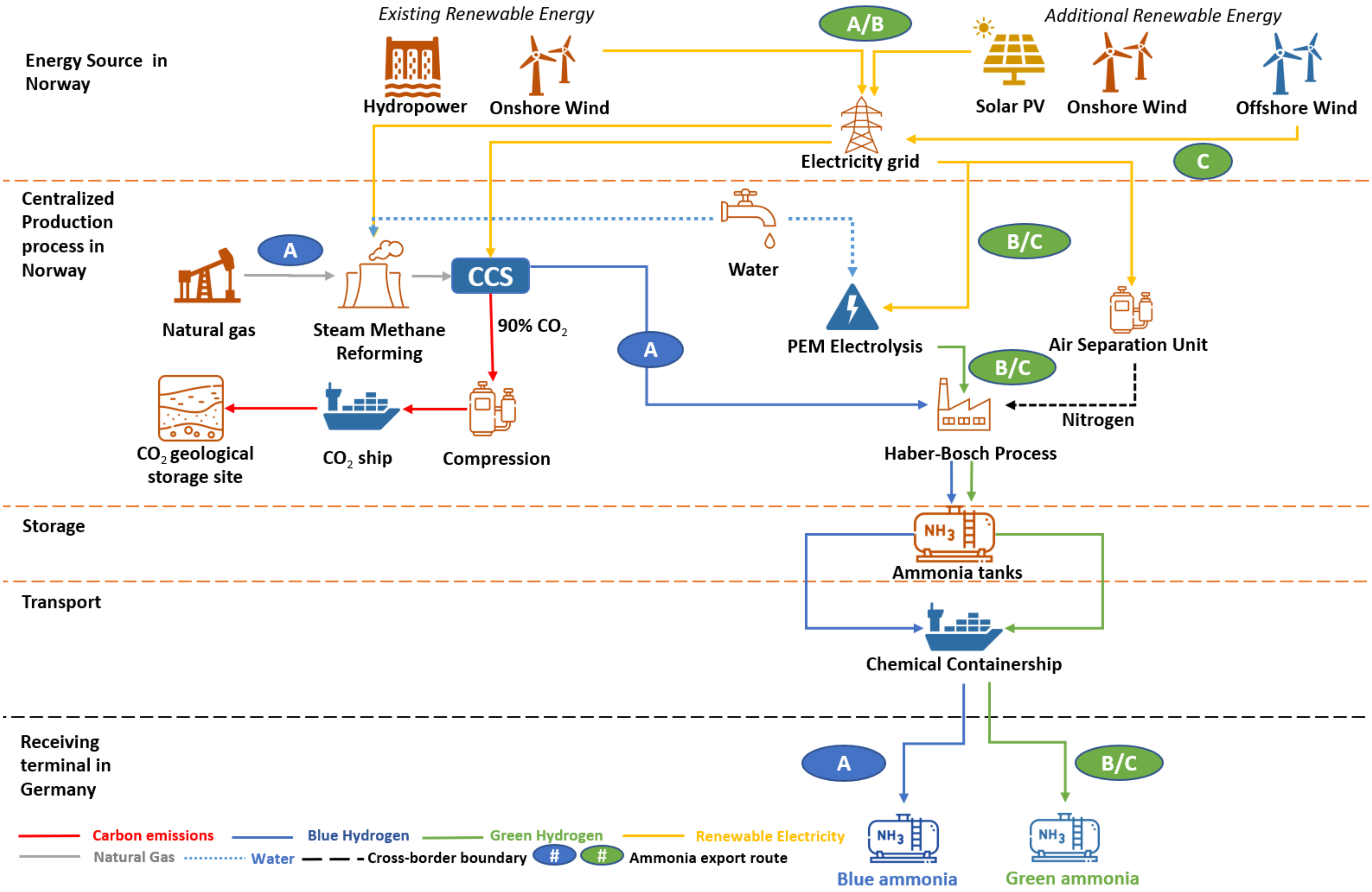
Research questions

C.S.W. Cheng, K. van Greevenbroek, I. Viole: Can Norway save the European Union's hydrogen ambition for 2030? Under preparation.

- How cost-competitively could Norway deliver 2 Mt of hydrogen/year to the EU by 2030?
- How would the export of low-carbon hydrogen from Norway to the EU affect the energy landscape in Norway in 2030?



