Hydrogen production mix and European trade flows: The impact of hydrogen certificates as support of green hydrogen production

Danish Energy Agency November 11, 2021

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SuperP2G and MSc thesis at DTU

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2. Hydrogen demand and certificates for green hydrogen
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Background

- Natural gas is a key component of the EU energy system. It accounts for 23,5% of the EU primary energy consumption.
- Present high natural gas prices highlights the challenges from this dependence on top of climate issues
- Hydrogen and other renewable gases can help in the energy transition by substituting natural gas in industry and later liquid fuels.
- Hydrogen demand is today mainly used as feedstock for industrial/chemical products
- For 2030 this traditional hydrogen demand and some new demand for energy purposes can be supplied by at least 3 different technologies with very different emission impact
- Grey, blue and green hydrogen production will compete depending on natural gas prices, ETS quota prices, electricity prices and hydrogen transmission capacity and cost

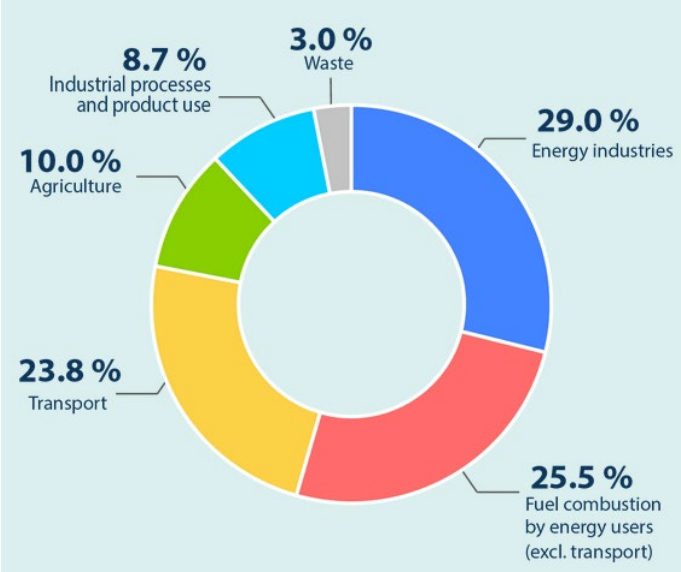


Figure 1. EU GHG emissions by source.

Green hydrogen competition with blue hydrogen and in natural gas substitution (low gas prices)

Break-even price according to Moraga et al.:

- Green hydrogen: 83 €/MWh.
- Biomethane from anaerobic digestion: 100 €/MWh.
- Natural gas: 20 €/MWh.

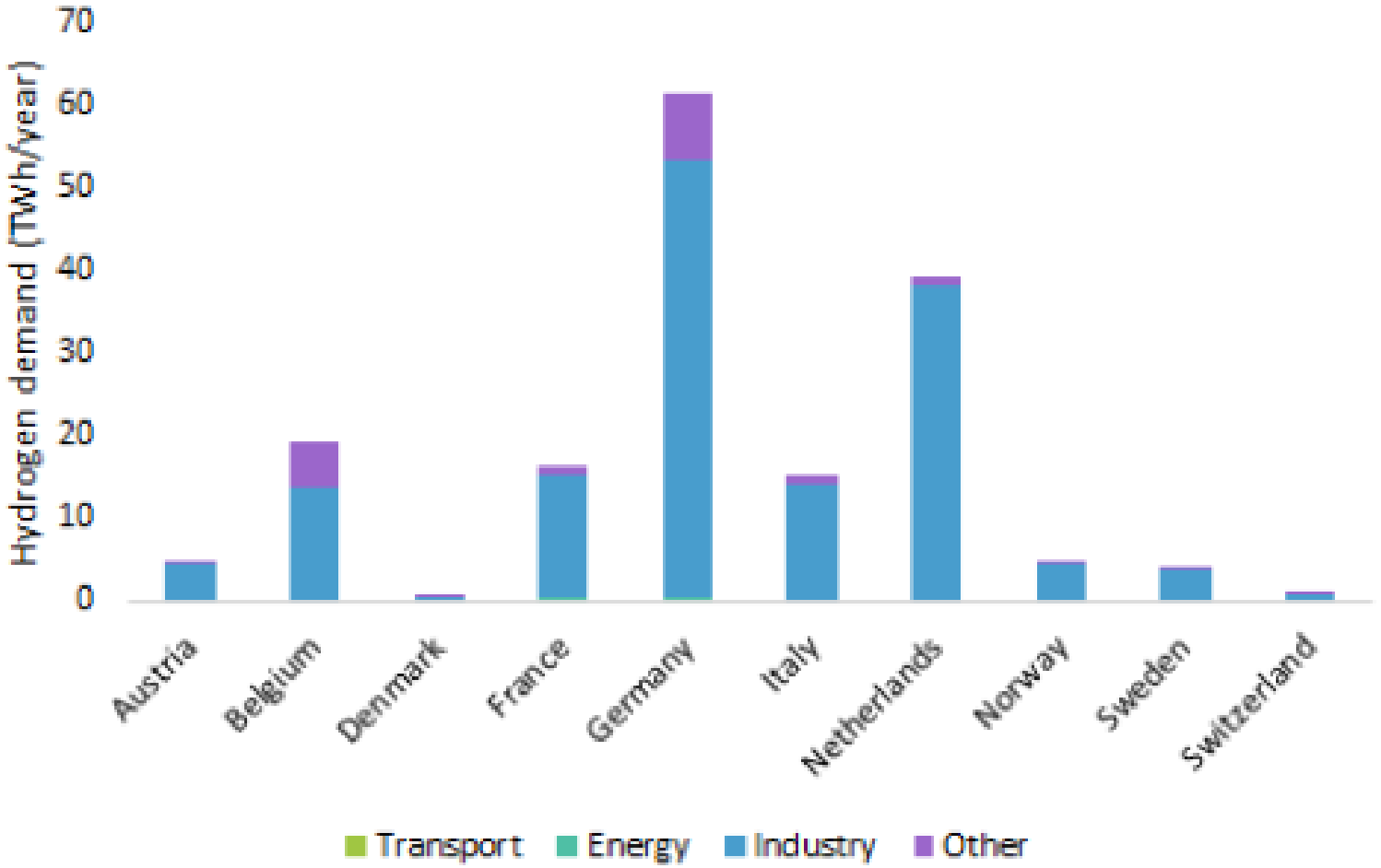
Under the techno-economical conditions until recently, renewable gases including green hydrogen are in an unfavourable position compared to fossil fuels.

Increasing ETS quota prices and additional regulatory measures as green hydrogen certificates may help green hydrogen becoming competitive versus grey and blue hydrogen.

This analysis focus on the impact of two regulatory aspects: green hydrogen certificates and taxes/quota prices. The energy system model Balmorel is used to simulate and optimise the energy system in 10 European countries.

The analysis include pipeline transport for natural gas and hydrogen but no other hydrogen transport technologies.

Current hydrogen demand



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Balmorel

- Energy system optimisation model that includes: electricity, heating and partly gas and renewable gases.
- Coverage of power sector is quite detailed, heating also but much less detail for end-use sectors.
- It performs hourly optimisation of generation, transmission based on exogenous demand assuming perfect competitive markets.
- Geographical resolution: It covers in this version 10 countries divided into more regions.
- Temporal resolution is focused on power sector balance (hours).

