BLUE AND GREEN HYDROGEN IN THE EUROPEAN ENERGY TRANSITION – A PATHWAY-DEPENDENT SCENARIO ANALYSIS FOR 2040

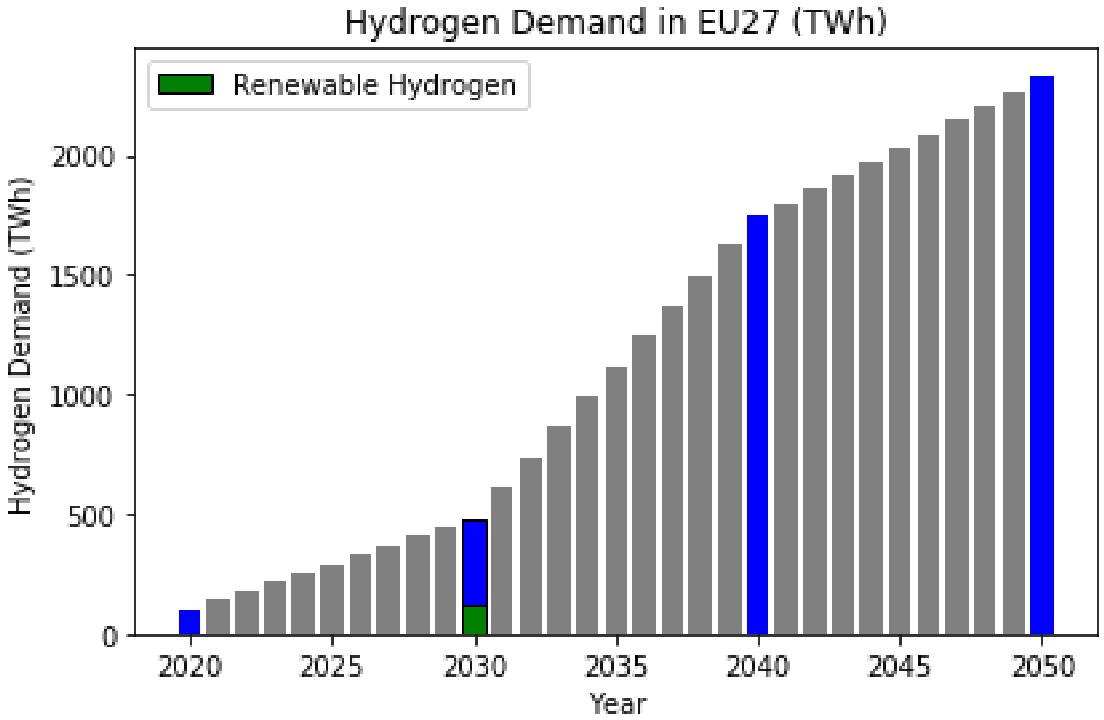
Niels Nagel

29.11.2024

Background

Green and Blue Hydrogen promises to help achieve the EU's Green Deal objectives of an emission-free energy system by:

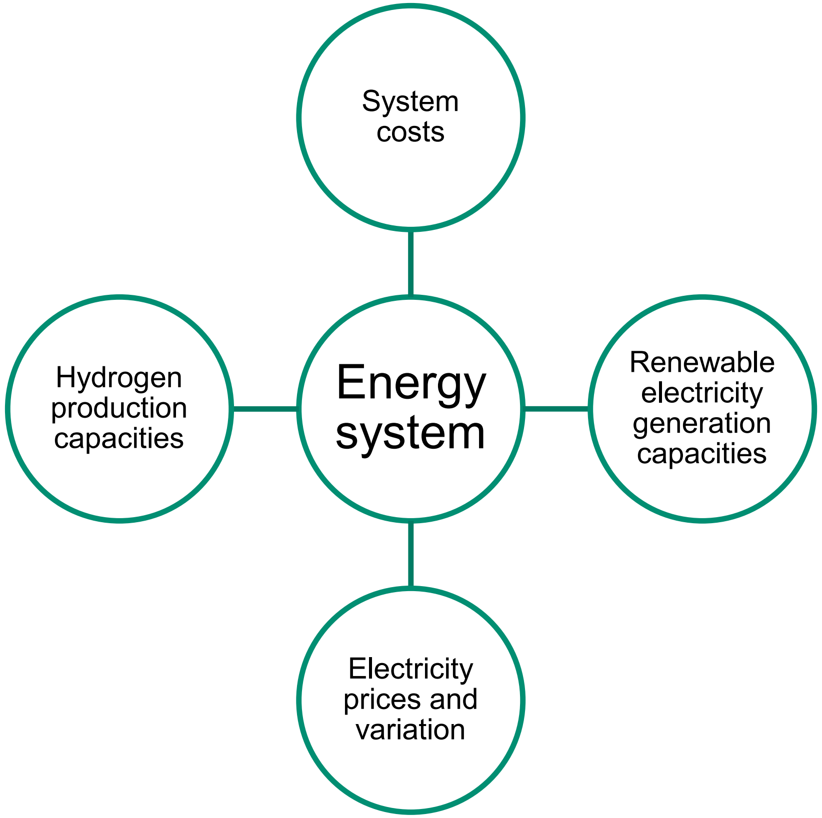
1. Enabling large-scale renewable energy integration
2. Decarbonize hard-to-abate sectors
3. Use as a feedstock for carbon-neutral fuels
4. Allowing for storage and distribution



*Based on Entso-e's Distributed energy scenario in the TYNDP 2024 with linear extrapolation between the given figures