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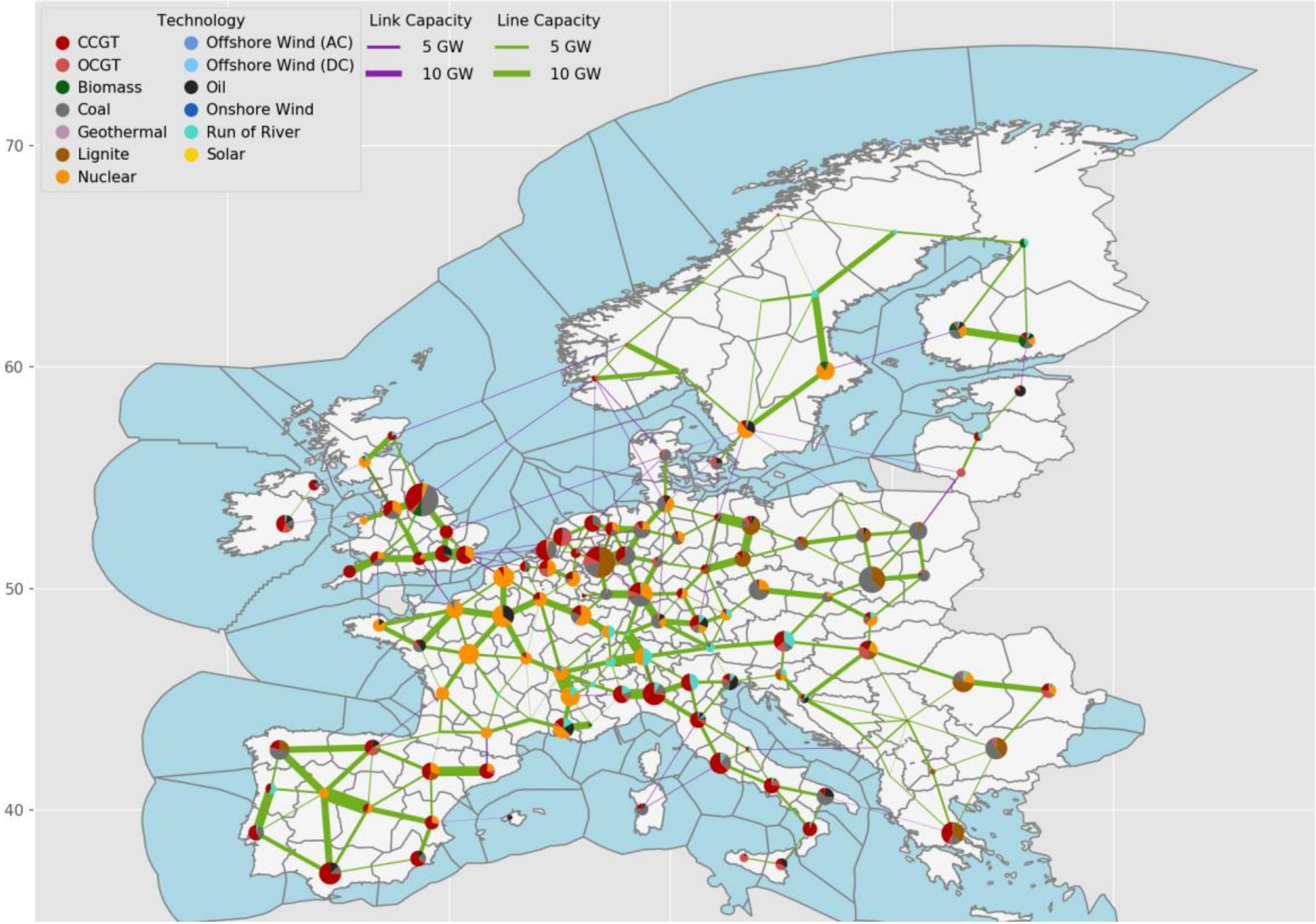
PyPSA-Eur: a capacity expansion model for the European energy system