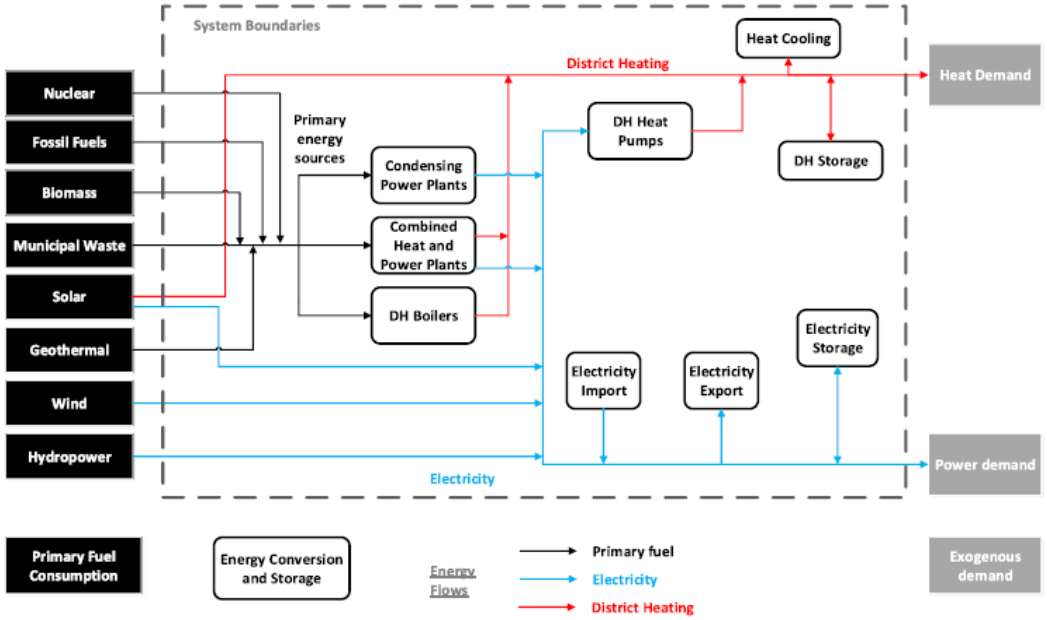


Figure Balmorel for electricity and heating.

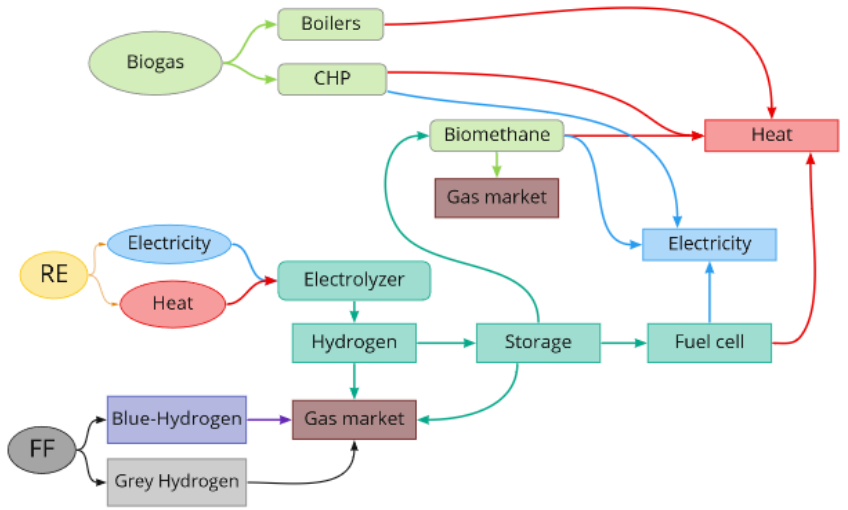


Figure Balmorel for renewable gases.

Model characteristics

- Countries included in the model for this analysis: Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden and Switzerland.
- Four representative weeks were considered to simulate 2030 and 2050 in order to reduce computational time.
- Most of the countries have only one region, except for Germany that has 4, Denmark has 2, Norway has 5 and Sweden 5.

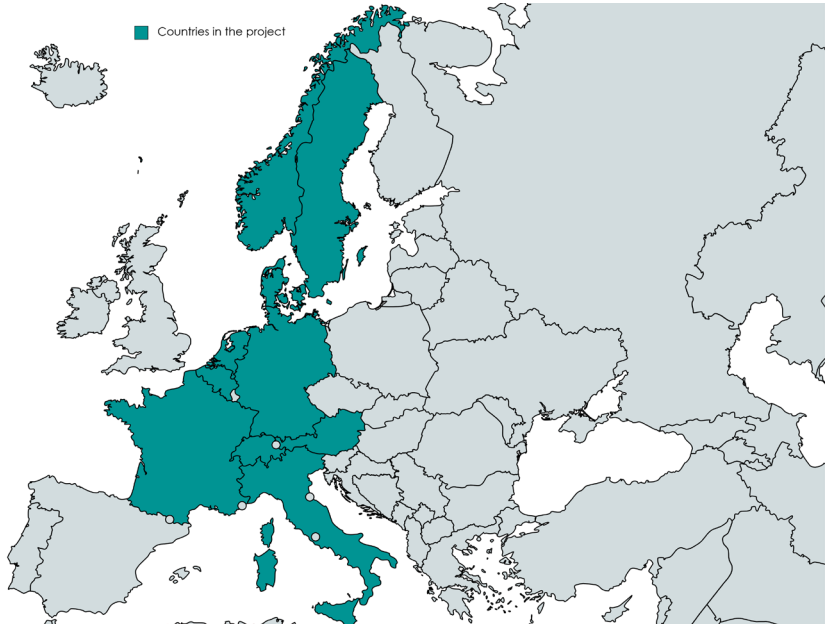
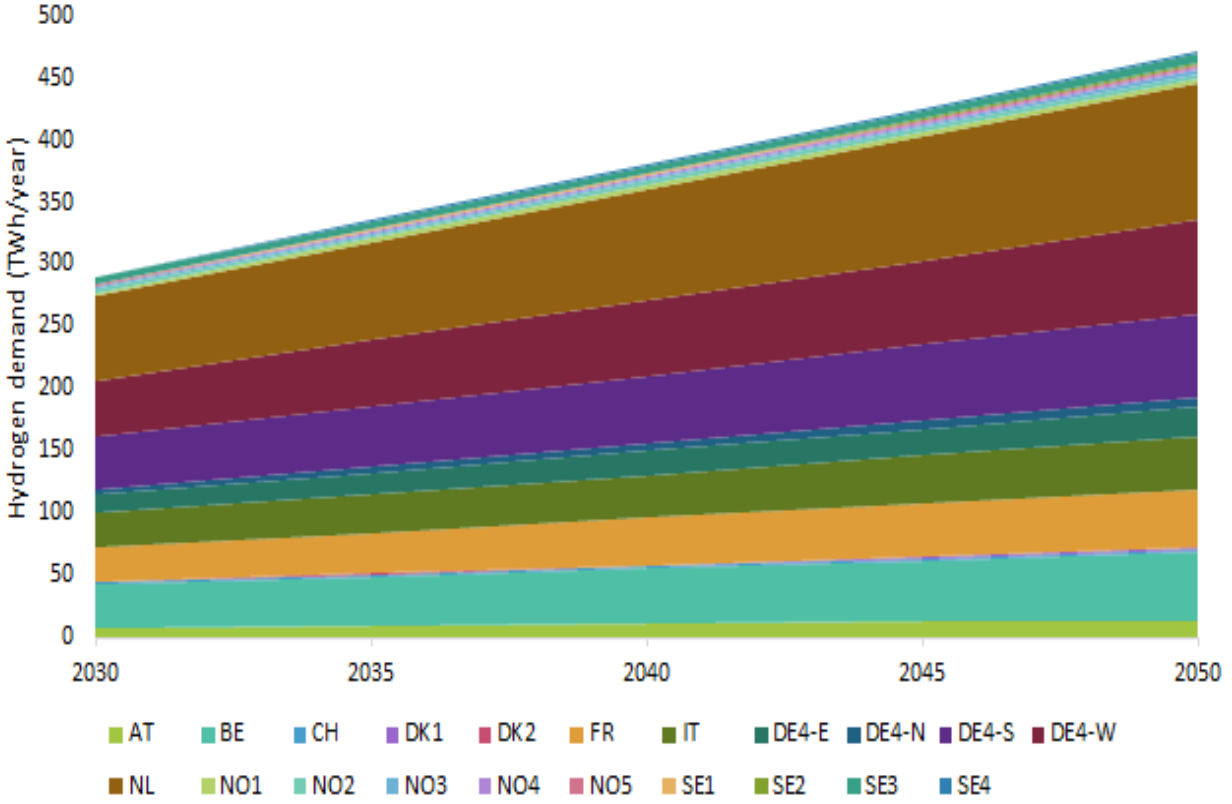