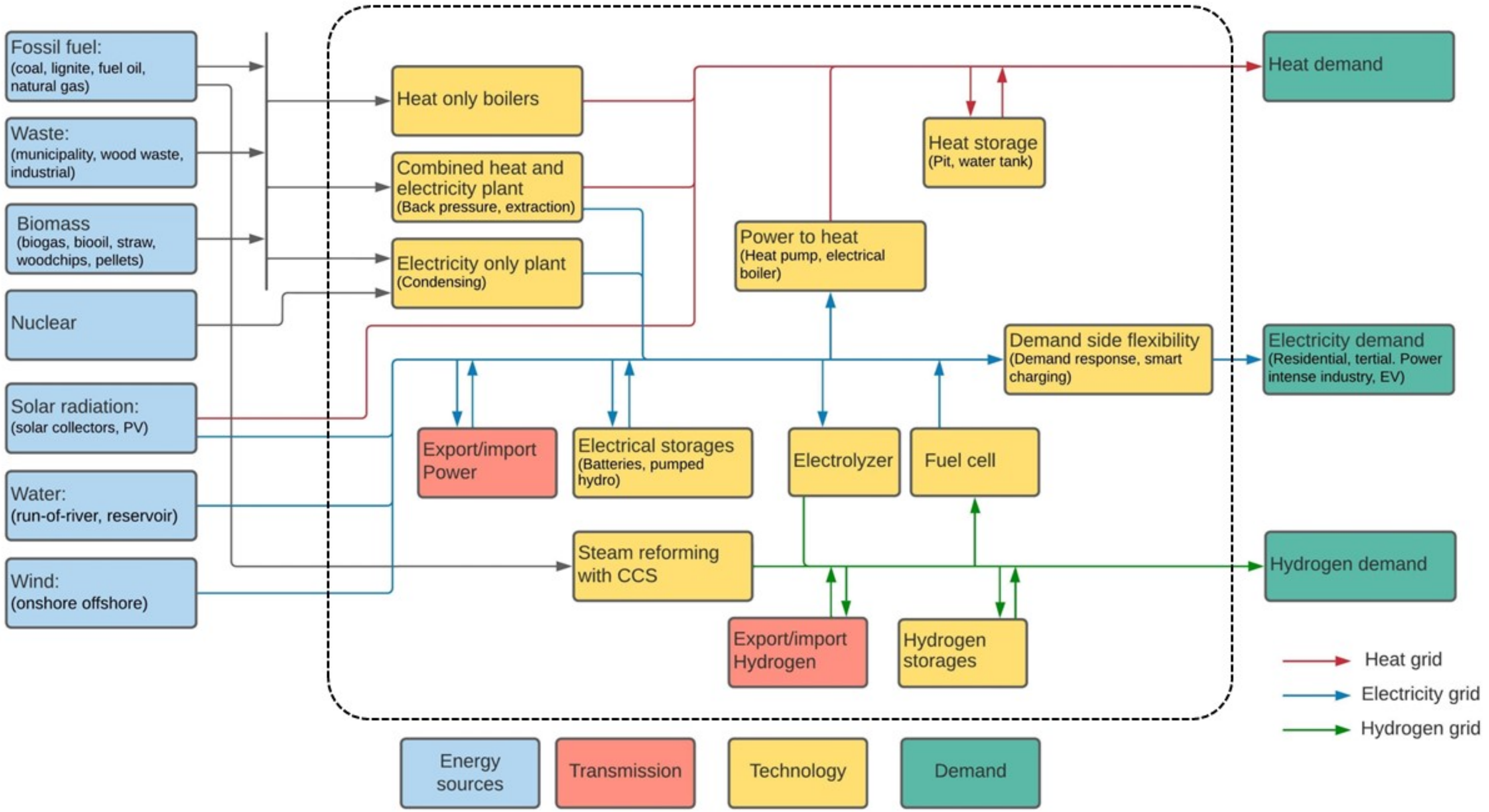
Research question

- How will the 2040 European energy system differ in scenarios with different shares of blue and green hydrogen production?



Method

- Partial equilibrium model Balmorel: Minimizing costs of investment and operation in the European energy system



Hydrogen modeling

Hydrogen technology assumptions 2040

