THE NORDICS AS A HUB FOR GREEN ELECTRICITY AND FUELS

Energy Modelling Lab

Till ben Brahim

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Project partners: COWI, Brinckmann Group

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AGENDA

- Hypothesis
- Model description
- Main model inputs
- Results
- Conclusions
- Lessons learned

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HYPOTHESIS

Nordics can be competitive on the global market for green energy

Reasoning

- Vast renewable energy potential, especially wind and biomass

If true

- When and where to build out required infrastructure capacities

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MODEL DESCRIPTION

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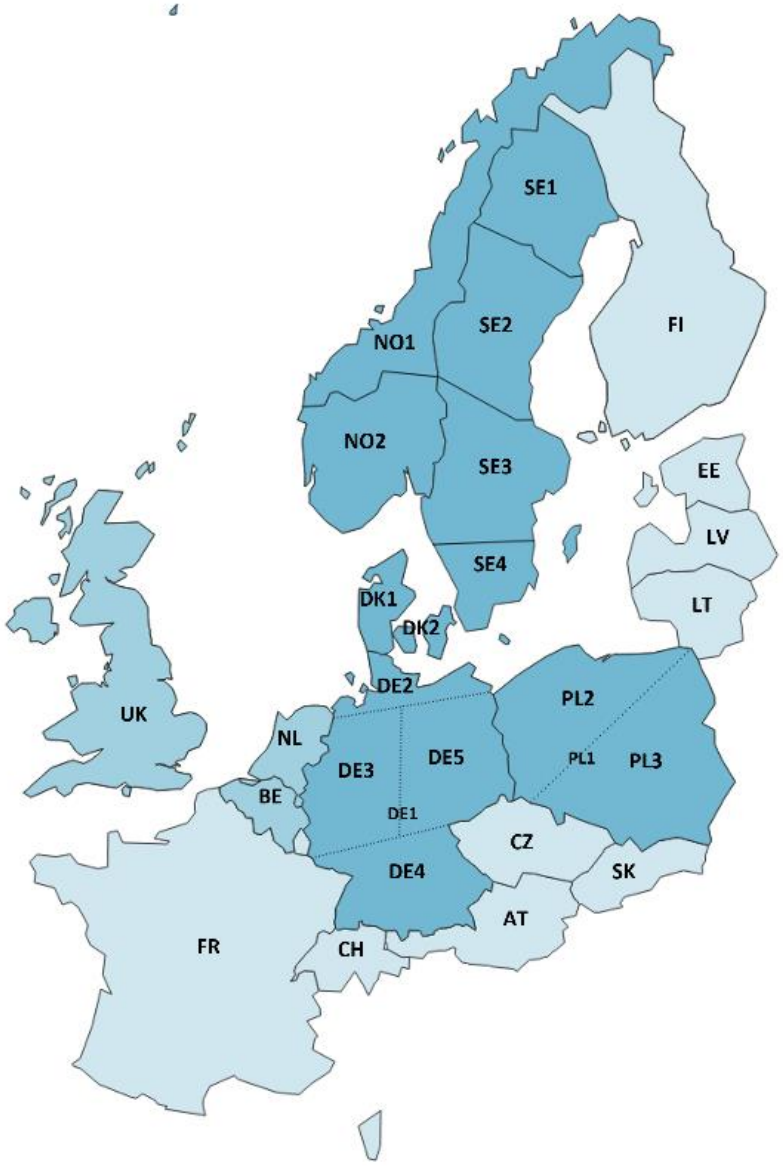
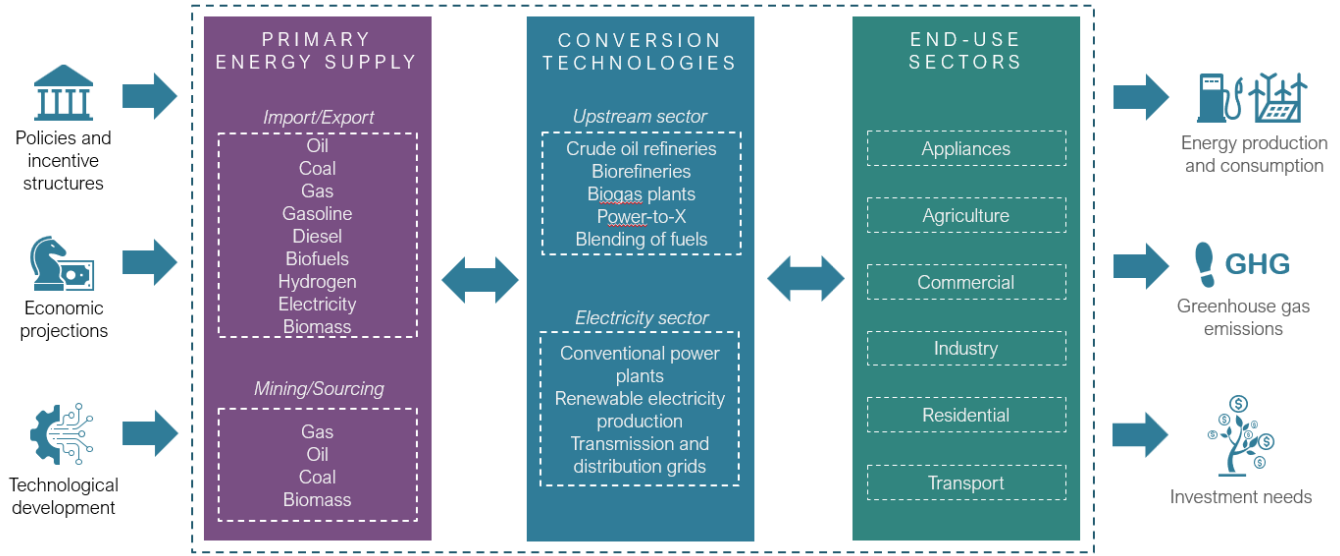
MODEL DESCRIPTION



TIMES-NEU (Based on ON-TIMES)

- 56 time slices a year – period until 2050
- Myopic in 10-year steps
- 2,84% discount rate
- NO, DK, SE, DE, and PL: all sectors included – internal trade with 8 energy carriers
- Surrounding countries (light blue) – power trade with price profiles to main model countries
- UK, Belgium, and Netherlands – also trade with 8 energy carriers



MAIN MODEL INPUT

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IMPORTANT ASSUMPTIONS

- National climate targets are respected
- Existing and projected carbon and energy taxes are included
- Stop for import of green fuels (except H2 and NH3) and biomass from 2040
- Exogenous green fuel supply and demand for UK, BE and NL
- Fuel prices for the global market, and landing prices for UK, BE, and NL
- Exogenous non-energy fossil fuels are faced out linearly from 2030 to 2050
- Exogenous nearshore wind capacity of 3 GW on Danish energy island in 2030
- Technology costs from Danish Technology Catalogues