Figure. Countries included in the model.

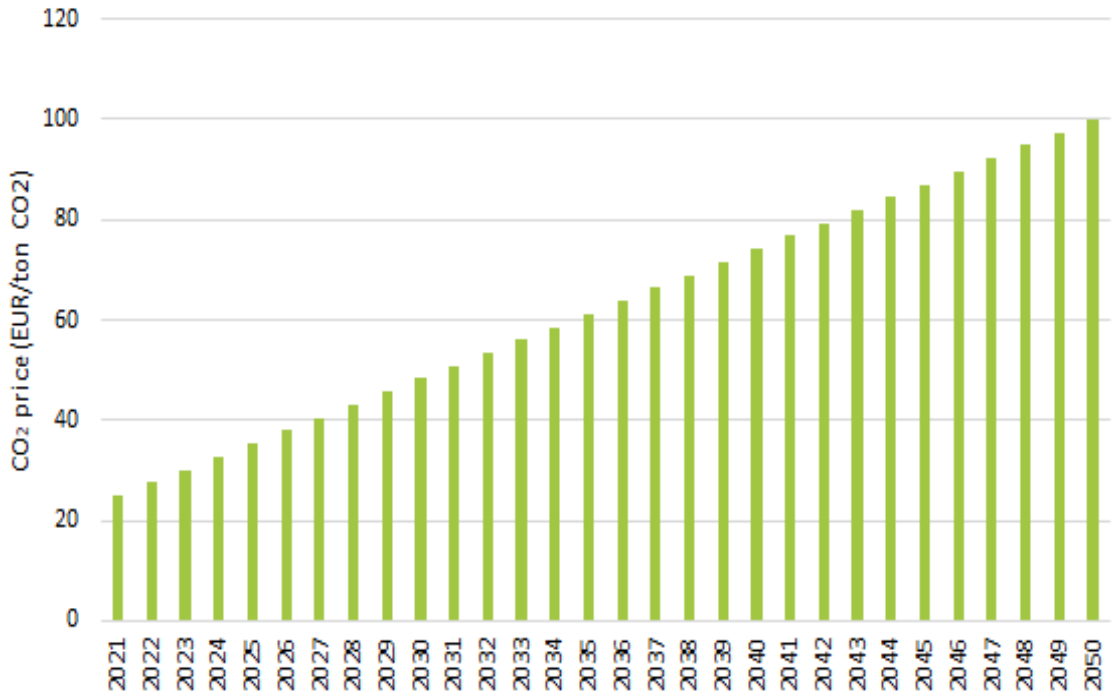
Main assumptions - hydrogen demand

- Future hydrogen demand: The current distribution of demand among the countries was used for future hydrogen demand.
- The annual hydrogen demand in the hydrogen roadmap Europe [7] was taken as reference. Germany and Netherlands are the countries with the largest demand, while Switzerland and Denmark have almost no demand.



Main assumptions - taxes

- Taxes are applied to all fossil fuels and are implemented in two ways:
  - Environmental taxes: They simulate the Emission Trading System and account for the CO2 emissions of fossil fuels. This level was set to 48 €/tonCO2 in 2030 and 100 €/tonCO2 in 2050.
  - Fuel taxes: Two distinctions were made, fuel taxes for heating use and for electricity use. In 2030, it was considered that all countries will have the current average level and in 2050 rates will have doubled



Main assumptions - certificates and costs

- Certificate price for green hydrogen: 2 €/MWh, implemented by reducing the production cost of green hydrogen.
- No certificate value included for blue hydrogen.
- Transmission costs: 1.5 DKK/MW/km according to Danish Energy Agency [8] .
- Possible pipeline connections based on the European hydrogen backbone study.
- Conversion cost of existing natural gas pipelines: 30% of the construction of new natural gas pipelines.

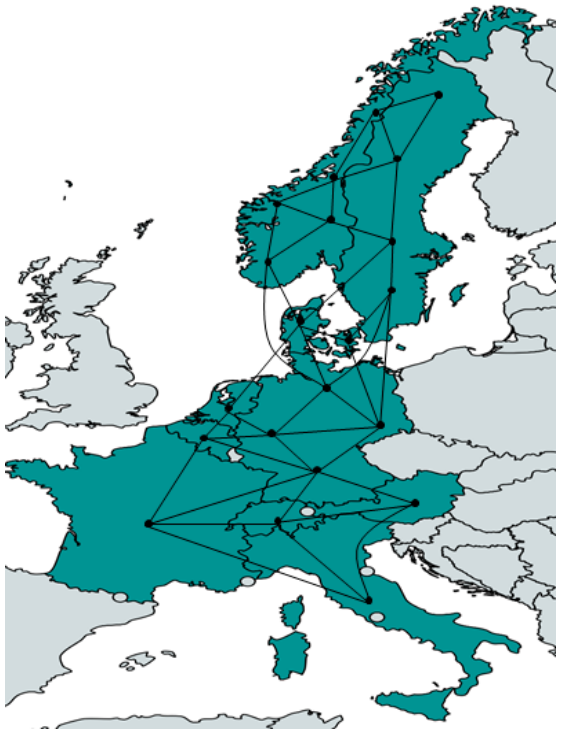


Figure. Pipeline connection.