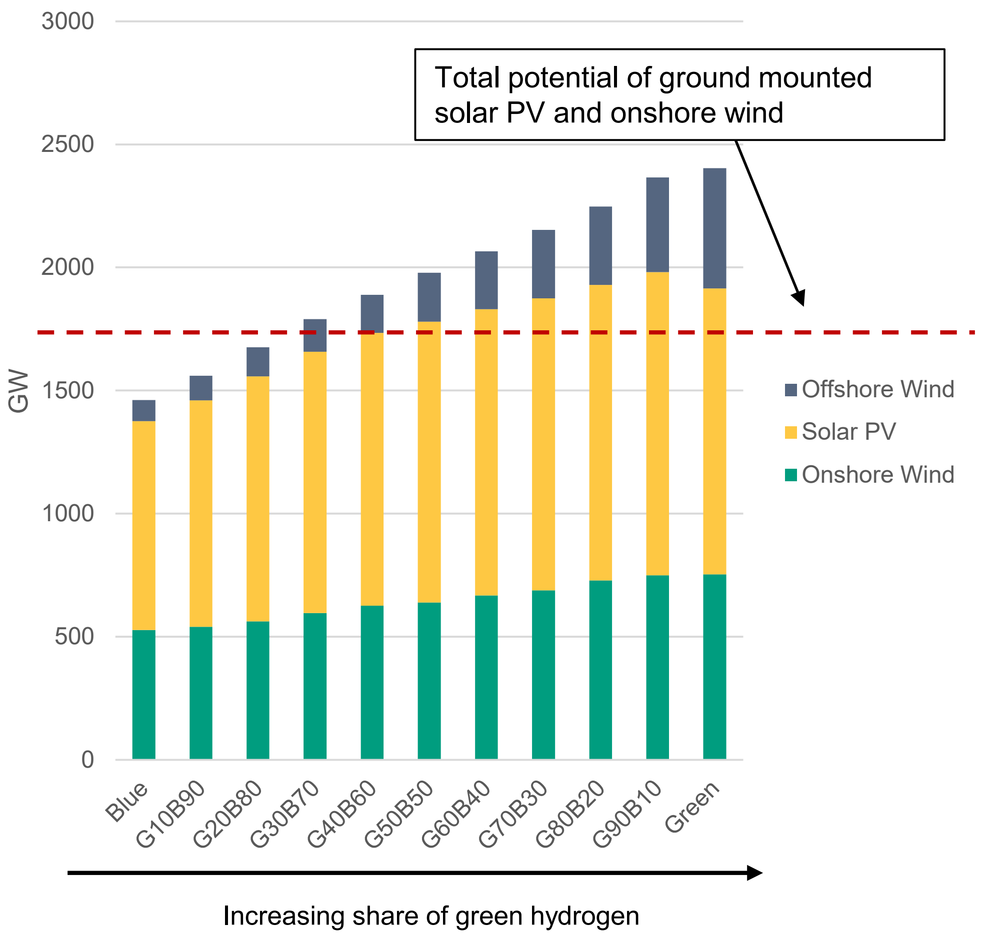
Electrolyzers	Fuel efficiency or roundtrip efficiency	Capital costs (MEUR/MW or MEUR/MWh)	Annual O&M costs (kEUR/MW)	Variable O&M costs (EUR/MWh)	Lifetime (years)
SOEC	0.71	0.65	7.8		25
PEMEC	0.62	0.5	10		25
AEC	0.65	0.425	17		25
Steam reforming with CCS	0.72	1.204	36.1	0.194	25
Hydrogen storage	0.99	0.0265	0.0024		30
Fuel cell	0.61	0.637	0.01	3,43	20