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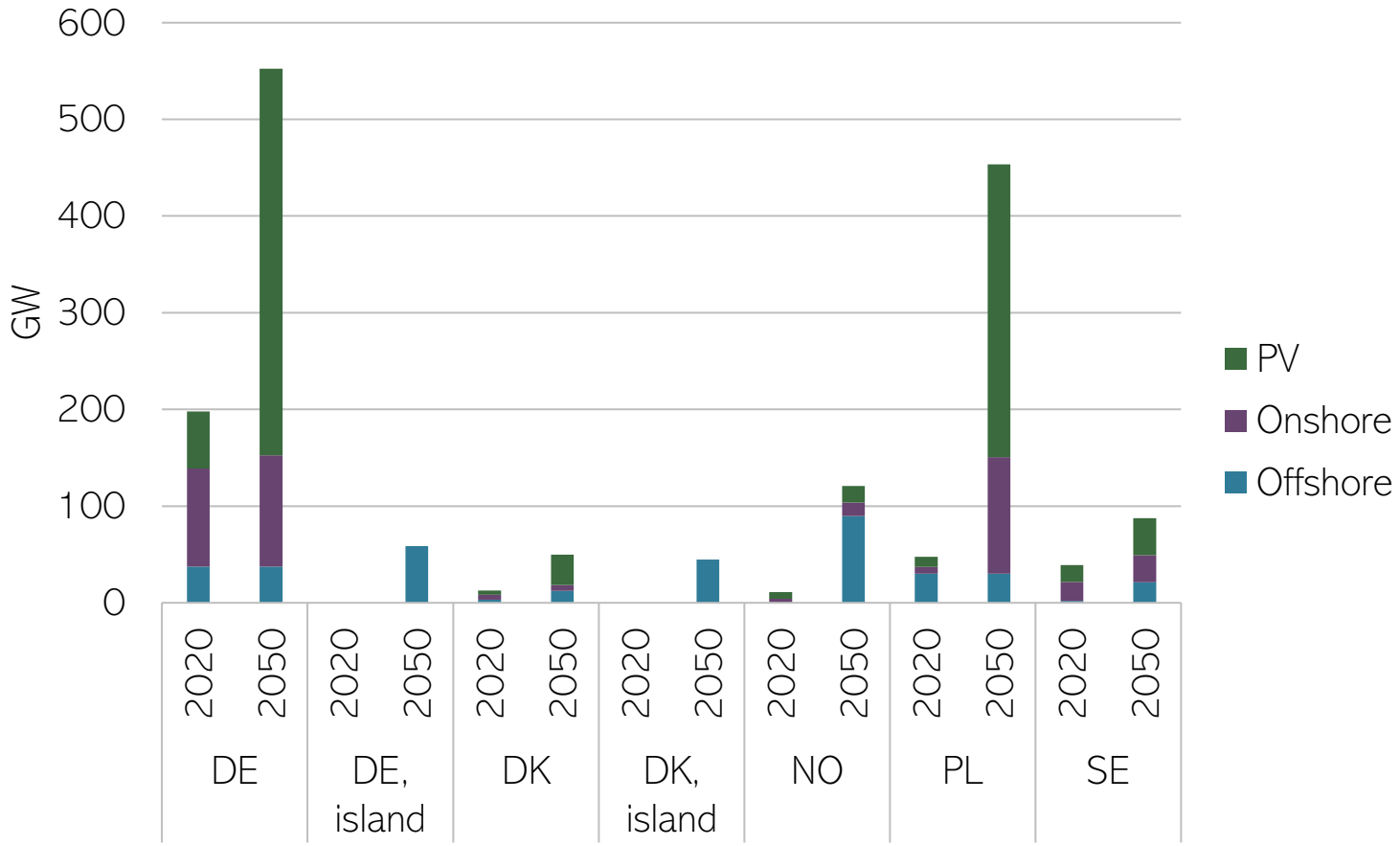
WIND & SOLAR POTENTIALS



- In total 1,36 TW in 2050
- DE with highest PV potential in 2050
- PL with highest wind onshore potential in 2050
- DK offshore potential ~50% of DE
- NO offshore like DE

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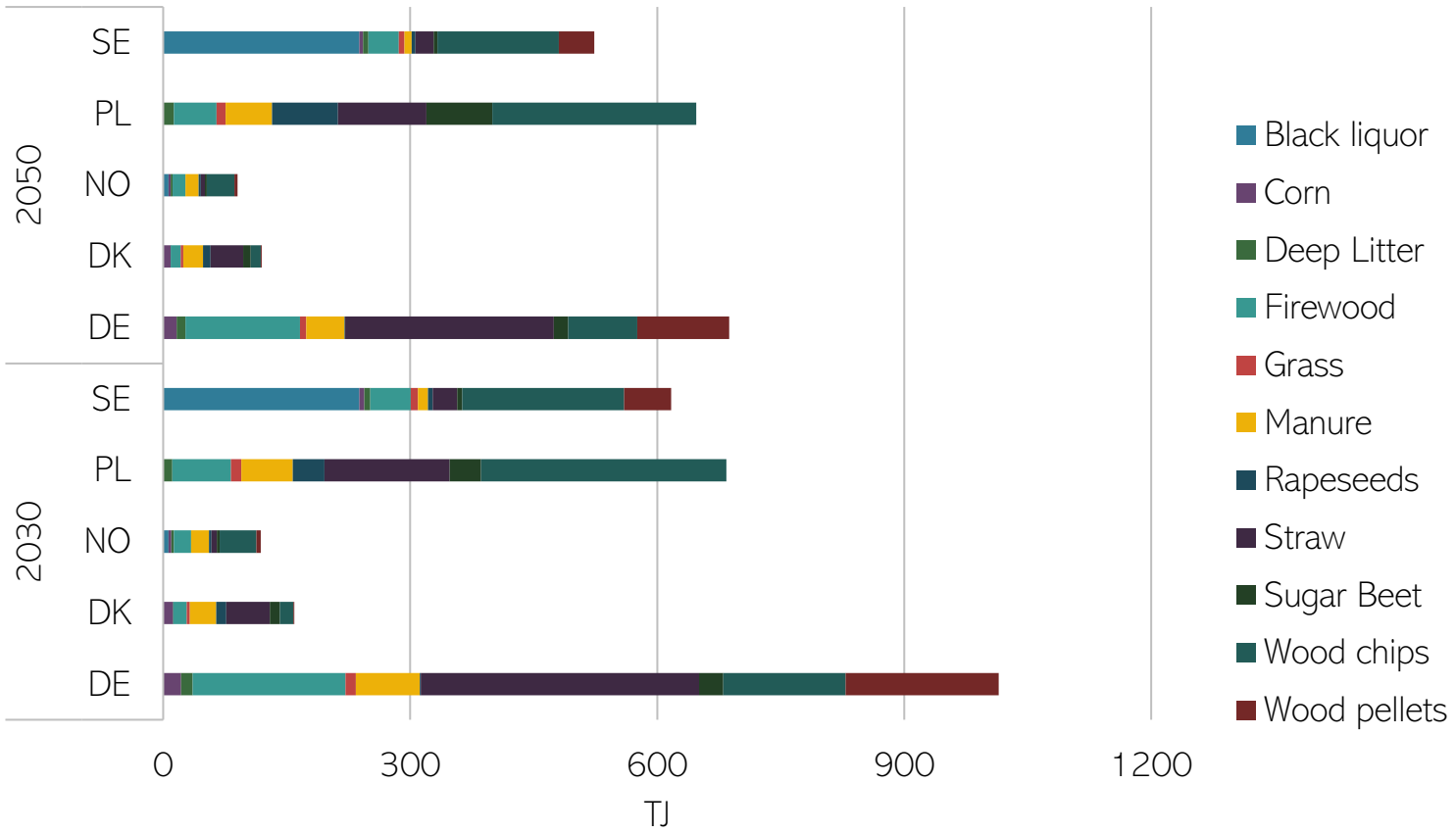
BIOMASS POTENTIALS



- Potential decreased from 2030 to 2050 by:
  - SE – 15%
  - PL – 5%
  - NO – 24%
  - DK – 25%
  - DE – 32%
- Totals:
  - 2030 – 2,6 EJ (12% of TPES)
  - 2050 – 2,1 EJ