Scenario variations

- Scenarios were formulated to compare tax elements, certificates and pipeline cost/options. The main assumptions and cost consequences for the base scenario are shown in the table below.
- Scenarios for taxes: all tax, CO2 tax, fuel tax and no tax.
- Scenarios for certificates: No certificate and certificate compared.
- Scenarios for hydrogen pipeline infrastructure: Optimal and restricted. In the optimal scenario, the maximum capacity for conversion is not constrained. In the conversion restricted, it is set to 60% of existing gas pipelines.

Table. Main assumptions and implications for cost in the base scenario.

Parameter	2030	2050	Unit
Fuel cost - blue hydrogen	9	10	€/GJ
Fuel cost - grey hydrogen	11.5	15.1	€/GJ
Fuel cost - biomethane	12	10	€/GJ
Fuel cost - natural gas	7.1	8.9	€/GJ
Carbon price	48.3	100	€/tonCO_2
Natural gas tax-heating	2.9	5.79	€/GJ
Natural gas tax-electricity	3.7	7.41	€/GJ
Cost of conversion natural gas pipes	30 %	30%	%

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Base scenario: electricity and heating

- The electricity sector is already decarbonized in 2030.
- In the heating sector, electrification is progressing. In 2030, only 5% of the heating is from fossil fuels.
- In 2050, the heating sector is decarbonized and the share that was fossil fuels is now biomethane and biogas.

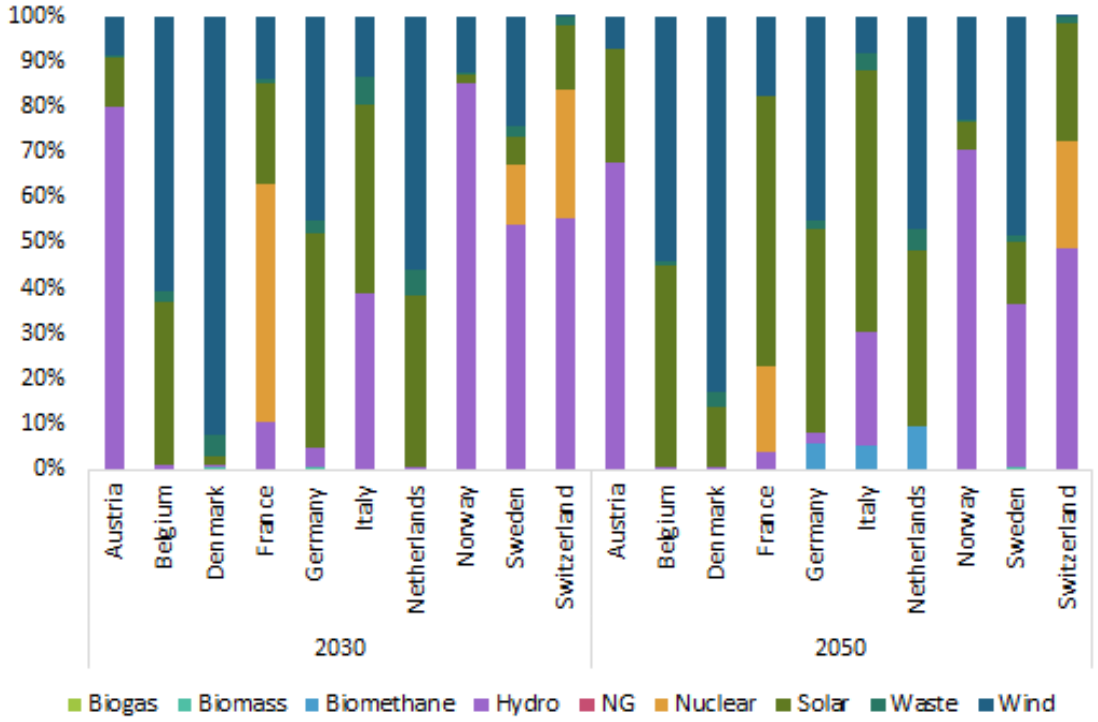

Figure. Electricity mix.

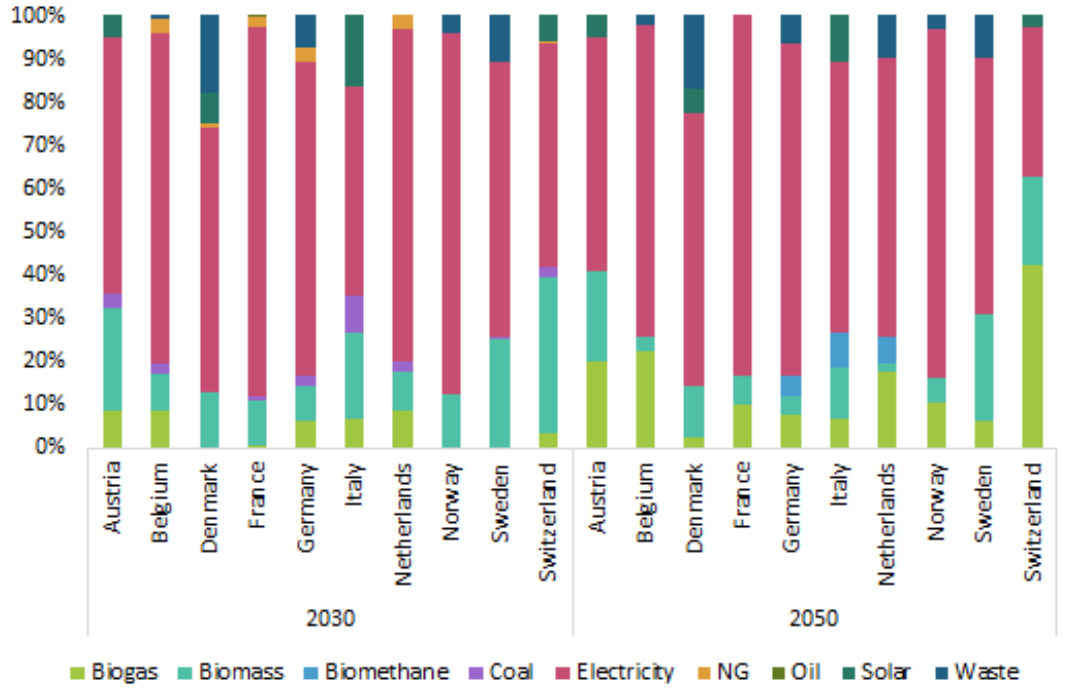

Figure. Heating mix.

Base scenario: hydrogen

- Hydrogen production in 2030 is located following the demand and most of the hydrogen production is blue (79%), green is only produced in Norway, Sweden and France. Grey hydrogen represents only 4%.
- In 2050, all the hydrogen is green and is produced mainly in France. The green hydrogen production is highly dependent on electricity prices, and these are endogenously determined by the model.