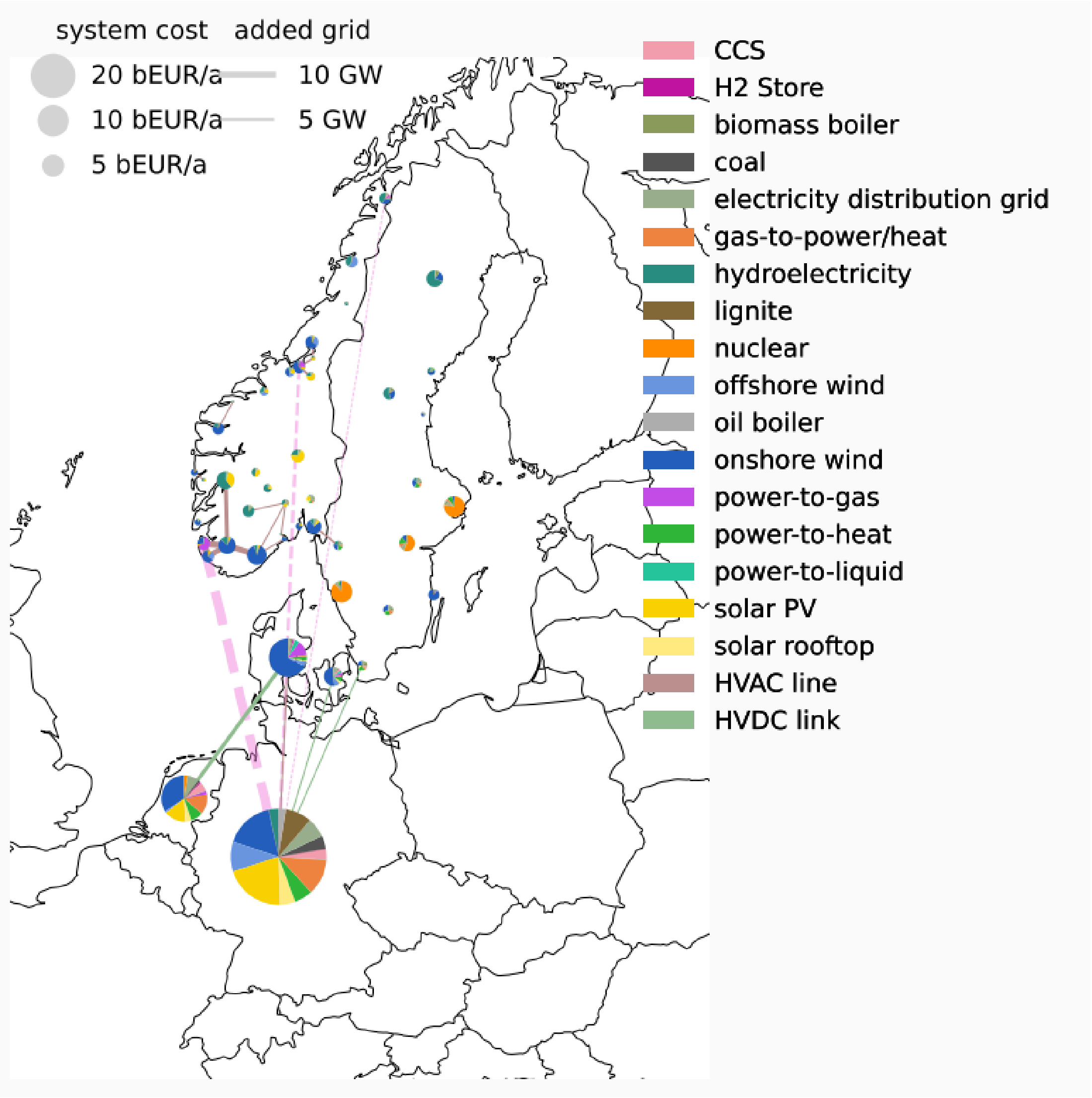
All



Model documentation: https://pypsa-eur.readthedocs.io/en/latest/introduction.html

