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Low-carbon hydrogen imports to Europe as a new pillar to achieve carbon neutrality – An economic analysis of potential hydrogen import pathways to 2050

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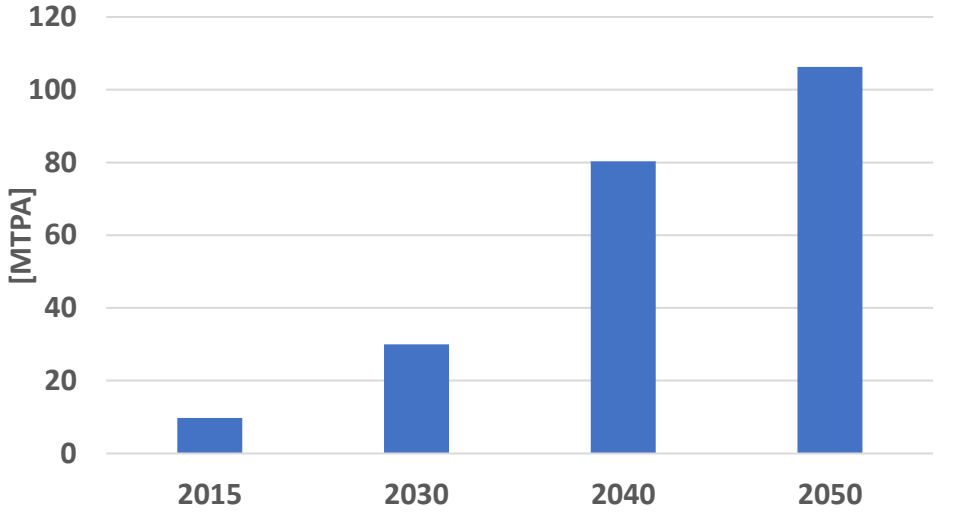
Context and motivation

- The « European Green Deal » sets ambitious climate goals that require actions to be taken - The speed matters.

- Low-carbon hydrogen is set as a pillar to meet emission reduction targets. The improving economics of green hydrogen open up a variety of possible supply options that are still exposed to significant techno-economic and policy uncertainties.

Projected evolution of hydrogen demand in the EU*



Hydrogen roadmap Europe & Hydrogen4EU

- The economic efficiency of low-carbon hydrogen supply is fundamental to guarantee international competitiveness. As the availability of sufficient and competitive low-carbon hydrogen resources within the EU exists is uncertain, imports are foreseen and anchored in the EU hydrogen strategy.

- Green hydrogen technologies need significant financial support to reach marketability. This should be effective and justifiable.

- Security of supply so that the economy does not run the risk of supply interruptions.

*incl. GBR

Research question and key findings

What are the economic drivers for importing low-carbon hydrogen to the EU?

Key findings:

- Retrofitting of exiting natural gas infrastructure is a key lever
- Requirement to rapidly scale up green hydrogen production capacity in favourable exporting countries
- Risk of high market concentration resulting in concerns about security of supply