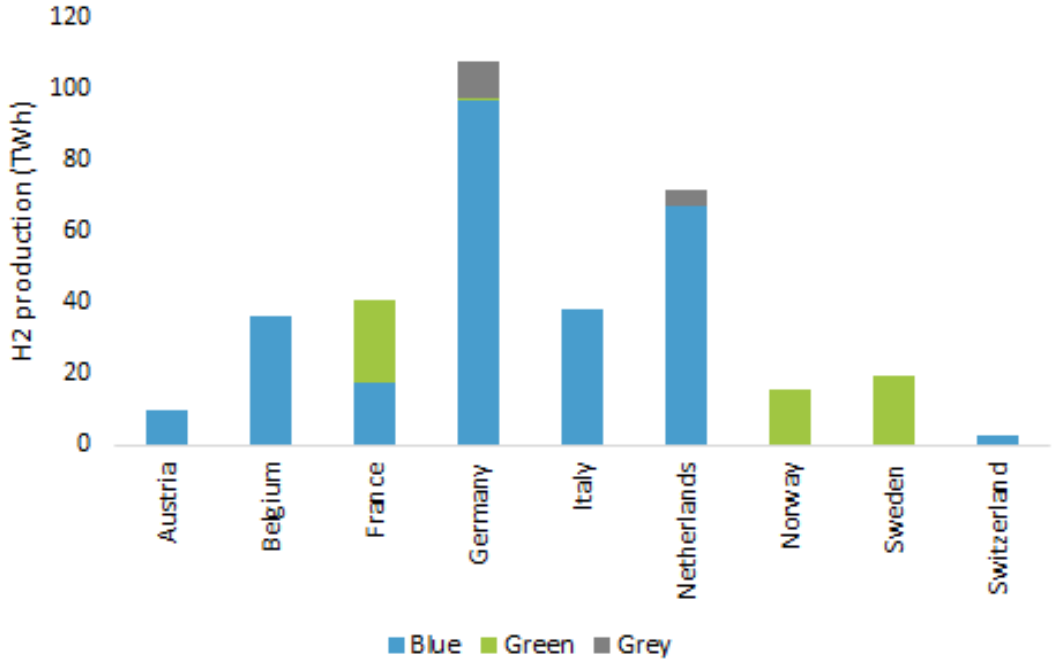

Figure. Hydrogen production 2030.

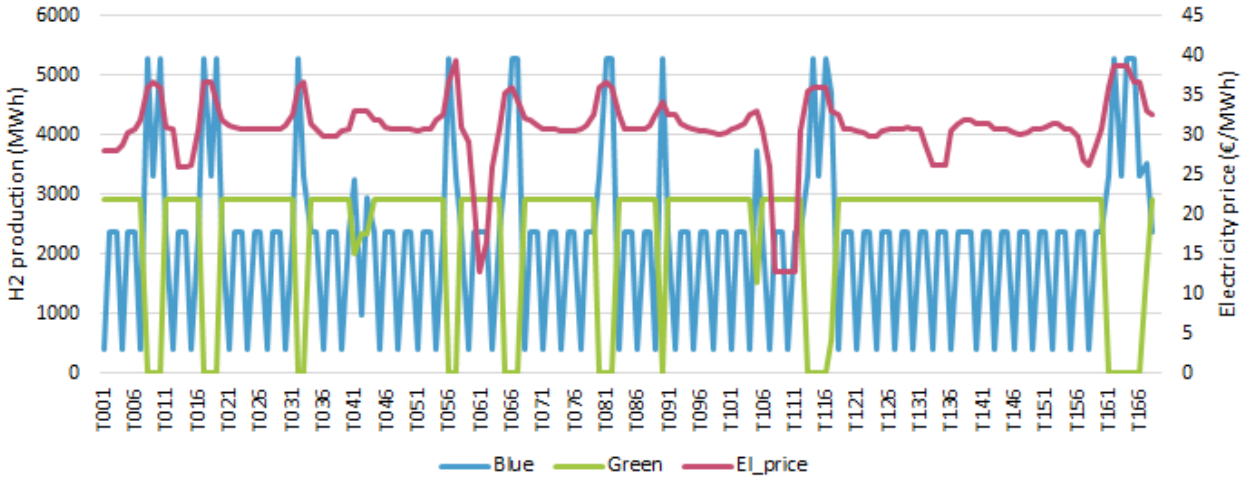

Figure Hydrogen production and electricity price variation in time. France, week 1, 2030.

Hydrogen production mix in certificate scenarios

- Without certificates, the production is located where hydrogen demand is found
- Without blue hydrogen accounts for most of the production namely 79%, green hydrogen 17% and grey 4%.
- Certificates substantially changes the hydrogen production mix for 2030 from blue to green hydrogen
- By adding a certificate, the production mix and location is shifted and the countries with cheaper electricity price have higher production. The green hydrogen share becomes 83% and blue share 17%.

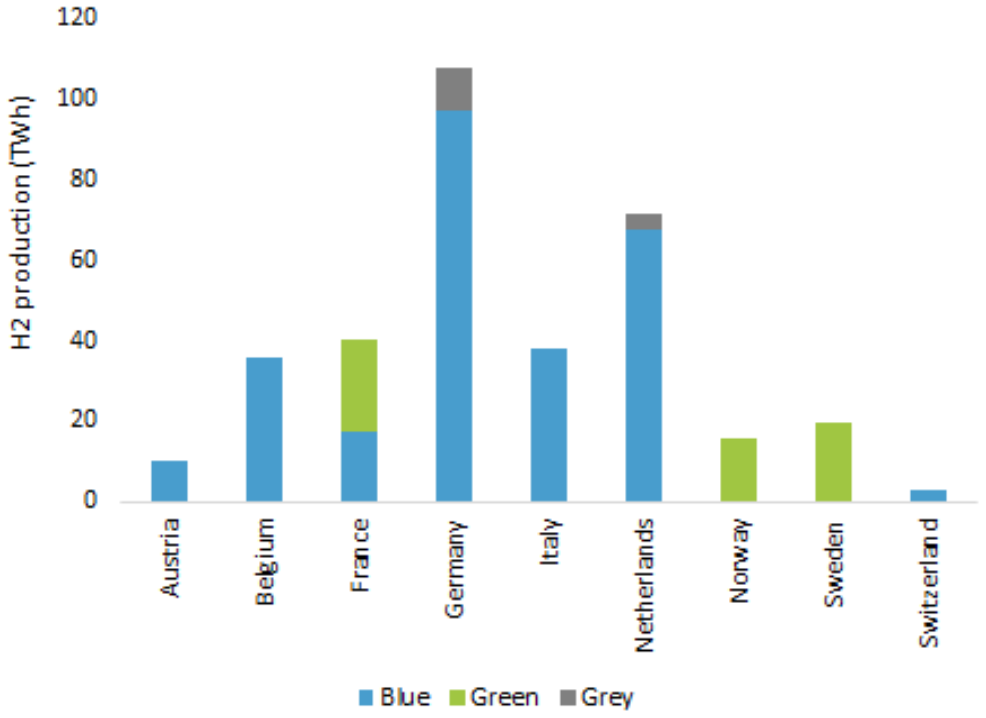

Figure. Hydrogen production without certificate.