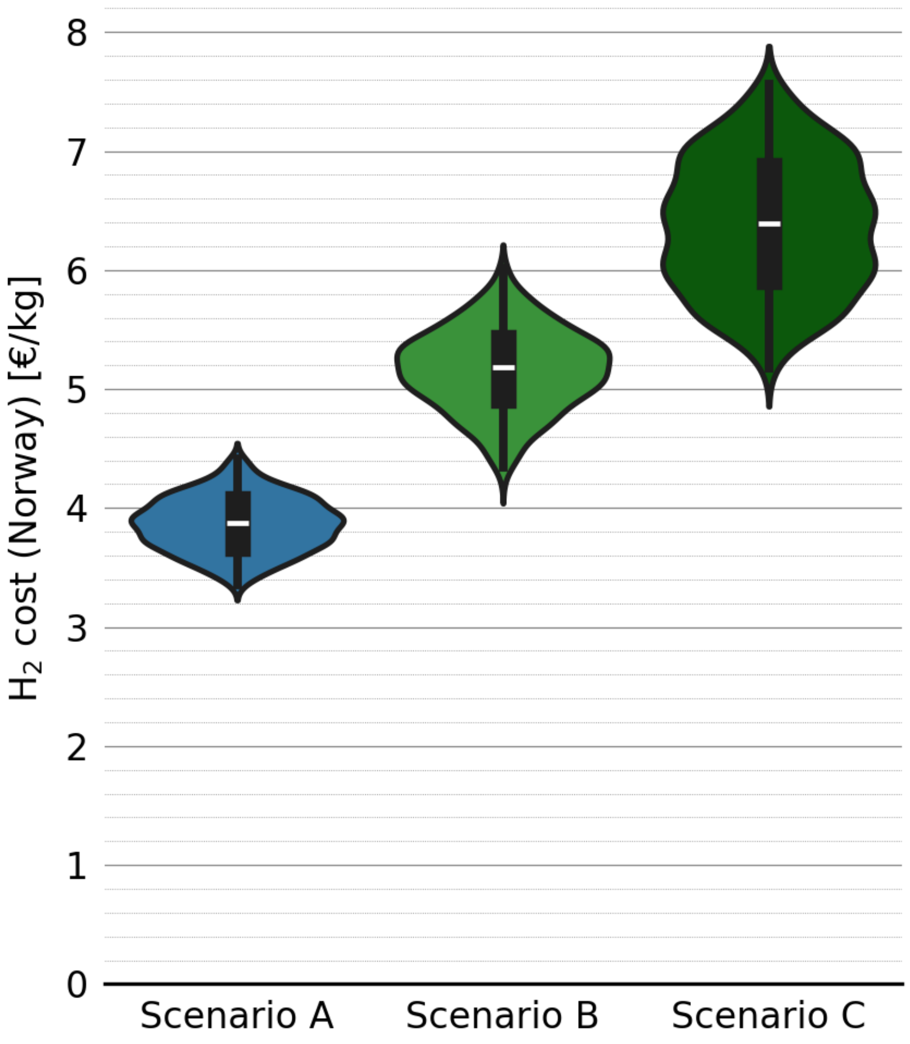
New components and linear constraints added to PyPSA-Eur

C



1. A new network bus with attached store/stockpile representing continental hydrogen demand, and three links from the Norwegian export hubs (Tromsø, Trondheim, Stavanger) to this bus.
2. A constraint forcing the hydrogen demand stockpile to be filled with the equivalent of 2 Mt of hydrogen (amounting to 66.7 TWh of ammonia in our case) by the end of the year.
3. A constraint forcing Norway to remain a net electricity exporter on a yearly basis.
4. In Scenario C, a constraint is added forcing total yearly Norwegian offshore wind production to match total yearly electrolysis electricity consumption.

Results: Blue hydrogen cheapest, offshore wind constraints lead to highest hydrogen costs