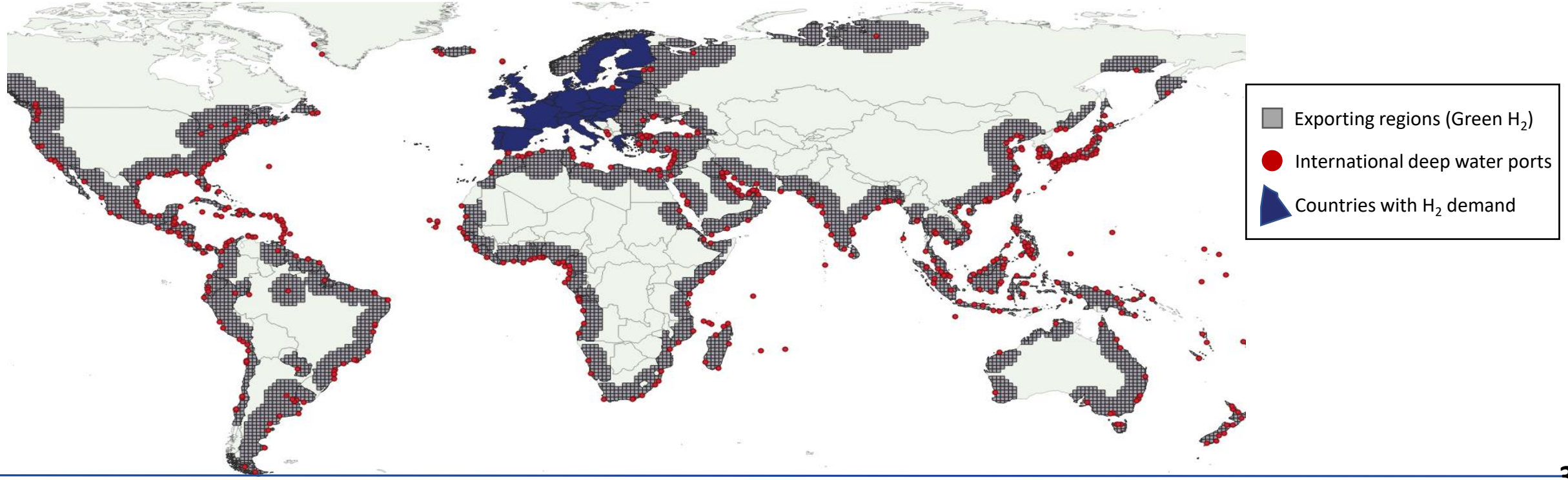
Approach

Quantitative analysis:

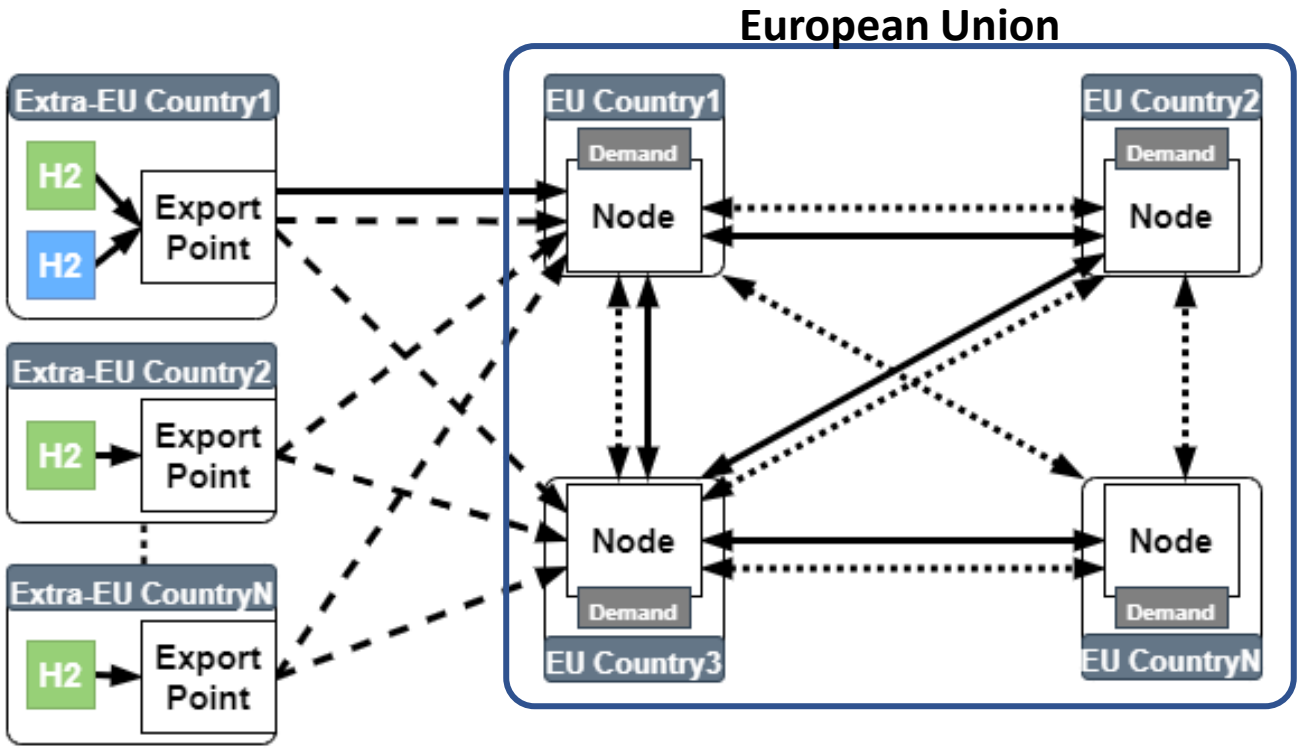
- Modelling framework combining mathematical optimization and GIS analysis
- Linear optimization model that minimizes overall supply cost:

$$\min: \quad c_{Total} = c_{Transportation} + c_{Conversion} + c_{Production}$$

- Time horizon 2030-2050 (static)
- Global scope in a high spatial granularity
- Volume-based approach to estimate hydrogen import demand