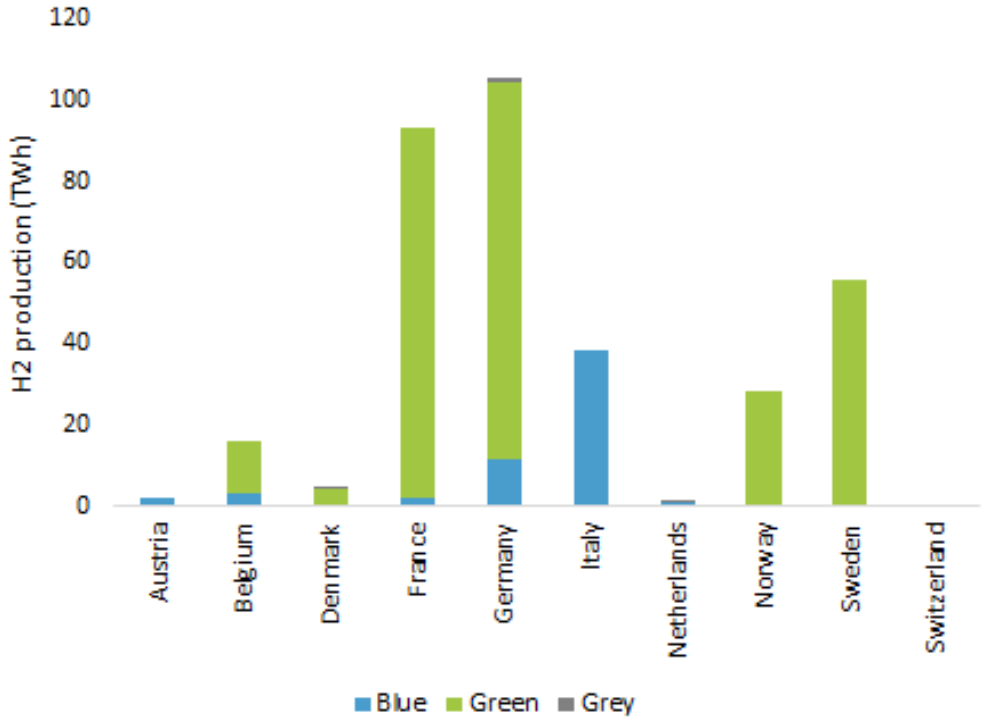

Figure. Hydrogen production with certificate.

Hydrogen transmission/trade in certificate scenarios

- Hydrogen net exports without certificates are only 15.5 TWh (4.5% of the total production). This is only green hydrogen going from Sweden and Norway to Denmark and Germany.
- With certificate, the net exports increase to 32% of the production. France is the main exporter.
- The countries importing hydrogen are Germany, Netherlands and Austria.

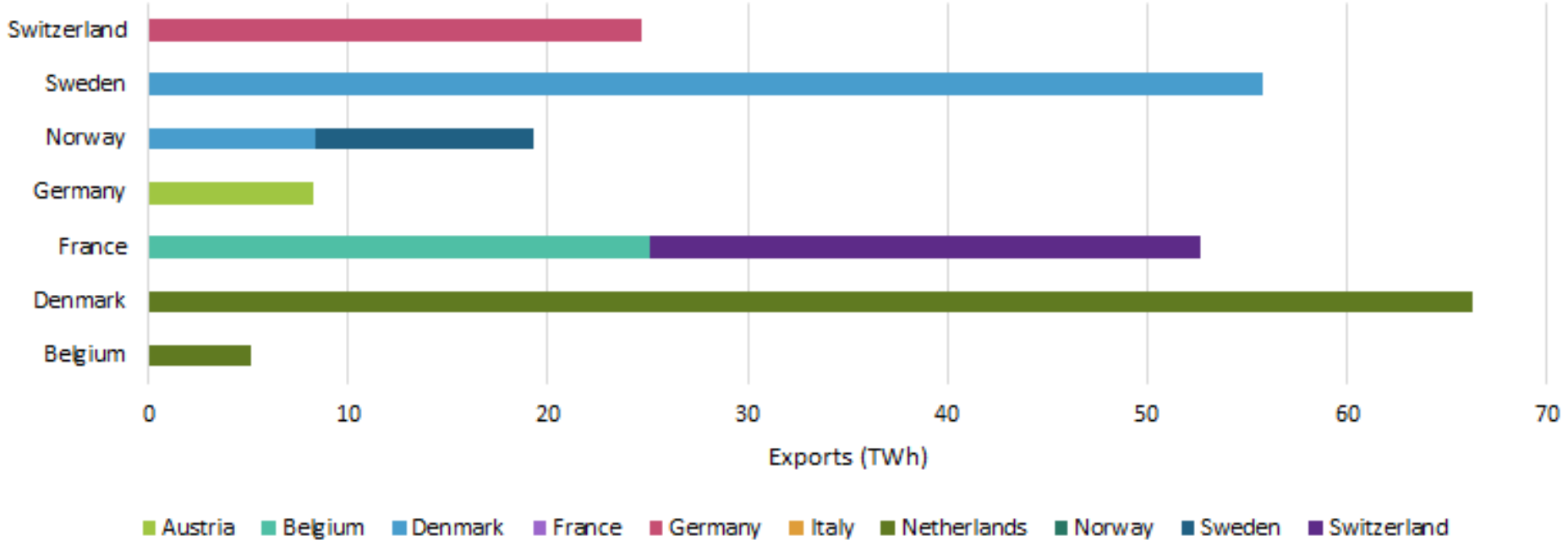

Figure. Gross hydrogen transmission flows in 2030. Scenario with certificate

Carbon price and fuel tax scenarios

- Fuel taxes are not applied to hydrogen, therefore there is no difference. Without taxes, grey hydrogen dominates the market in 2030. Including CO2 tax, the distribution change and blue accounts for a large share and green for a smaller share.

- For heating, in a scenario without taxes, coal and natural gas have a significant share of 9% and 19% respectively for 2030.

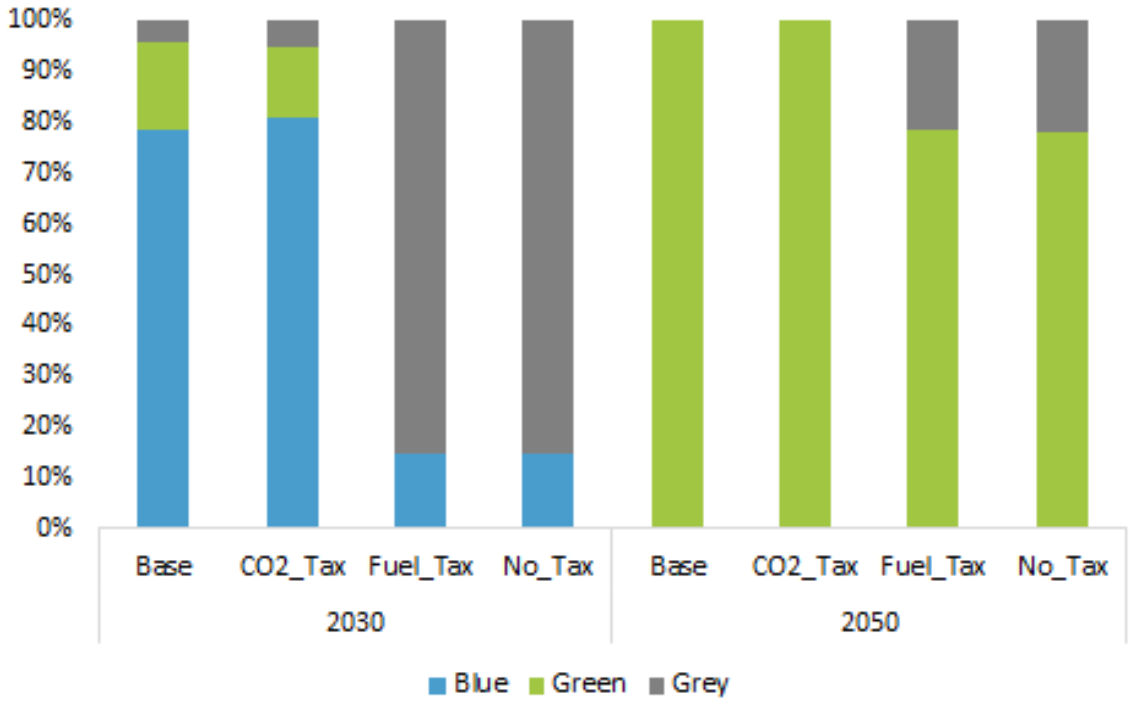

Figure. Hydrogen mix. Tax scenarios.