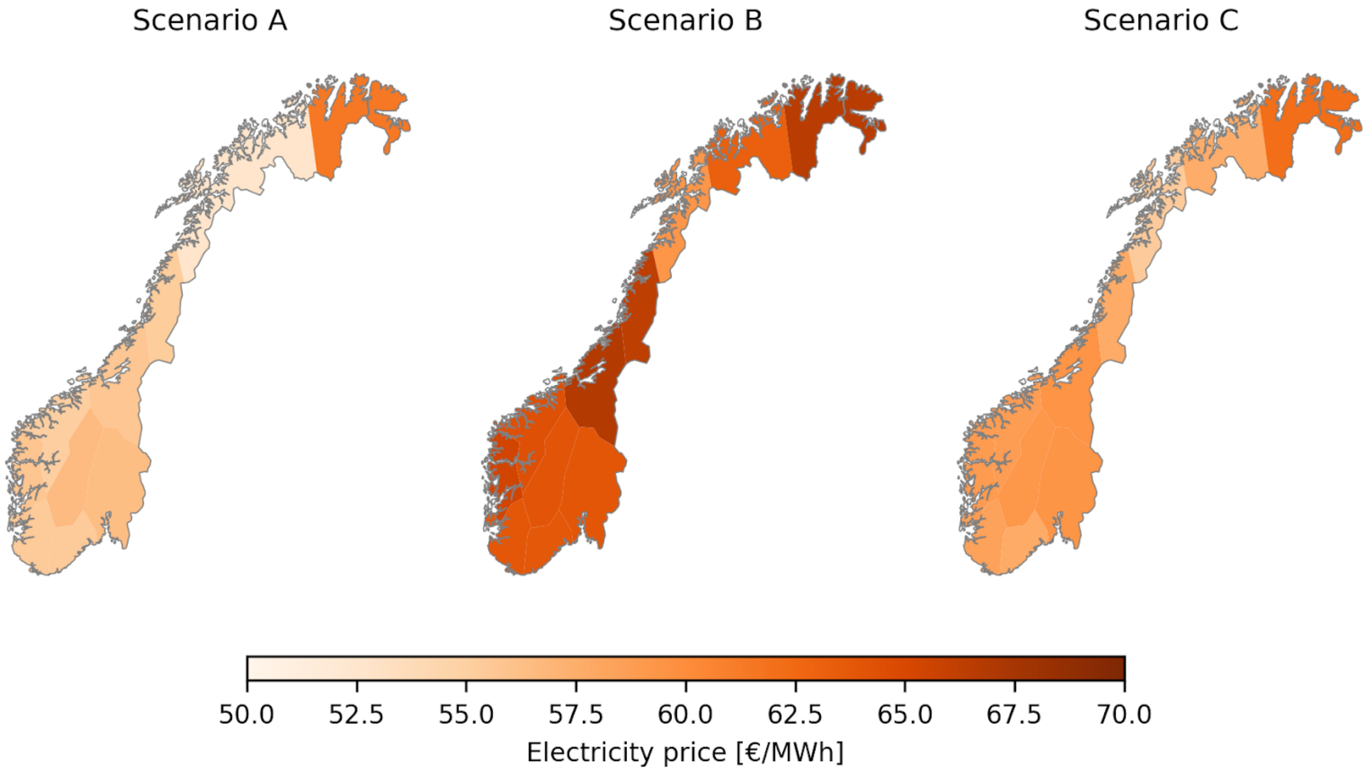


Distributions of levelised costs of Norwegian hydrogen seen across 500 model runs in each of the three Scenarios. These include production, conversion to ammonia and transportation and correspond to the figures in the second row of Table 3. The median costs are marked in white, and the 75^{th} and 95^{th} percentiles are marked with thick and thin black lines respectively. The coloured areas show kernel density estimations for the probability distributions of the costs.