Approach



Upstream

H2 Green H2 (Off-grid: Solar PV, onshore wind, hybrid systems + alkaline electrolyser)

H2 Blue hydrogen (Natural gas + Stream methane reforming)

Midstream

— Pipeline (Gaseous hydrogen)

– – Seaborne (Ammonia and liquified hydrogen)

···· Road (Compressed hydrogen and ammonia)

Downstream

Demand Gaseous hydrogen demand

Approach

1. Step: Analysis of base case

Key settings of base case

Downstream: Share of import volumes set to 50% of demand in Hydrogen4EU study

Costs of midstream technologies (including conversion processes)
- Average costs of in the literature

Retrofitting timeline of exiting natural gas pipelines:
- Based on « European Hydrogen Backbone » study
- Unlimited transfer capacity of intra-EU cross-border interconnectors

Upstream - Green hydrogen:
- Average costs / learning rates in the literature
- Availability of renewables per country based on average global capacity addition between 2015-2019 corrected by both GDP per capita and 2050 emission targets to account for domestic decarbonization.

Upstream - Blue hydrogen:
- Natural gas production prices based on Global Gas Model (GGL)
- Availability of natural gas feedstock is set to 25% of trade in 2018 with respective exporting countries

2. Second: Sensitivity analysis

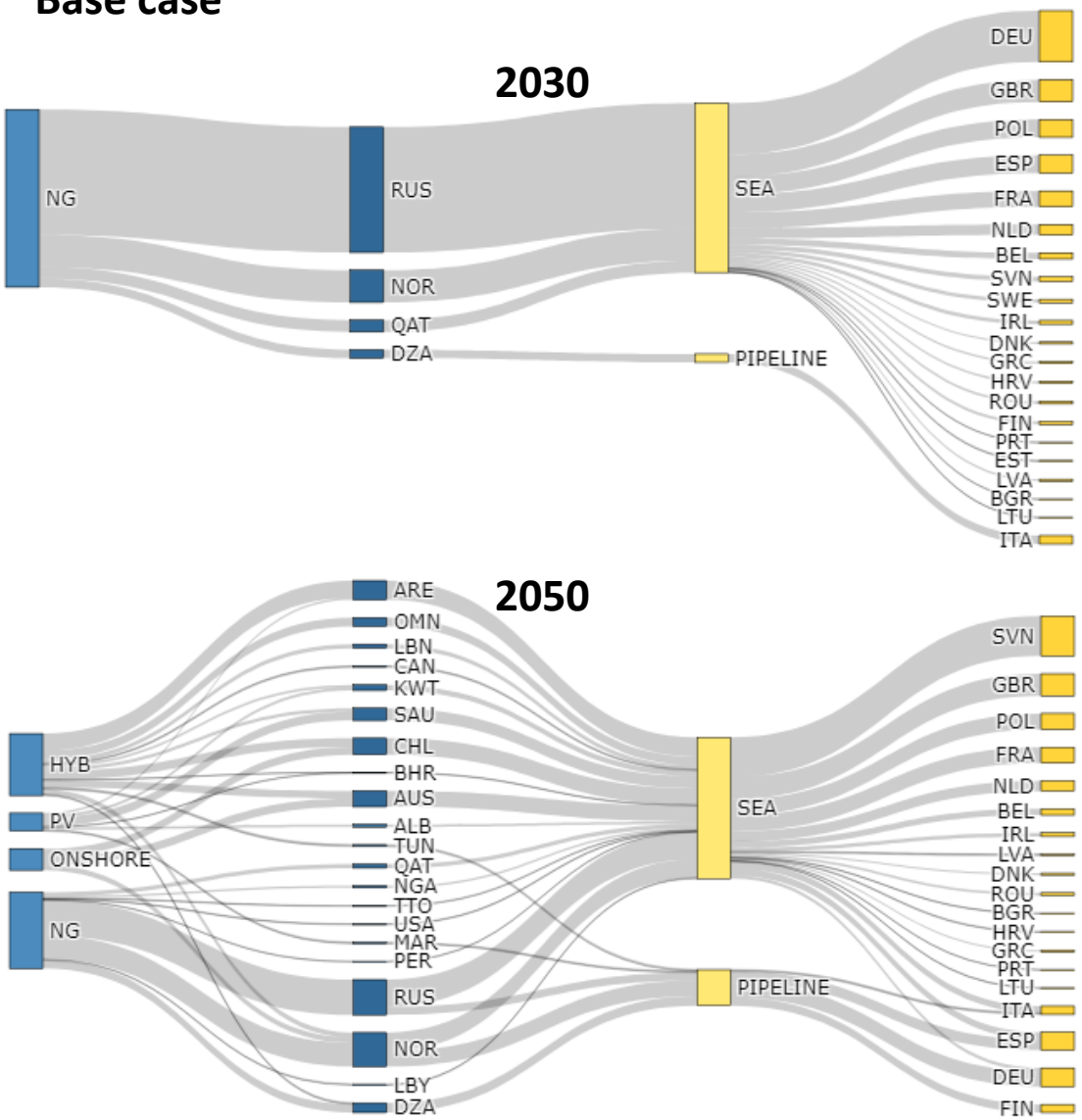
Introduction of sensitivities on (lower/higher range):