Further important assumptions and limitations:

- No use of existing infrastructure
- Europe will be hydrogen self-reliant (no import or export)
- No use of grey hydrogen

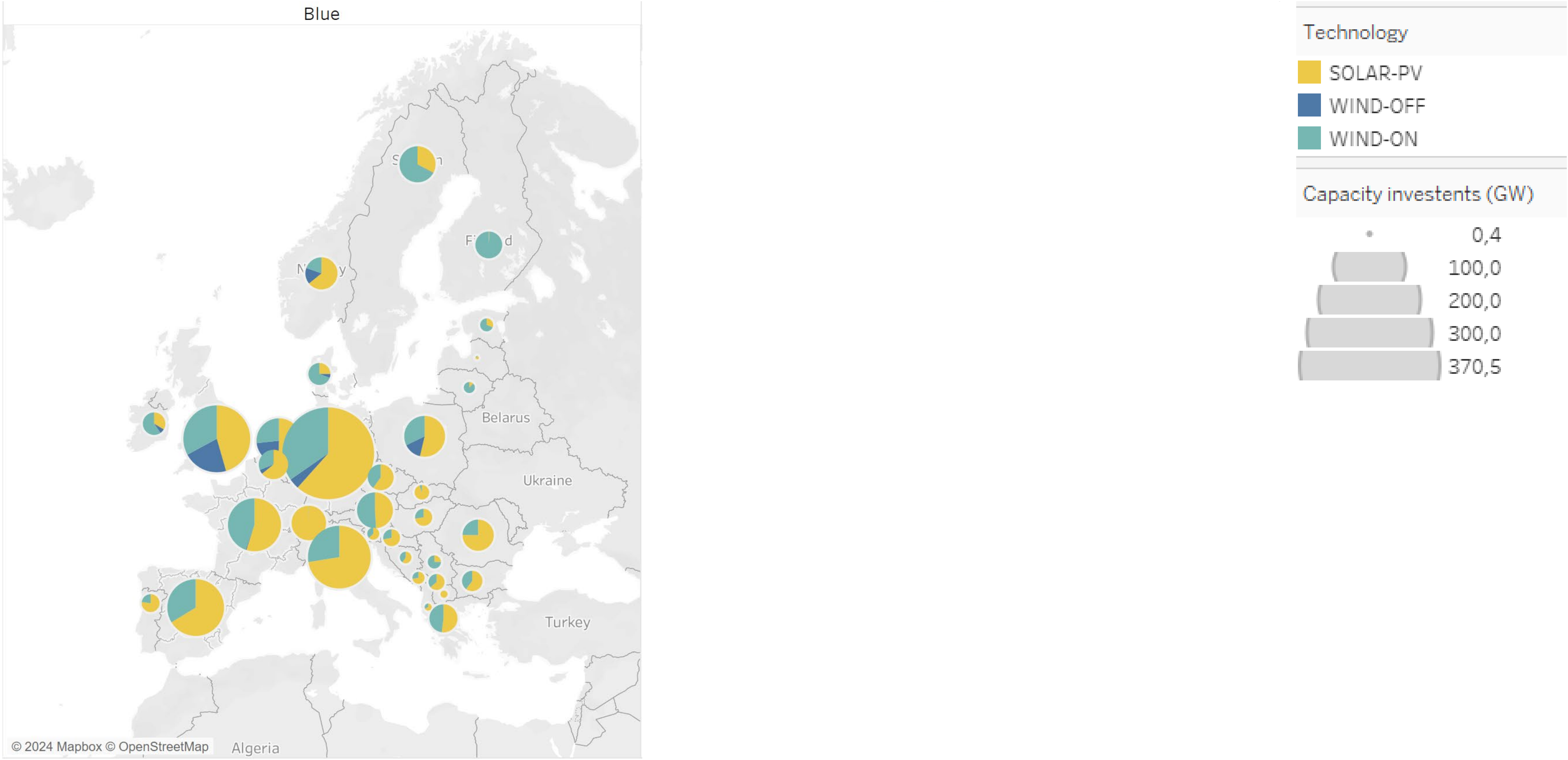
*image by freepik

RESULTS: Green hydrogen requires large-scale renewable capacity investments

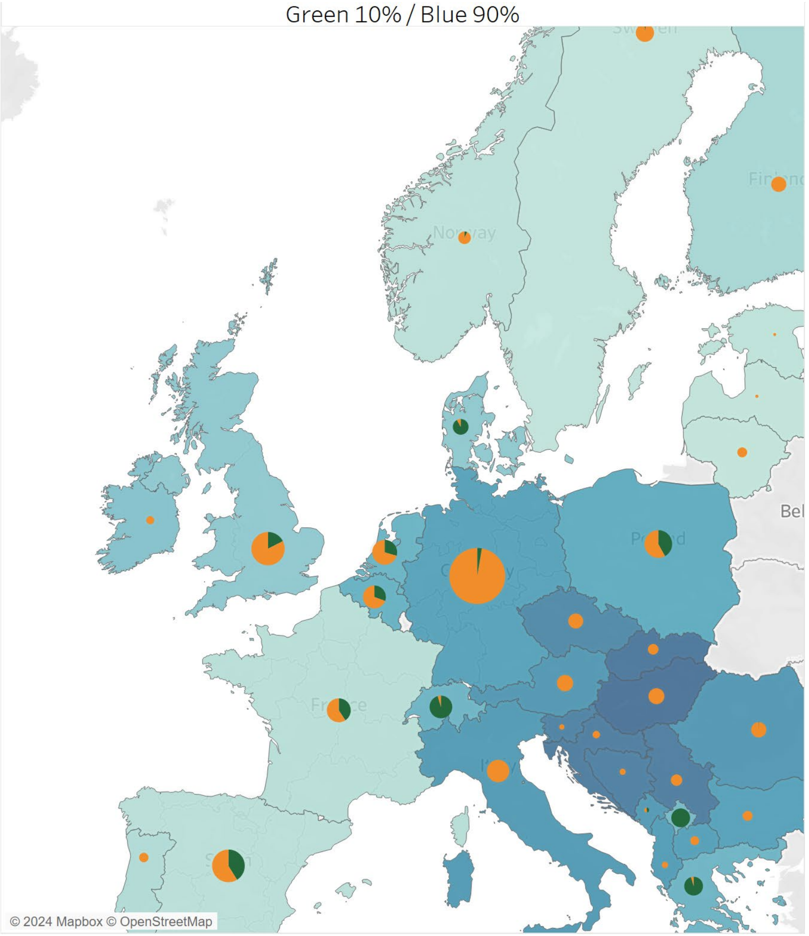


- 65% higher model-endogenous renewable capacity investments in Green compared to Blue scenario
- 87% and 85% of regions exhaust their ground-mounted solar PV and onshore wind potential respectively with only green hydrogen