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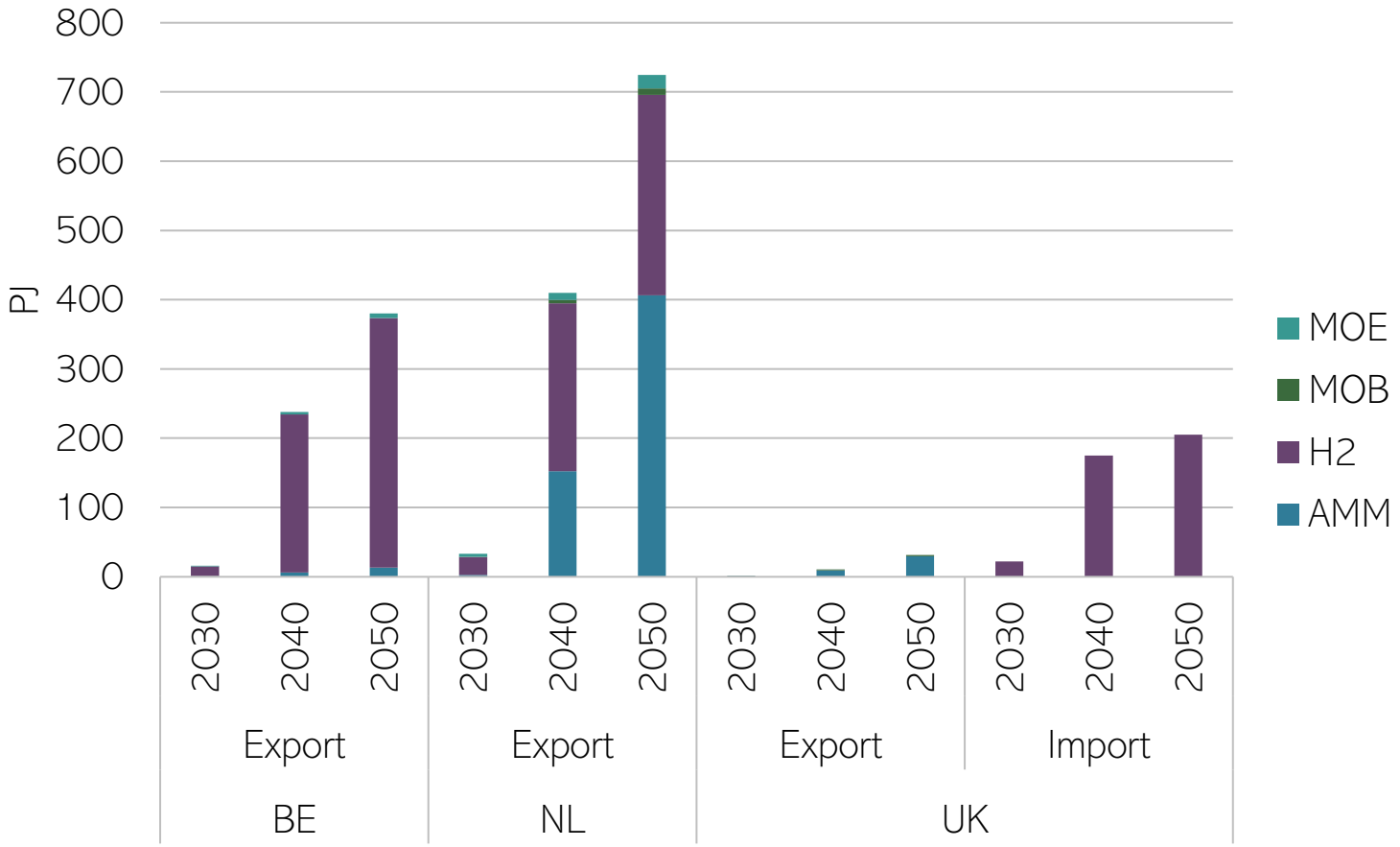
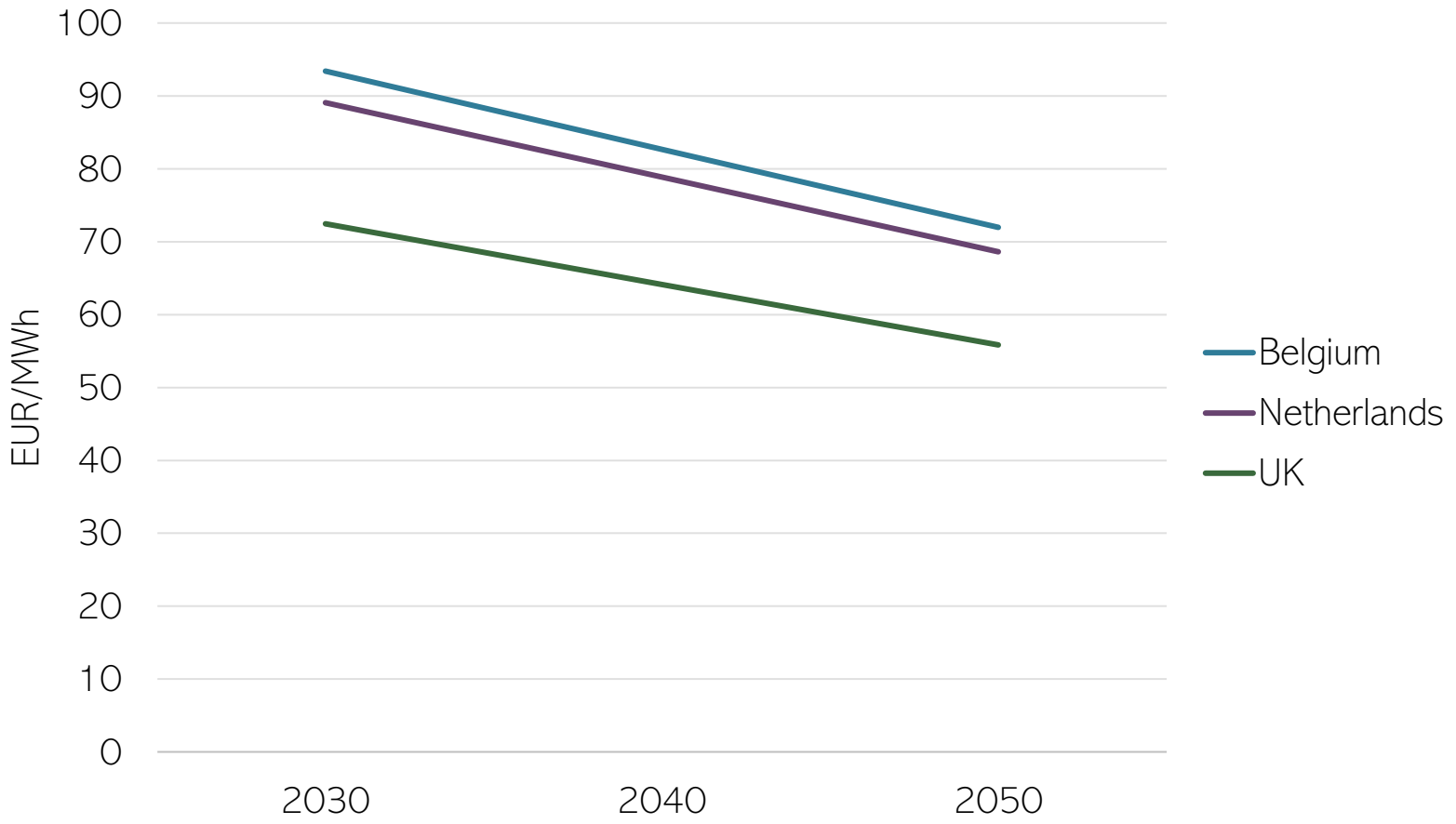
EXOGENOUS TRADE LIMITS



- Upper limits (not fixed)
- BE and NL net importers
- UK net importer except for H2

HYDROGEN EXPORT PRICES TO NEIGHBOURING COUNTRIES



RESULTS OF BASE SCENARIO

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GREEN FUEL DEMAND & PRODUCTION

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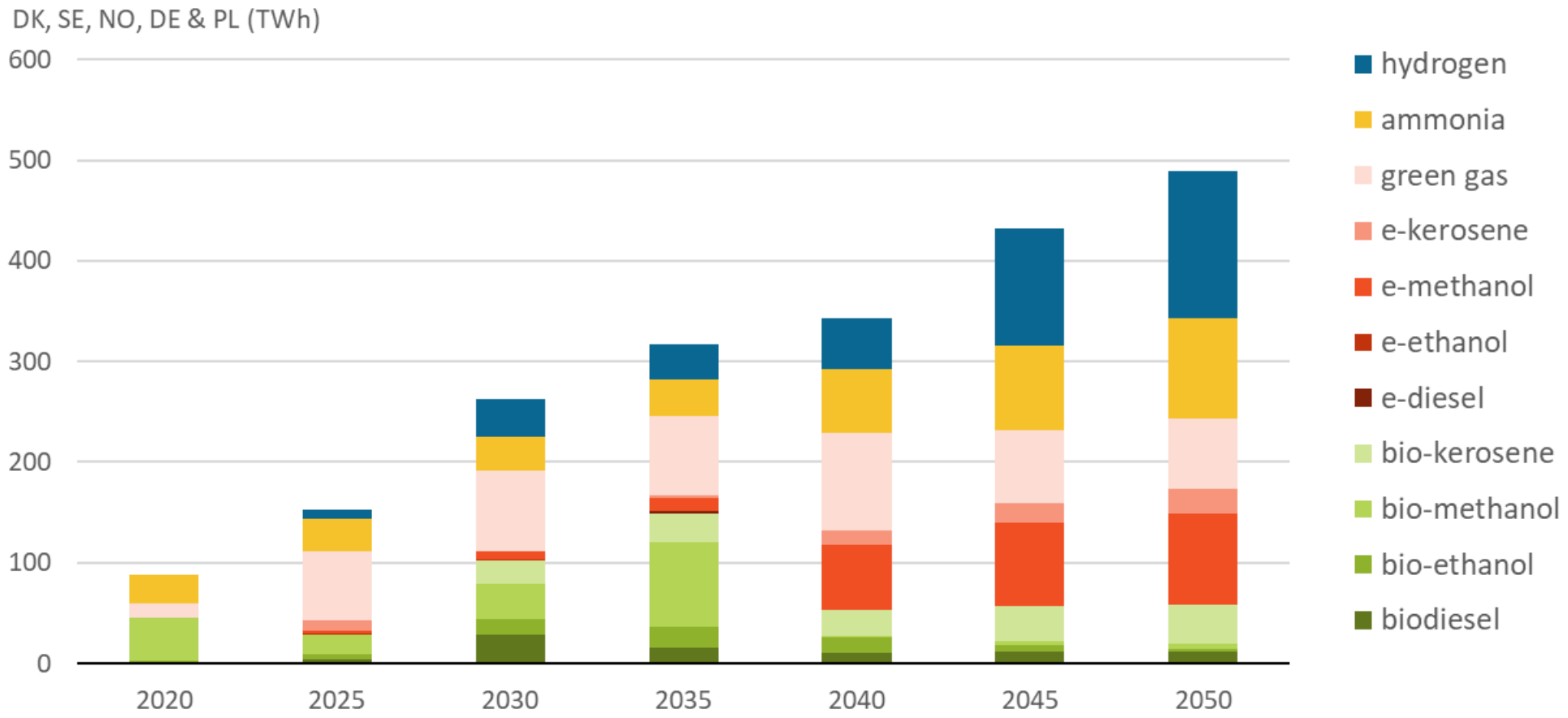
TOTAL FINAL DEMAND FOR GREEN FUELS