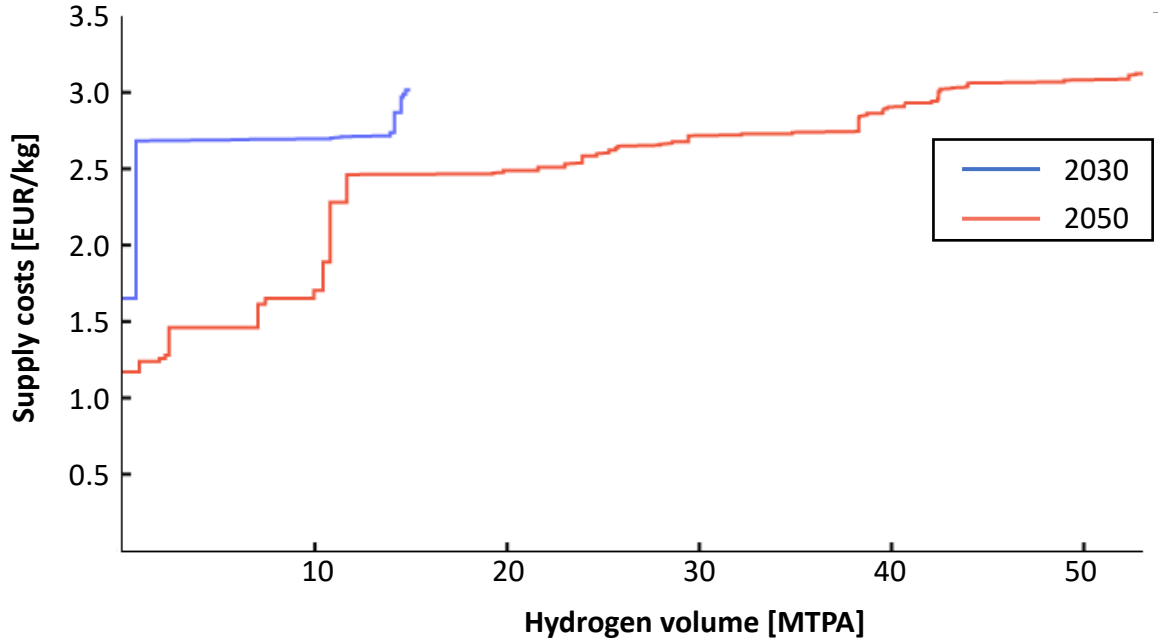
Down stream	• Import share on EU hydrogen demand
Mid stream	• Retrofitting timeline of pipelines • Costs - Seaborne transport of LH2 • Costs - Pipeline transport
Up stream	• Costs - Blue hydrogen / Natural gas • Costs - Green hydrogen technologies • Availability of natural gas • Availability of renewable energies

Assessment of sensitivities on:
- Hydrogen supply costs
- Hydrogen supply structure (Exporting countries, upstream and midstream pathways, etc.)