- More green hydrogen results in additional investments in less cost-effective production sites and technologies, more expensive operation and 26% higher system costs

RESULTS: Green hydrogen production could make investments in bottom-fixed offshore wind economical in several regions



RESULTS: Electrolyzer capacity is most profitable in regions with low-cost renewable resources



Electricity price (EUR/MWh)

37,13 — 94,03

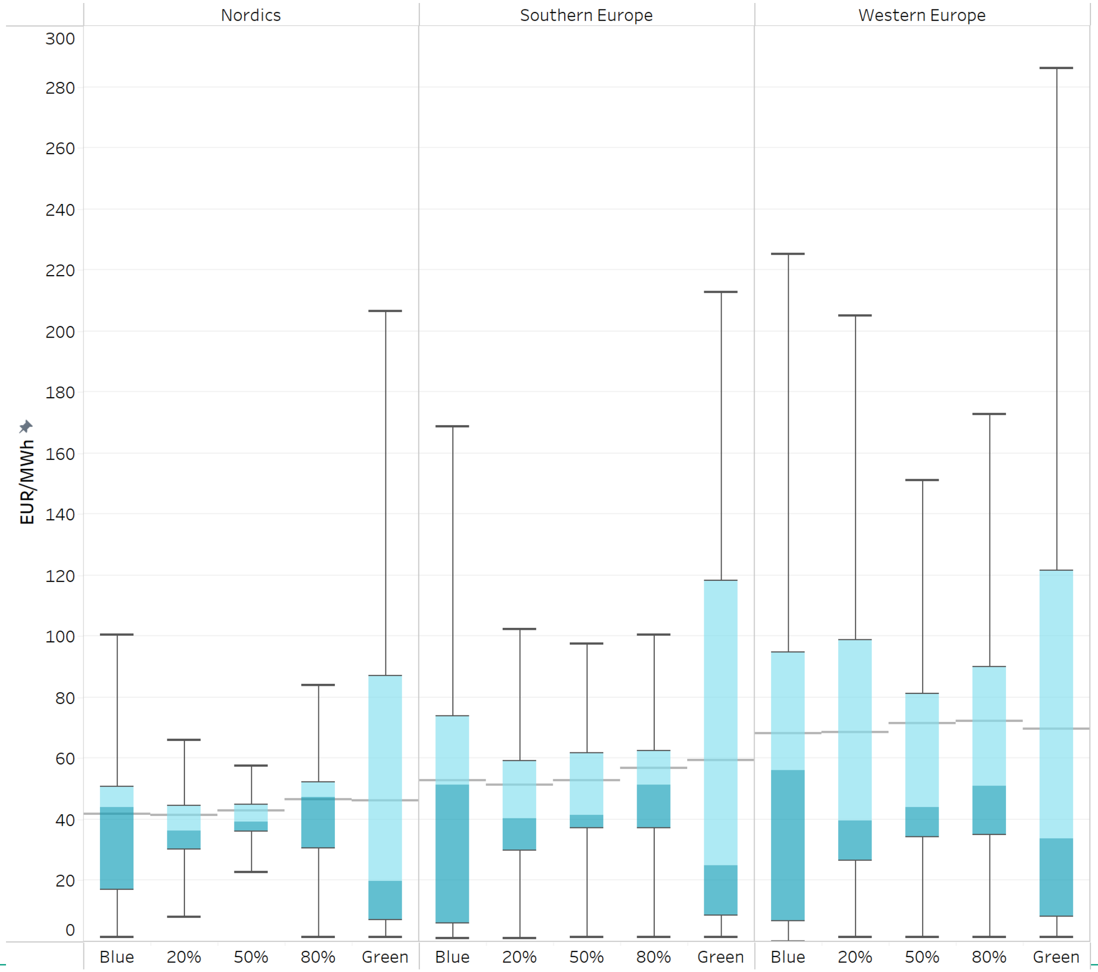
Capacity investment (GW)