Modelled demand for green fuels (bio- and electro) in the fully modelled countries (DK, SE, NO, DE, PL) – not including UK, NL, and BE!)

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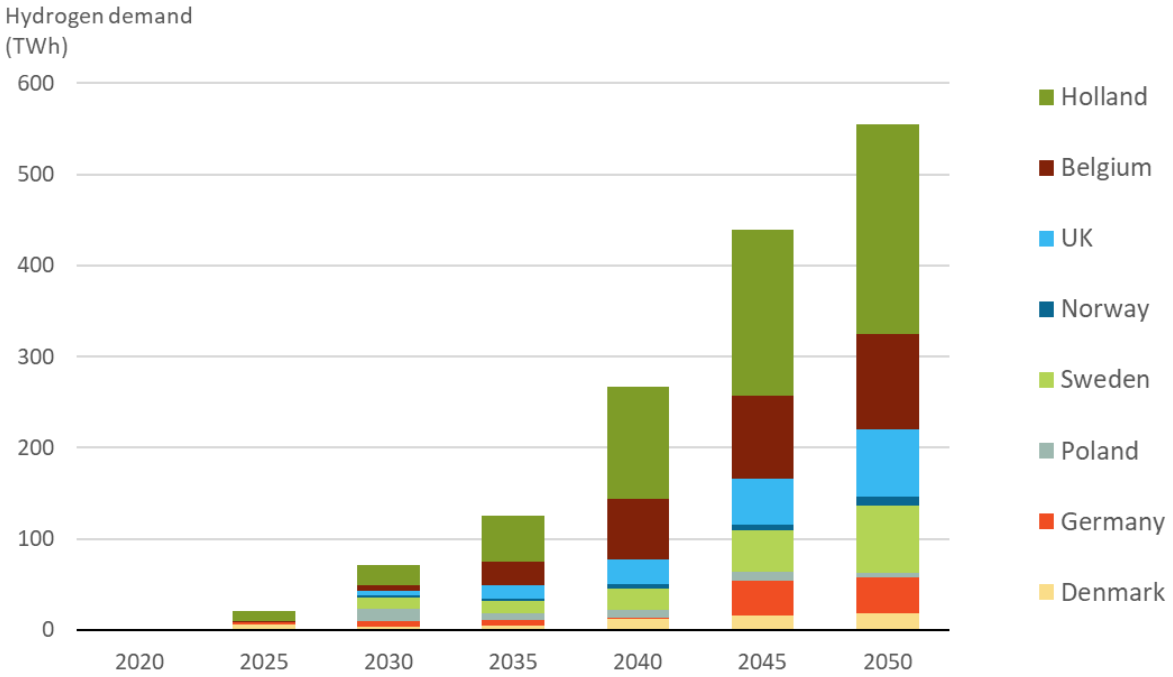
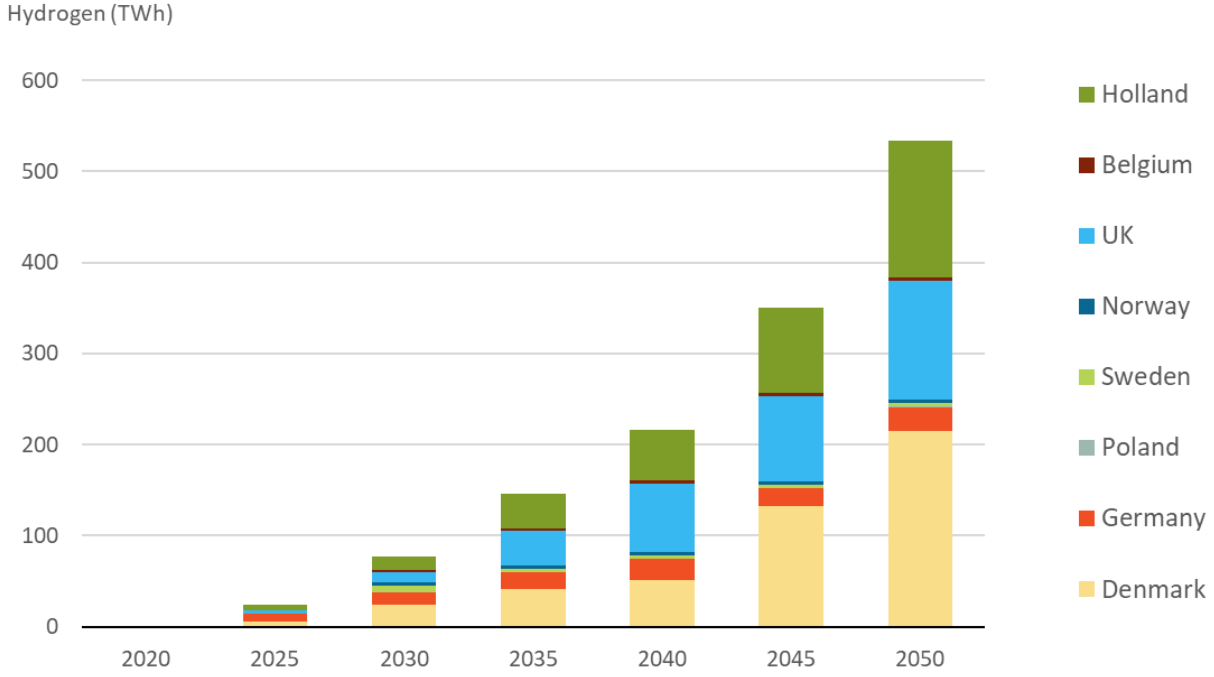
HYDROGEN DEMAND AND PRODUCTION

DEMAND



Direct hydrogen demand in the extended model area. This includes use in industry, transport and for e-fuel production. The demand is endogenous decided by the model in DK, NO, SE, DE and PL while it is exogenous added to the model for NL, BE and UK.

PRODUCTION



Expected hydrogen production in the model area. The production is endogenous decided by the model in DK, NO, SE, DE and PL while it is exogenous added to the model for NL, BE, and UK.