Norway could be cost-competitive with other hydrogen supplying nations in 2030

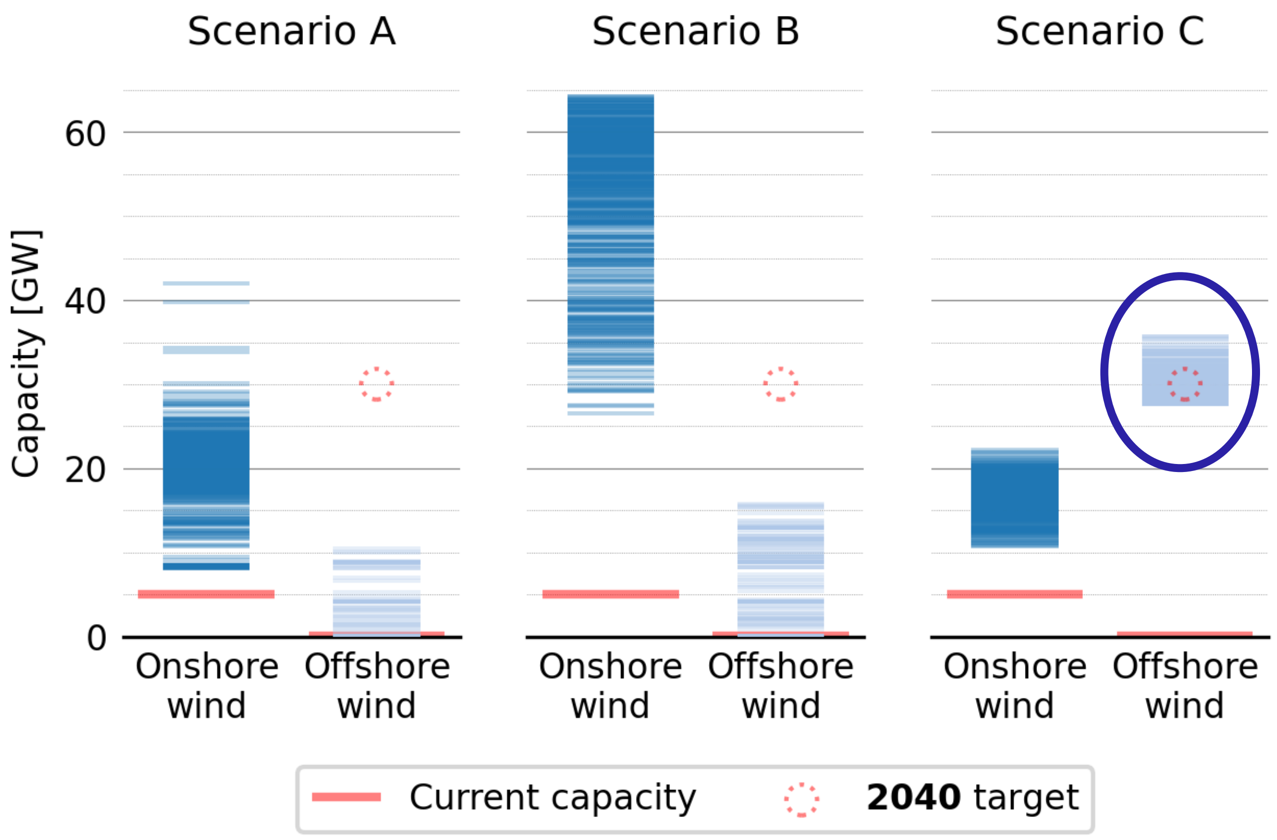
Origin	Transport medium	Production method	Hydrogen Production cost [€/kgH_2]	Cost of delivered hydrogen [€/kgH_2]
Norway[11]	Ammonia	Scenario A: SMR + CCS (90%)	2.05–2.63	3.50–4.27
	Ammonia	Scenario B: Elec.	2.95–3.83	4.61–5.72
	Ammonia	Scenario C: Elec. (offshore wind)	3.78–5.17	5.54–7.25
Western Canada[12] [14]	Ammonia	SMR + CCS (85%)	1.85	5.56
	Ammonia	Elec. (onshore wind)	2.68	6.39
Morocco [11]	H_2 pipeline	Elec. (onshore wind & solar)	1.59–3.07	3.54–5.71
Chile [11]	Liquid H_2	Elec. (onshore wind & solar)	1.29–2.53	2.67–4.47
Argentina [39][13]	Ammonia	Elec. (on- and offshore wind & solar)	-	2.72–4.02
Australia [39]	Ammonia	Elec. (on- and offshore wind & solar)	-	3.32–4.93

Effects on Norwegian energy landscape



- Especially Scenario B leads to increases in power prices
- Standard model run distributes burdens unevenly. Significantly more onshore wind development in southern Norway

Effects on Norwegian energy landscape



- Especially Scenario B leads to increases in power prices
- Standard model run distributes burdens unevenly. Significantly more onshore wind development in southern Norway
- Scenario C would require most of Norway’s planned offshore capacity for hydrogen production

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Norway could deliver 2 Mt hydrogen/year to the EU by 2030, BUT…

Scenario A

- SMR typically only captures 90% of CO_2, so Norwegian emissions would effectively rise
- Blue hydrogen export contingent on the availability of CO_2 storage infrastructure

Scenario B

- Hydrogen from Norwegian onshore wind not cost-competitive with hydrogen from solar PV (lower LCOE)
- Low social acceptance for onshore wind parks in Norway
- Land-use conflicts between the Sámi people and power companies

Scenario C

- Offshore wind enjoys stronger political support compared to onshore wind in Norway
- Given the current pace of developments in offshore wind installations, this scenario is not very likely