- 0,09
- 10,00
- 20,00
- 30,00
- 36,33

Technology

- ELECTROLYZER
- STEAMREFORMING

RESULTS: A blend of blue and green hydrogen production decreases electricity price variation and increases the robustness of the energy system



- Increased el. generation capacity and demand side flexibility reduce price variability (except in Green scenario)
- Higher electrolyzer full-load hours in scenarios with high green hydrogen shares counter the impact of increased generation capacity
- Average electricty prices stay flat or moderately increase with green hydrogen due to increased electricity demand
- Less price peaks indicate less stress in the electricity system in mixed (blue and green) scenarios

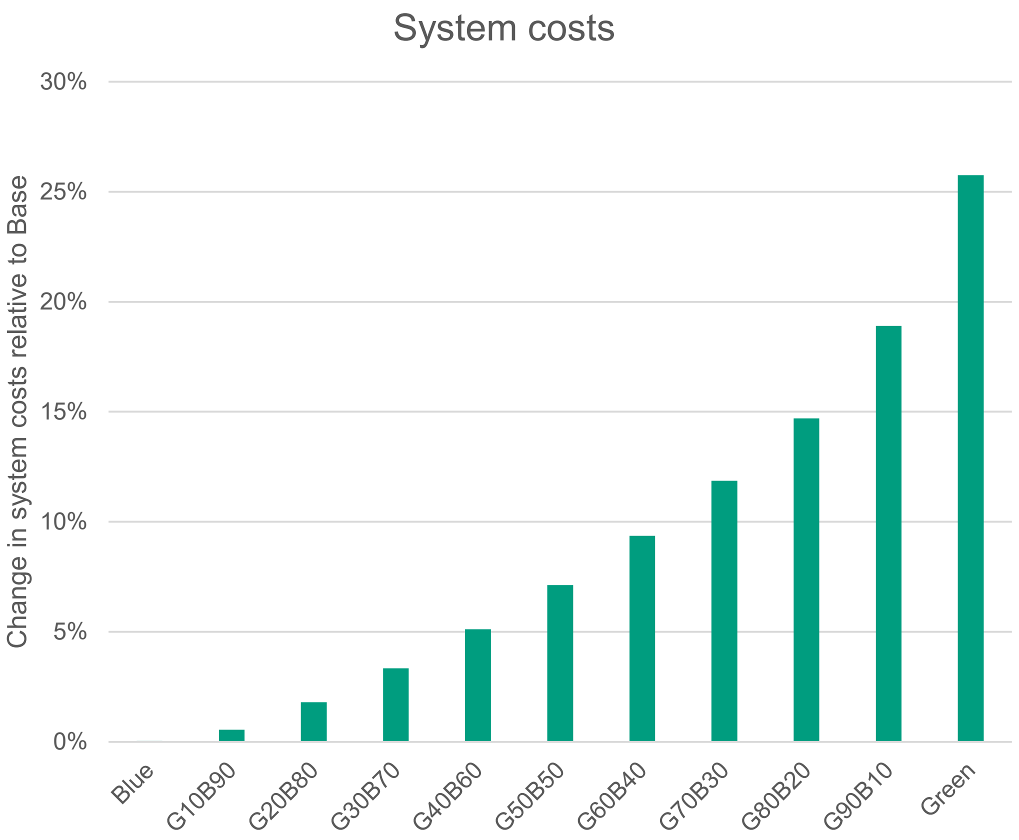
Conclusion

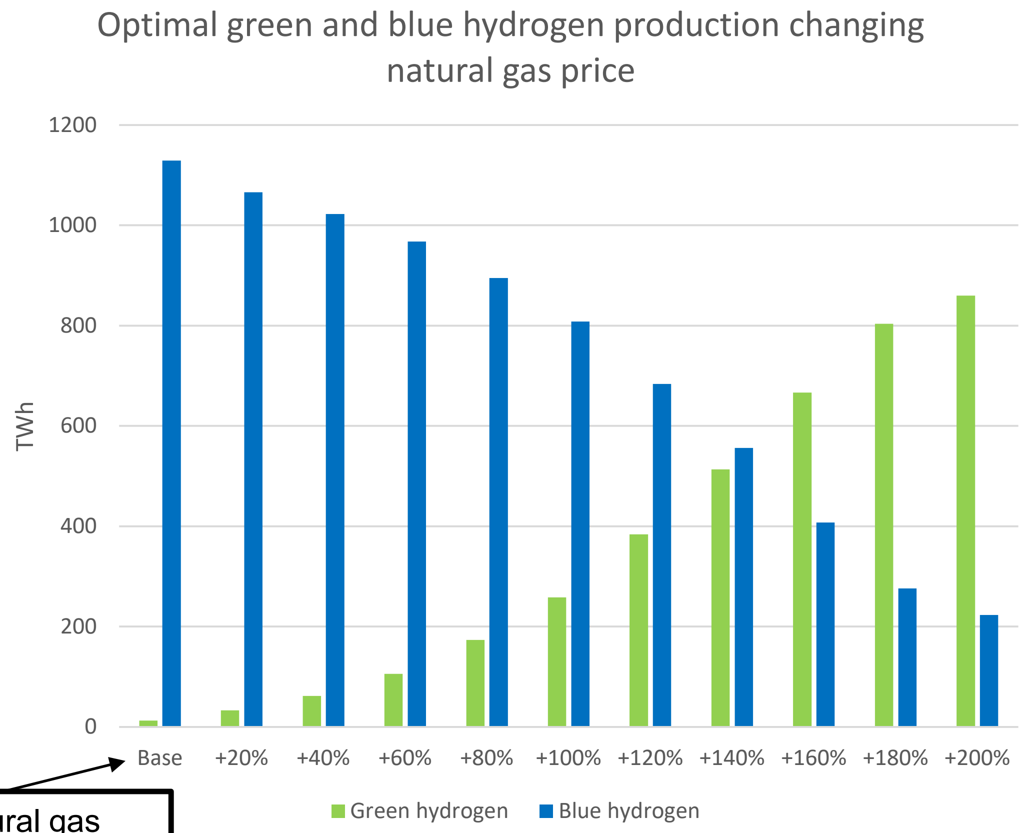
- System costs will be higher with increasing shares of green hydrogen
- Green hydrogen production will require massive renewable capacity investments, exhausting available potentials for low-cost technologies in many regions
- Northern and Southern Europe are particularly suited for renewable and electrolyzer investments due to good renewable potentials and low power prices
- A mix of blue and green hydrogen will reduce electricity price variability and increase the robustness of the energy system

Funding for this study was provided by the Research Council of Norway through the project ‘Norway in the European green transition - Strategies and policy measures combining cost-effective emission reduction with high acceptability’ [NRF-335878]

Thank you!

RESULTS: Green hydrogen increases system costs and requires significantly higher natural gas prices to outcompete blue hydrogen





2040 Natural gas price: 52 EUR/MWh