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ELECTRICITY AND H2 TRADE

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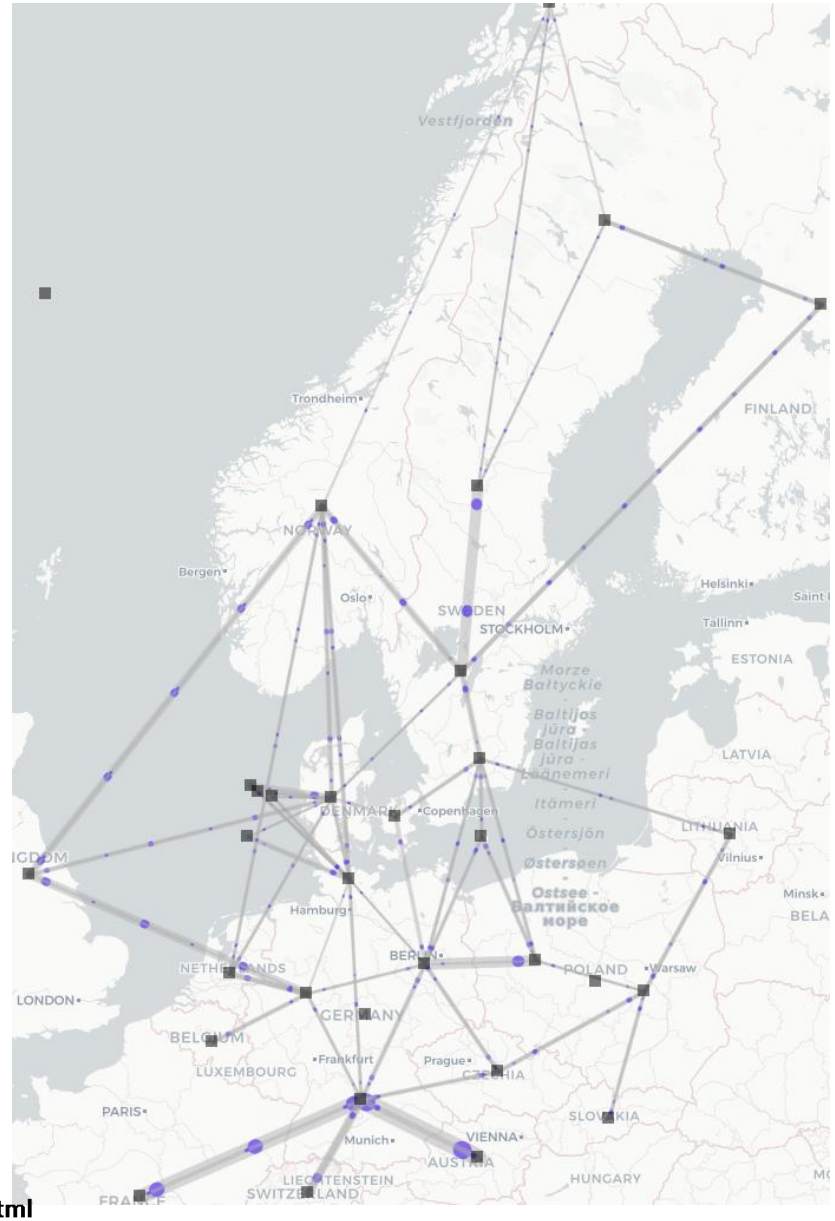
POWER TRADE IN 2050

- NO, net exporter of electricity mostly to SE, DK and DE
- SE, net importer mostly from NO, FI and LT.
- Main electricity consumption hub stays in DK, that becomes a net importer of electricity, mostly from DE, NO, UK, and SE.
- The electricity flows to the energy islands where the electrolyzers are built.



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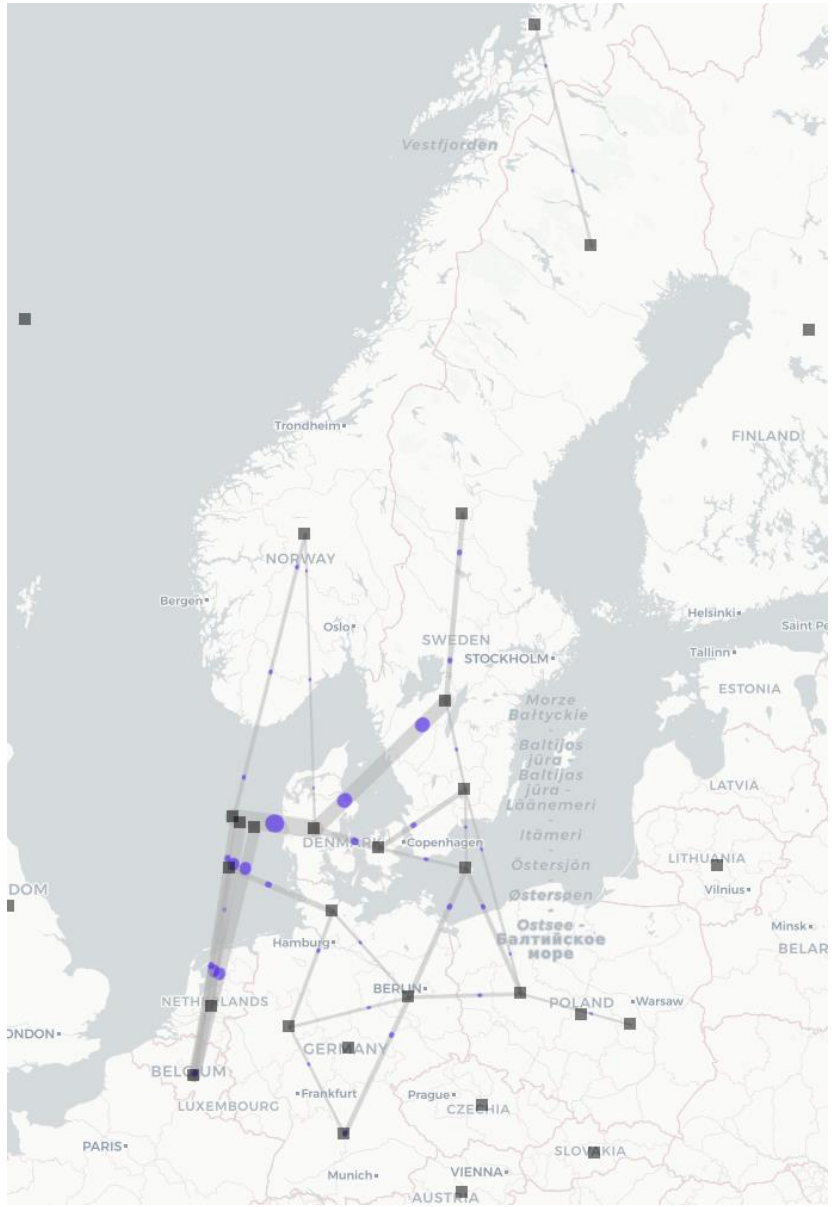
HYDROGEN TRADE IN 2050

- Chemical industry and steel industry in south SE as well as the extensive BE and DE industries are the main hydrogen consumption hubs.
- DE can produce two thirds of its own hydrogen, but still needs to import from Denmark to cover its total consumption.
- SE and BE become net importers of hydrogen, mostly from Denmark, and partially from Poland in the Swedish case.



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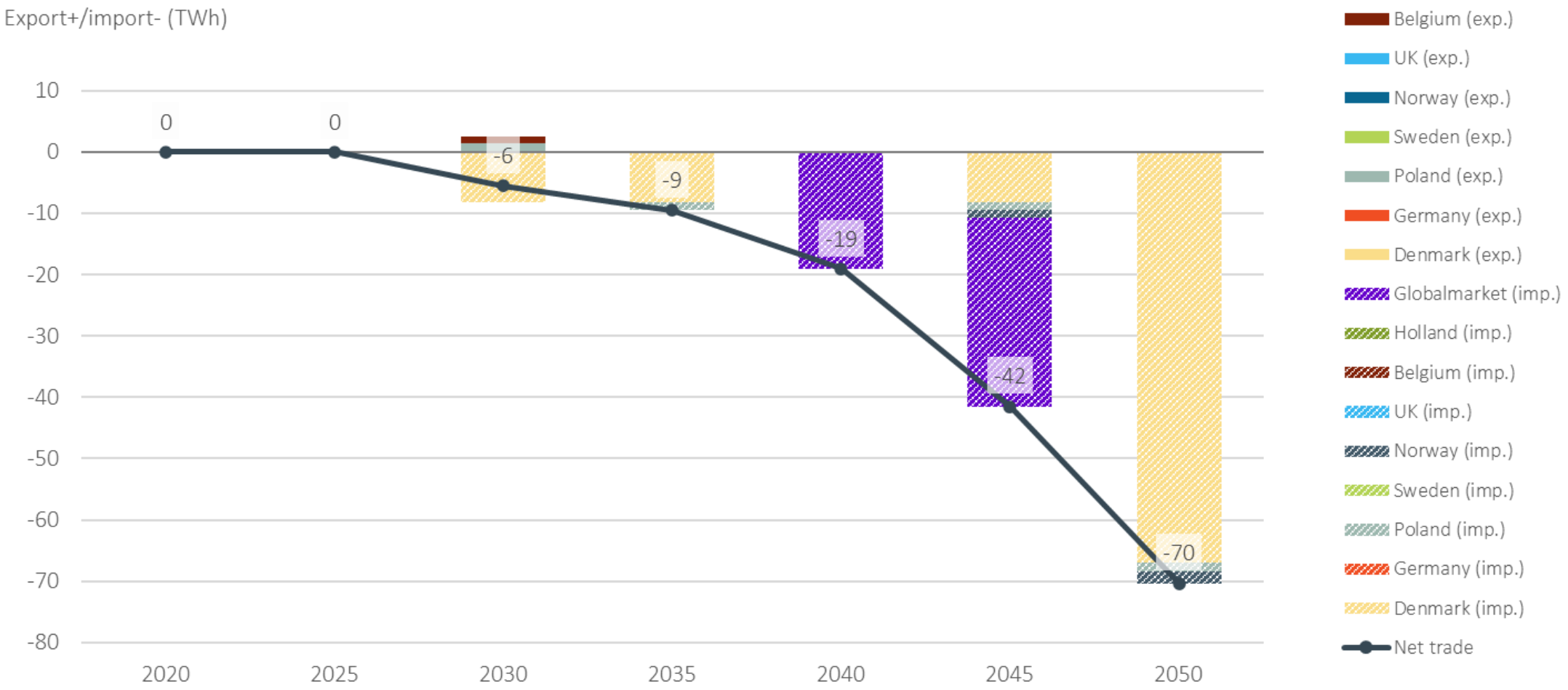
SWEDEN'S TRADE WITH HYDROGEN