Annex

Cost assumptions

All in 2023-€

Technology	Baseline assumption	Range
Onshore wind investment	€1413 /kW	+/-20%
Bottom-fixed offshore wind investment (excluding connection)	€2921 /kW	+/-20%
Floating offshore wind investment (excluding connection)	€5269 /kW	+/-20%
Steam-methane reformation with 90% carbon capture rate	€728 /kW_{CH_4}	+/-20%
Steam-methane reformation conversion efficiency[4]	69%	fixed
Natural gas	€30 /MWh_{th}	+/-20%
CO_2 sequestration[5]	€36.50 /tCO_2	+/-20%
PEM electrolysis	€429 /kW_e	+/-20%
PEM electrolysis efficiency[6]	65%	61%–69%
Ammonia synthesis[7]	€1570 /kW_{th}	+/-20%
Ammonia synthesis hydrogen consumption[8]	1.15 MWh_{H2}/MWh_{NH3}	fixed
Ammonia synthesis electricity consumption[9]	0.25 MWh_{el}/MWh_{NH3}	fixed
Ammonia shipping	€1.47 /MWh_{th}/1000km	+/-20%

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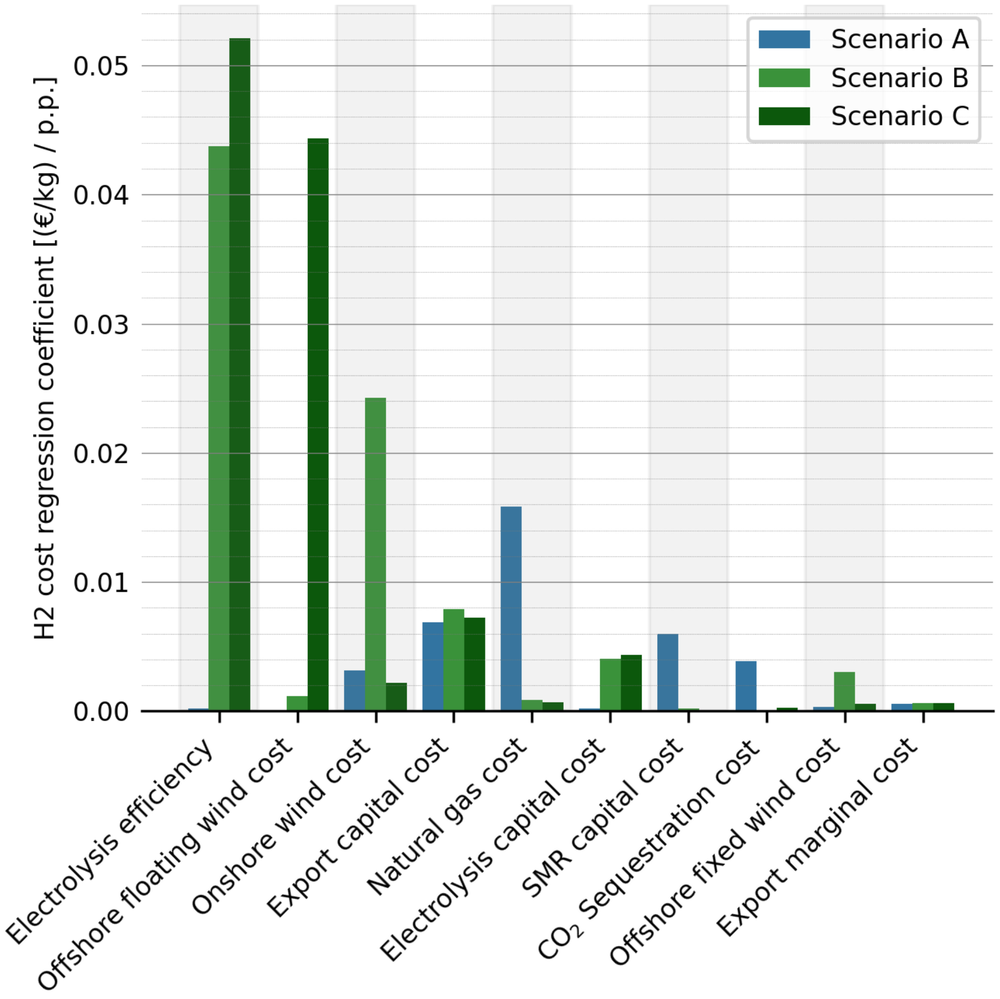
Green hydrogen costs mostly affected by assumed electrolysis efficiency

(assuming 65% in base case)



Sensitivities of Norwegian H_2 export costs in Scenarios A, B & C to variations in technological parameters. The coefficients are expressed in LCOH (€/kgH_2) per percentage point (p.p.) change in respective technological parameters.