Key results (1/3) – Base case

Base case





- Increasing share of green hydrogen until 2050
- Number of export countries grows from 4 to 21
- Pipeline imports take bigger share over time
- The number of import countries decreases slightly
- The slope of the supply cost curve declines

Key results (2/3) - Sensitivities - Impact on Supply Costs

- The availability of competitive EU hydrogen reduces market share of imports and hence, the supply costs of imported H_2
- Fast decreasing green hydrogen technology costs result in an increasing competitiveness of imports in mid- and long-term
- The availability of both renewable energies and natural gas increases the import competitiveness in mid-term and long-term

- Average weighted supply costs in the base case

Unit	Y2030	Y2040	Y2050
[EUR/kg]	2.66	2.62	2.48

- Relative change in average weighted supply costs compared to the base case

Parameter	Unit	High			Low		
		Y2030	Y2040	Y2050	Y2030	Y2040	Y2050
Import share on EU hydrogen demand	[%]	1	13	10	0	-22	-16
Cost - Seaborne transport of LH2	[%]	0	0	1	0	0	-4
Cost - Pipeline transport	[%]	0	0	0	0	0	0
Timeline of retrofitting	[%]	2	5	0	-14	0	0
Cost - Blue hydrogen / natural gas	[%]	4	2	2	-4	-3	-2
Cost - Green hydrogen technologies	[%]	0	10	16	0	-10	-15
Availability of natural gas	[%]	0	-14	-9	46	28	17
Availability of renewable energies	[%]	0	-17	-17	0	3	5

Key results (3/3) - Sensitivities – Impact on Set of Exporting Countries

- An increasing availability of competitive EU hydrogen increases the market concentration of exporting countries
- Decreasing natural gas resources relieve the concentration of exporters in the supply structure
- With improving capabilities of countries to scale up green hydrogen production, market concentration increases

- HHI index of the base case and the sensitivities

Parameter	Unit	High			Low		
		Y2030	Y2040	Y2050	Y2030	Y2040	Y2050
Base case	[#]	5363	1389	1168	5363	1389	1168
Import share on EU hydrogen demand	[#]	3382	1281	1057	7913	3636	2548
Cost - Seaborne transport of LH2	[#]	5363	1389	1209	5363	1389	1113
Cost - Pipeline transport	[#]	5363	1392	1166	5363	1473	1169
Retrofitting timeline	[#]	5500	1480	1168	5317	1389	1168
Cost - Blue hydrogen / natural gas	[#]	5340	1389	1168	4012	1389	1168
Cost - Green hydrogen technologies	[#]	5363	1826	1246	5363	1512	1091
Availability of natural gas	[#]	7913	3704	2489	2035	1349	1058
Availability of renewable energies	[#]	5363	1933	1993	5363	1856	1570

Conclusion

- The **repurposing of exiting natural gas pipeline** is a key driver for having access to low-carbon hydrogen imports. Long-term planning for the usage of the exiting natural gas infrastructure is essential.

- **Partnerships with non-EU countries** should be established in a strategic and timely manner so that private investments in hydrogen production capacity take place.

- **Financial support might be needed in Extra-EU country** to kick-start the development of green hydrogen production in the short-term and to build up respective local industries.

- **Social aspects on the economic sustainability** of low-carbon hydrogen exports should be kept on the agenda and adequately addressed to ensure that local acceptance is given.

- **Potentially mitigating the risk of security of supply** through import restrictions on certain regions as well as through the repurposing of exiting LNG terminal that allow for access to wider geographical low-carbon hydrogen sources.

Thank you

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References

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- FCH Joint Undertaking, 2019. Hydrogen Roadmap Europe.
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Limits and further work

- Static analysis that does not include dynamic effects on investments nor on the transportation infrastructure. Therefore, the supply cost assessment gives only indications on the evolution of a future hydrogen market structure.
  ➔ Modelling the hydrogen markets with endogenous investments offers further research possibilities

- No endogenous interaction with natural gas markets. However, the results obtained in this study suggest that there is a close link between natural gas markets and hydrogen supply.
  ➔ Assessment of the interaction between the natural gas markets and hydrogen supply.

- Volume-based assumptions on hydrogen imports are assumed that mimic a lack of coordination/ market failure/ delayed exploitation of low-carbon hydrogen within the EU
  ➔ Integrating low-carbon EU hydrogen sources to obtain price-based import assessment

- Only hydrogen as end-product considered in this study. The import economics of other hydrogen-derived products such as ammonia might be different.
  ➔ Adding demands of hydrogen-derived products to the analysis

- Green hydrogen production facilities were entirely considered as off-grid systems. Their connection to the domestic power system might improve their economics.
  ➔ Linking hydrogen supply to electricity markets