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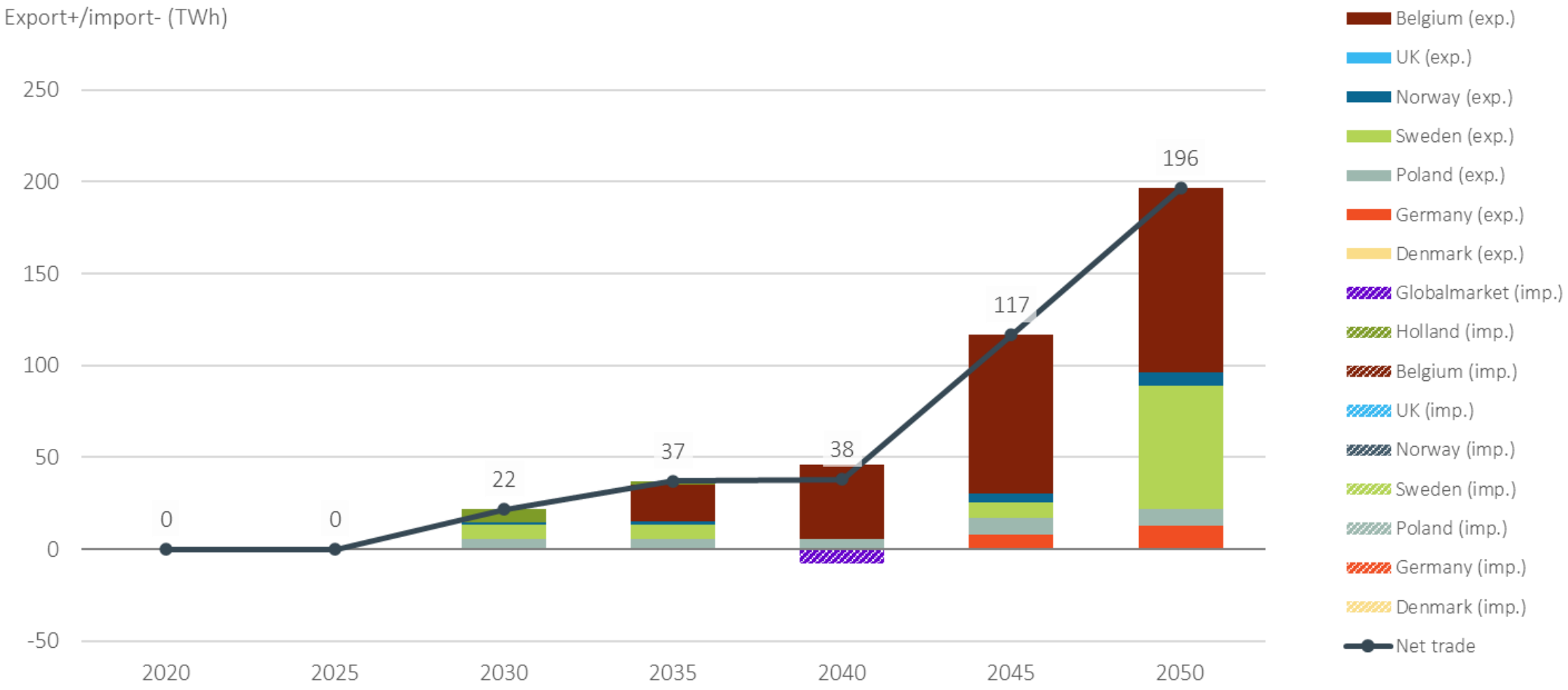
DENMARK'S TRADE WITH HYDROGEN



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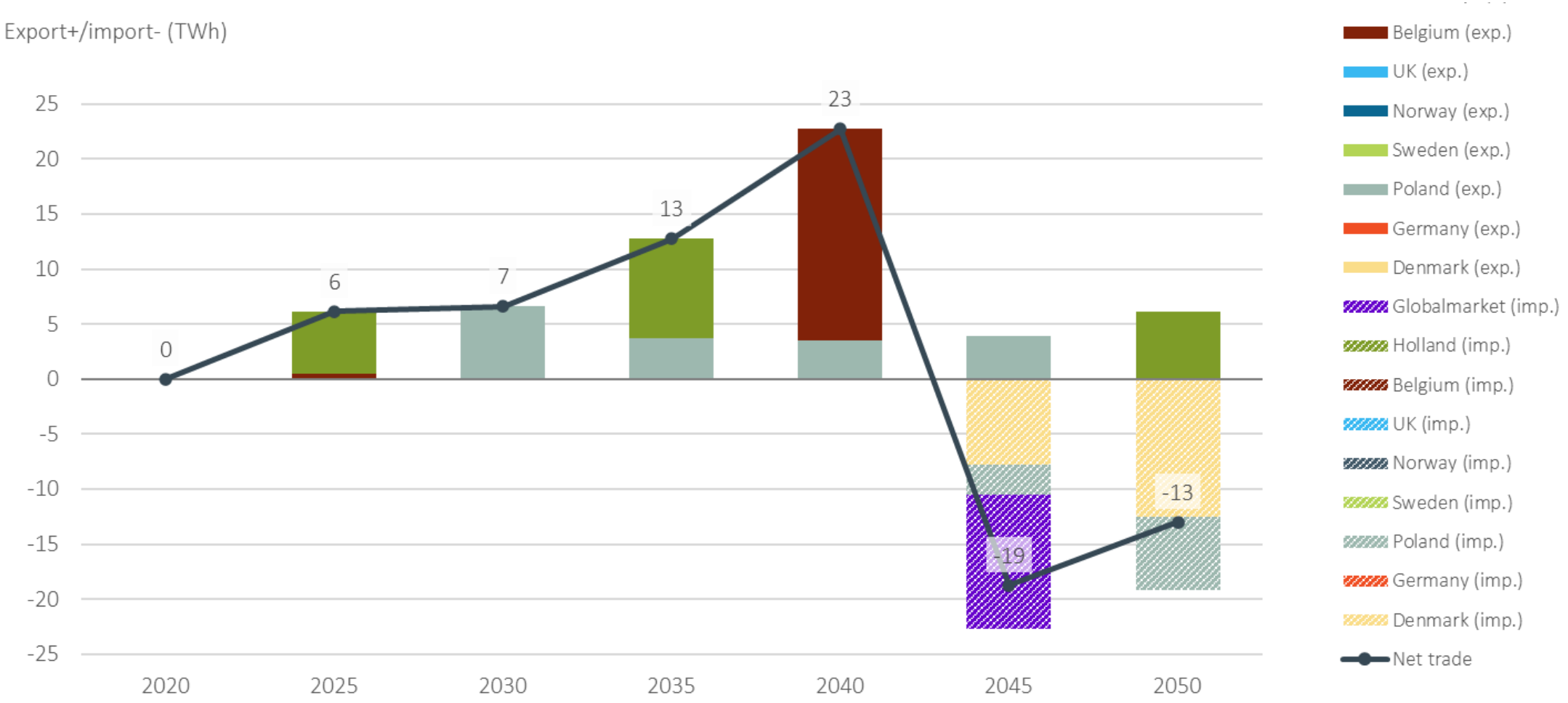
GERMANY'S TRADE WITH HYDROGEN