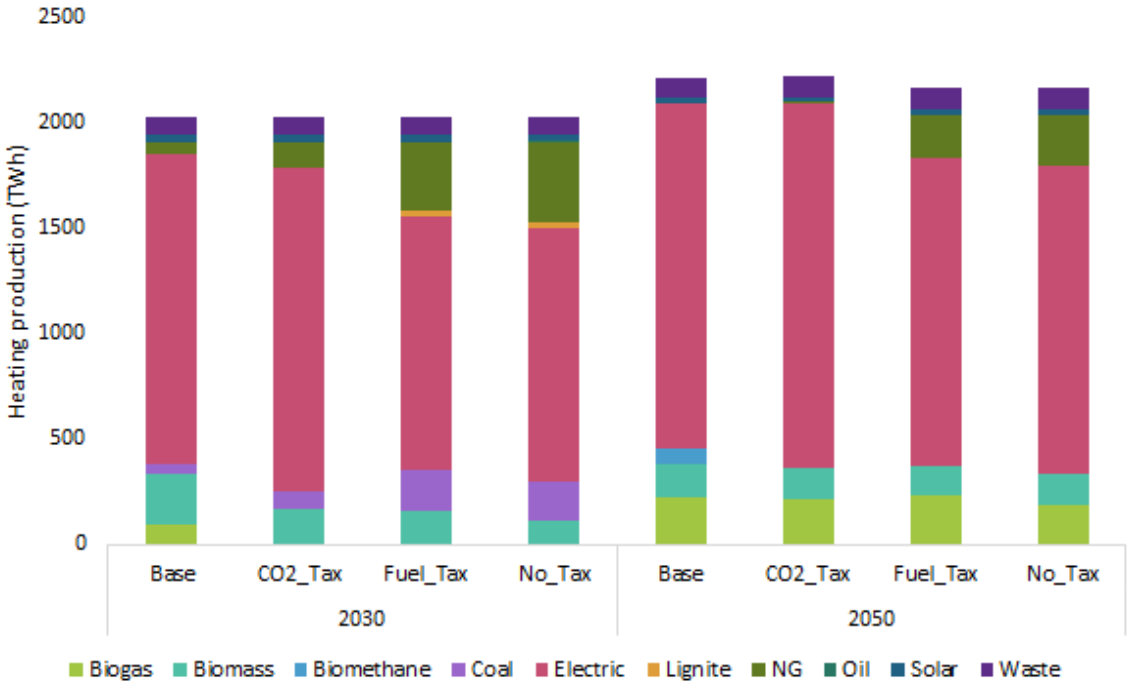

Figure. Heating mix. Tax scenarios.

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Sensitivity analysis - gas price and ETS price

Environmental tax/ETS price 2030
Base: 48 €/tonCO_2

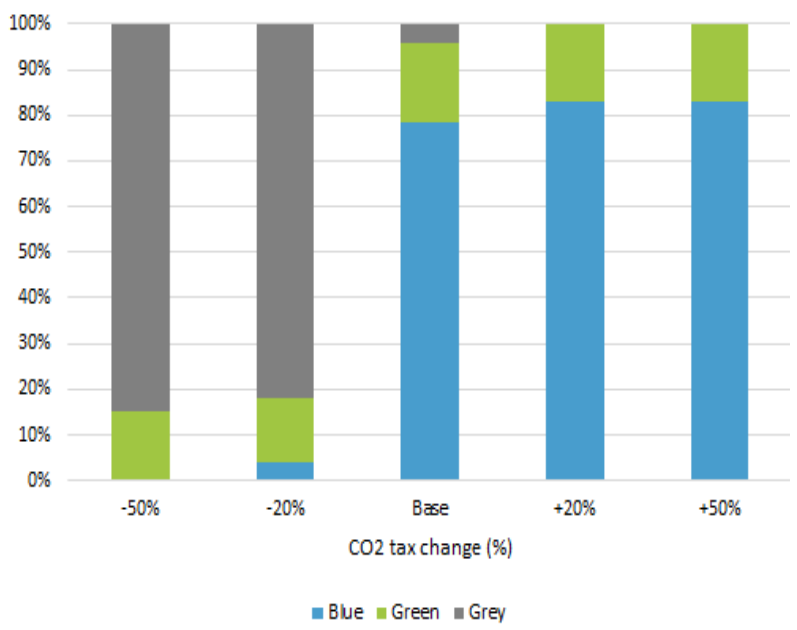

Figure. Hydrogen mix variation with CO2 tax.

Natural gas price
Base: 7.1 €/GJ

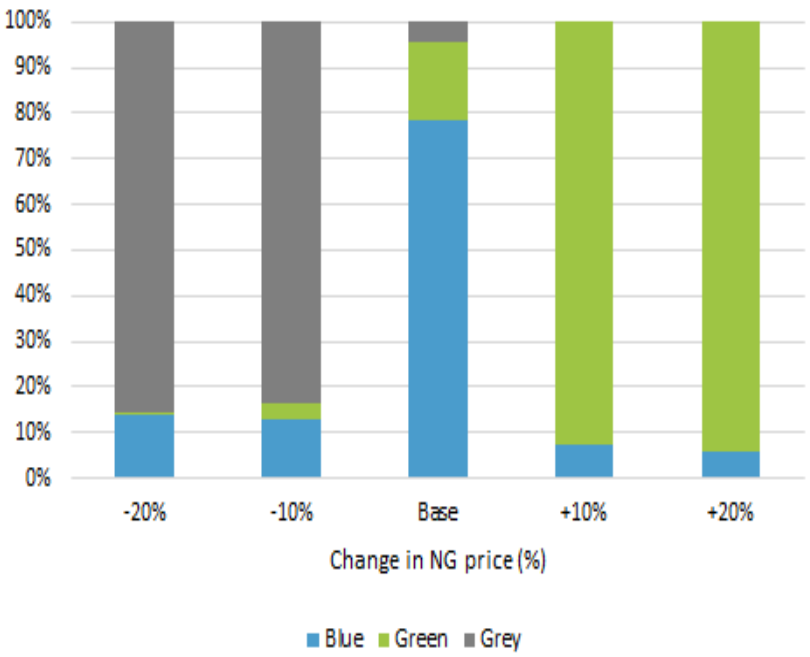

Figure. Hydrogen mix variation with natural gas price.