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ELECTROLYZER AND WIND CAPACITIES

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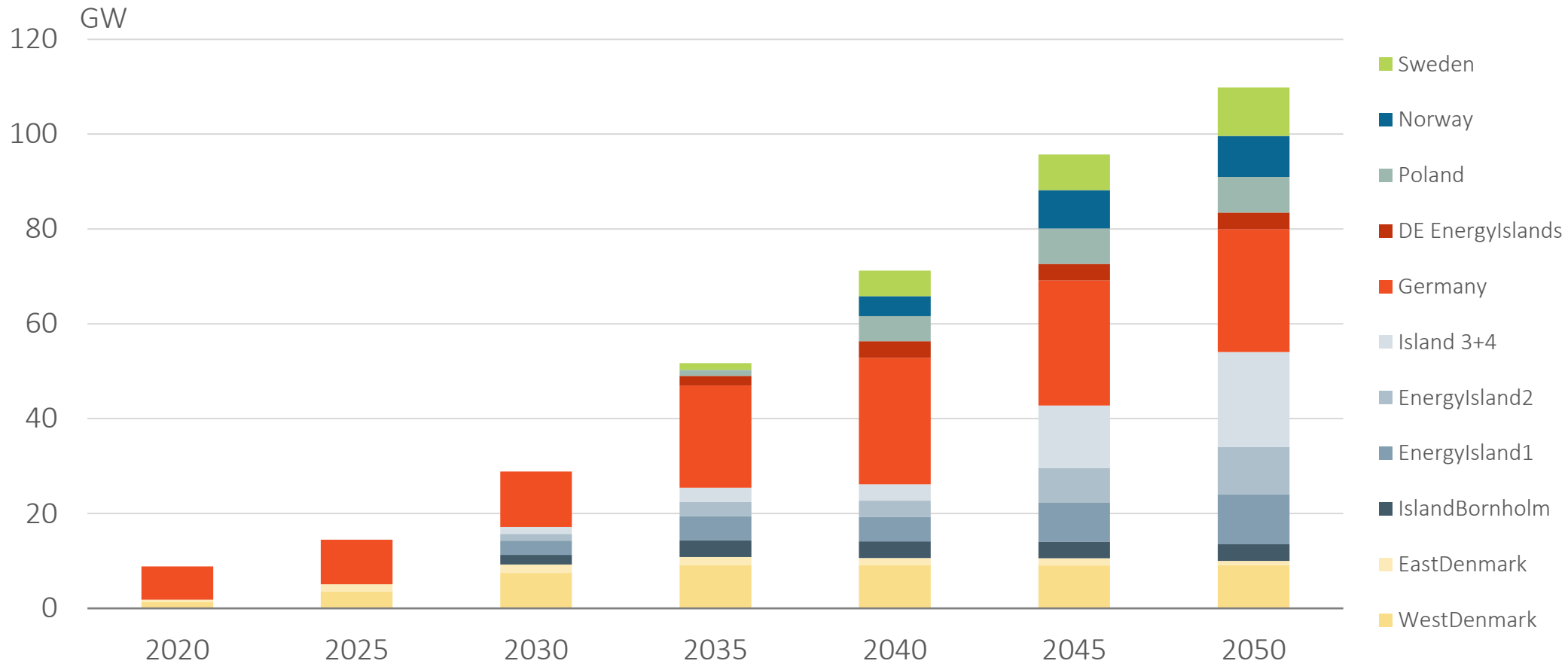
WIND OFFSHORE CAPACITY



North sea wind potential is fully utilized in the energy islands.
Norway and Denmark are close to their offshore potential.
Sweden only installs 10 GW out of 20 GW potential, model finds more optimal to import hydrogen

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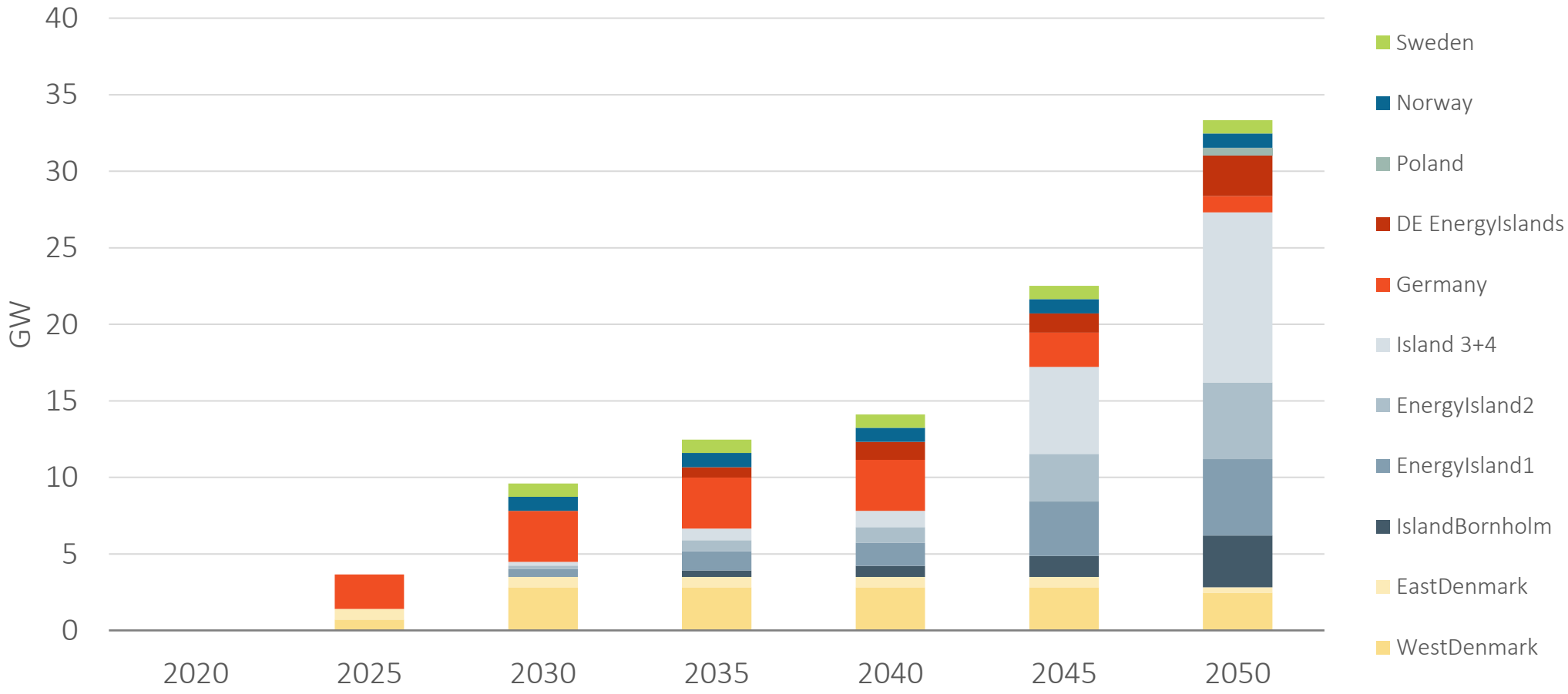
ELECTROLYZER CAPACITY



First movers in installing enough electrolyzer capacity dominate the market share in the short to medium term.

Without planned capacity, build-out describes a hockey stick curve.

CONCLUSIONS

- Nordics can be a hub for some green fuels, especially H2 shows high potential
- Energy islands seem feasible with modelled costs, but are recently stalled due to more conservative estimates
- Overall cheaper to produce H2 directly offshore and export it to main demand hubs at the expense of electricity exports.

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LESSONS LEARNED

- H2 demand projections tend to be very optimistic in the short and medium term
- Buildout of H2 capacity follows more strategies, rather than feasibilities
  - Models with exogenous demand are blind to this behavior
  - We need to be careful with national strategies in multi-national models, as they might contradict and drive the model solution
- North sea is the cheapest place to produce H2 in the model
- Complexity of fuel trade not fully captured in our model

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END

Thank you for your attention.