Natural gas price
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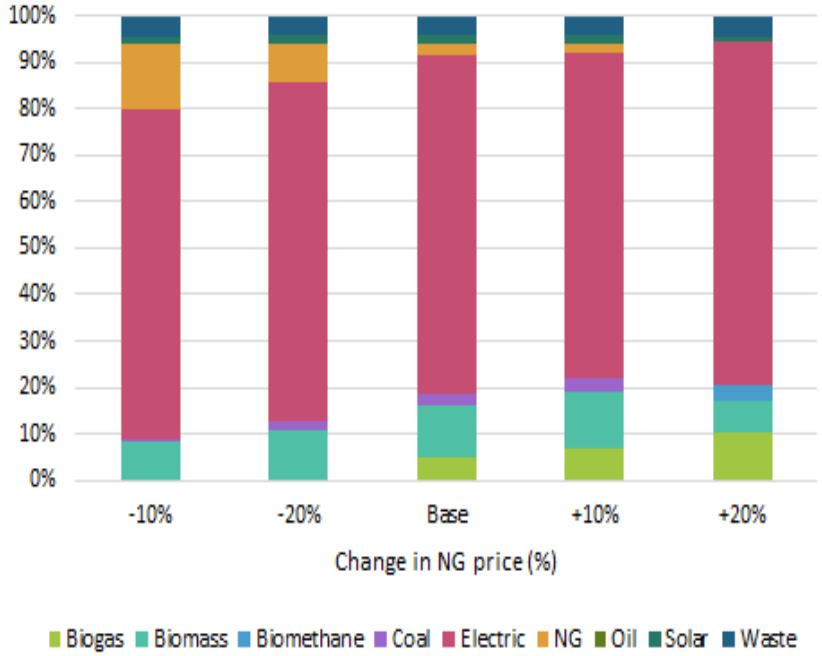

Figure. Heating mix variation with natural gas price.

Sensitivity analysis - certificate price

Hydrogen certificate
Base: 2 €/MWh

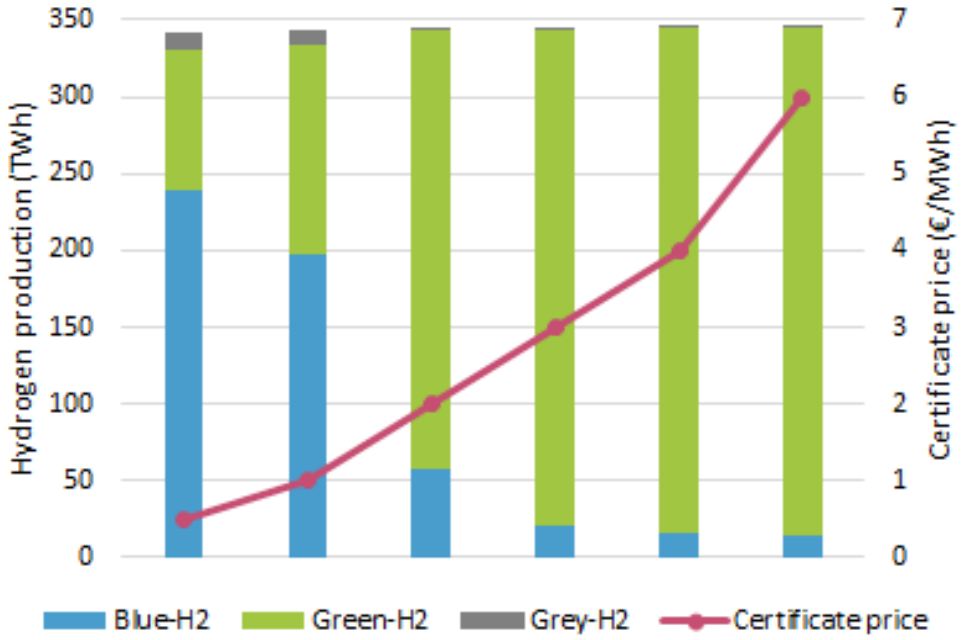

Figure. Variation of hydrogen production with certificate level.

Hydrogen certificate
Base: 2 €/MWh

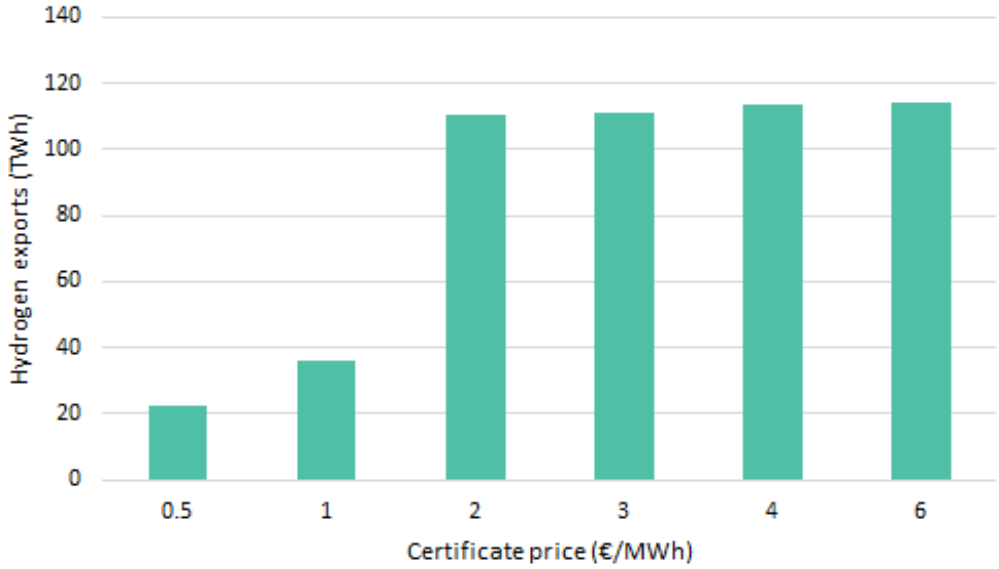

Figure. Variation of net hydrogen exports with certificate level.

Conclusions

- Hydrogen production mix in Europe depends on ETS quota/CO2 prices, natural gas prices and electricity price.
- In 2030 hydrogen will be produced mainly where the demand is and by blue and a bit of green hydrogen technology.
- The CO2 price ensure that blue hydrogen will be produced instead of grey hydrogen in 2030 in our base scenario.
- Using green hydrogen certificates as a support instrument could increase green hydrogen considerably.
- With a certificate of 2 €/MWh, green hydrogen share increases from 17% to 83%. This support also increases considerably the trade of hydrogen across countries due to electricity price differences.
- The countries exporting hydrogen are France, Sweden and Norway and the importing ones are Netherlands, Germany, Austria and Belgium.
- Sensitivity analysis show that also gas prices are critical for the switch to green hydrogen (+10%)
- Sensitivity show that certificate prices at 1€ or less will not induce a shift to green hydrogen and prices above 2€ will only marginally increase green hydrogen.
- Hydrogen transmission cost affects the hydrogen transmission capacity installed and consequently the transmission flows as well as the share of green hydrogen.

Thank you

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For additional questions or reports
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