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ENERGY PRICES

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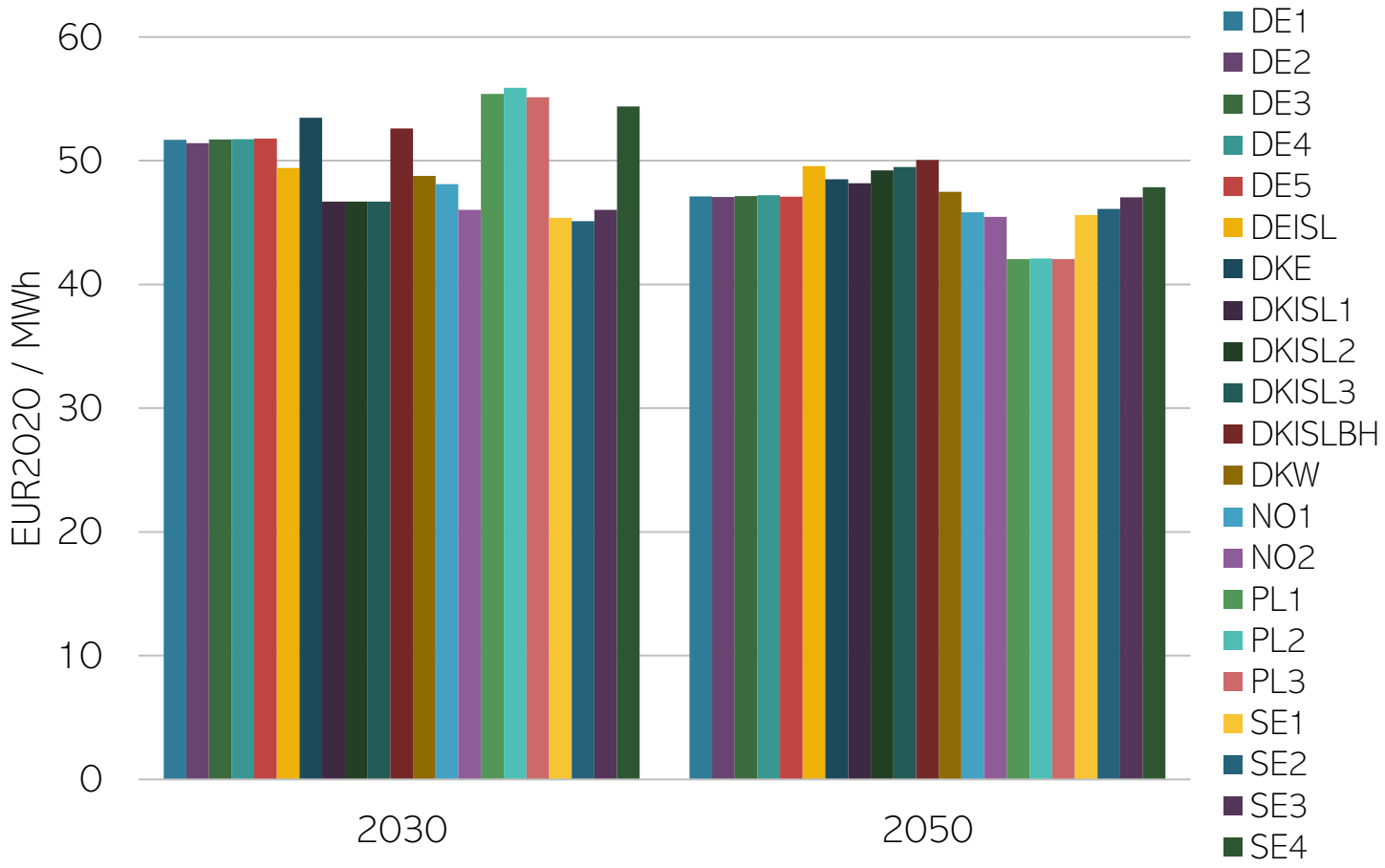
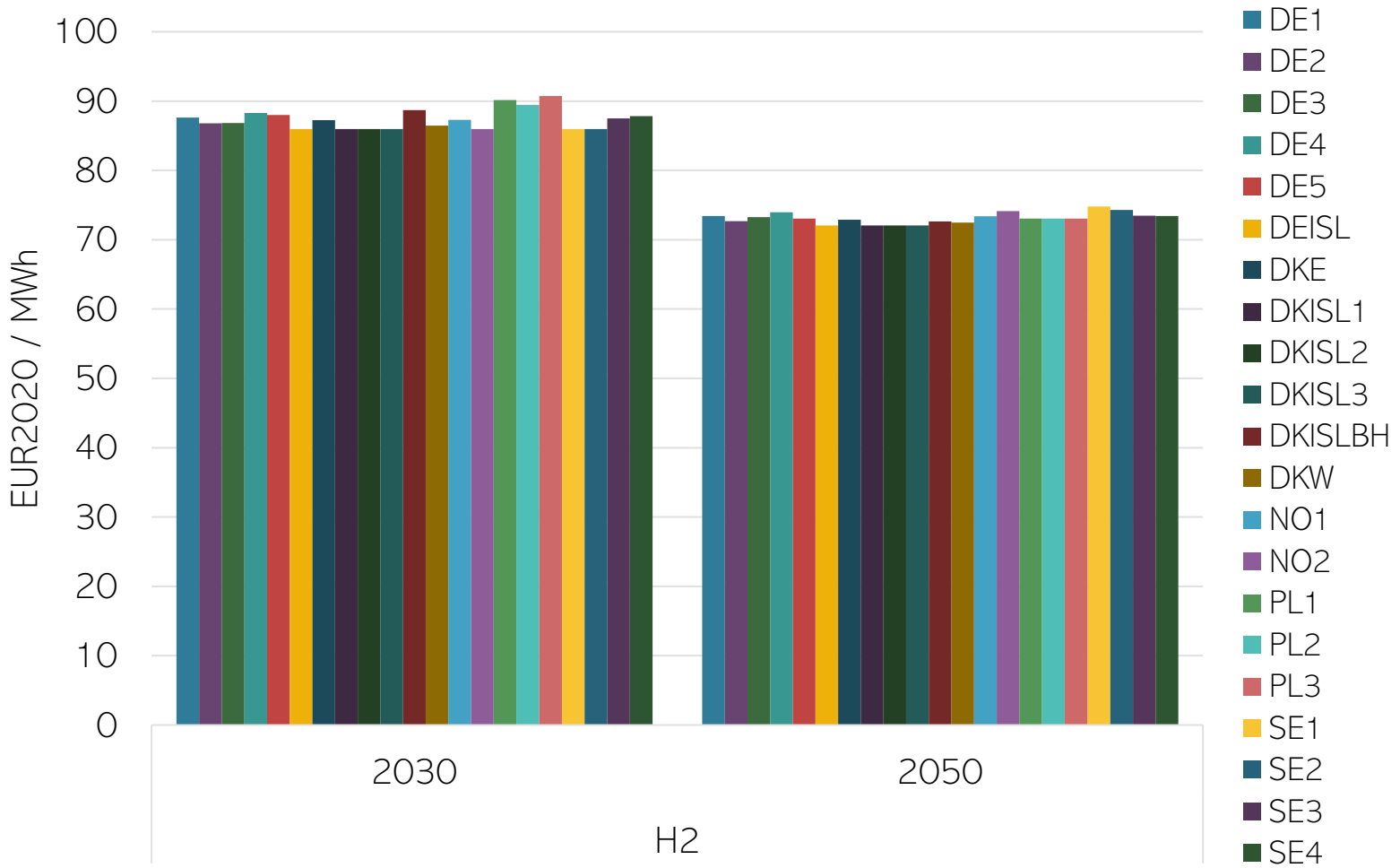
MARGINAL POWER PRICES



- Slightly higher on average prices in 2030 compared to 2050
- In 2030:
  - DE and PL with highest prices
  - SE and DK islands with lowest prices
- In 2050:
  - Trend of 2030 flipped

MARGINAL HYDROGEN PRICES



- Decrease in H2 production prices from 2030 to 2050
- No major differences across regions
- Hydrogen prices in 2050 ranges from 72-74 €/MWh
- Cheapest production on the energy islands (North Sea) due to higher wind resources