Deloitte.

Study on hydrogen in ports and industrial coastal areas

EU Research Days

October 2022

Objectives and tasks of study on hydrogen in ports and industrial coastal areas

Commissioned by

Clean Hydrogen Partnership

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Performed by

Deloitte.

Objectives

Foresight: visibility on the market potential of hydrogen in ports, and a clear roadmap to implement it.

Community building: collaborative resolution of common issues and developing case studies that can act as blueprints to accelerate take-up of financial assistance for hydrogen plans in ports.

Overview of tasks

Report 1

Task 1	**Hydrogen demand and market potential**	November 2022*
Task 2	**Hydrogen supply, storage and distribution**	November 2022
Task 3	**Definition of business models**	November 2022
Task 4	**Case studies**	November 2023
Task 5	**Recommendations on future activities with particular focus on R&I in the short term**	December 2022
Task 6	**Coalition building**	November 2023

The study feeds into the work of the **Global Hydrogen Ports Coalition**, launched at the latest Clean Energy Ministerial (CEM12). This important international initiative brings together ports from around the world to work together on hydrogen technologies.

* Dates refer to expected delivery date of final reports

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Framework for the study

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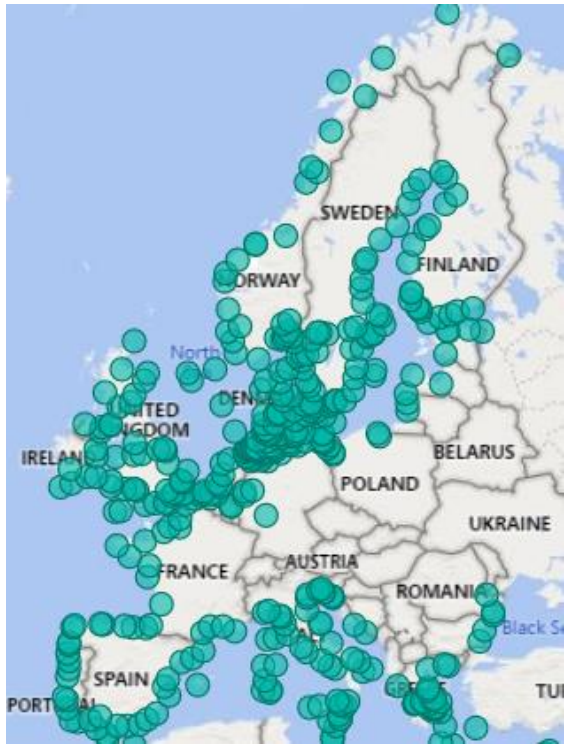
The link between future hydrogen demand and supply with European ports: overview of the general approach

Geographical coverage

Overview of ports in scope



Geographical coverage include ports in Europe, defined as **EU27 + UK + Norway**

Hydrogen demand

- Transport
- Port activities
- Urban areas
- Industries

Hydrogen supply

- Green Hydrogen from onshore and offshore windfarms
- Green Hydrogen hydrogen from solar PVs
- Blue Hydrogen from existing grey Hydrogen production sites
- Imported green and blue Hydrogen

Out of scope: pink hydrogen

Hydrogen business models

Comprehensive overview of relevant business models

Development of case studies

Selection of specific ports and development of case studies

Recommendations

Analysis of technological, safety and non-technological barriers and definition of policy recommendations

Broad stakeholder's representativity*

- Port authorities
- Terminal operators
- Shipyard representative
- Ship owner and operators
- City/municipal authorities
- Heavy industries
- Gas infrastructure operator
- Heavy-duty transport
- Hydrogen and renewable energy producers
- European Commission

*Not exhaustive

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Hydrogen demand
high-level results

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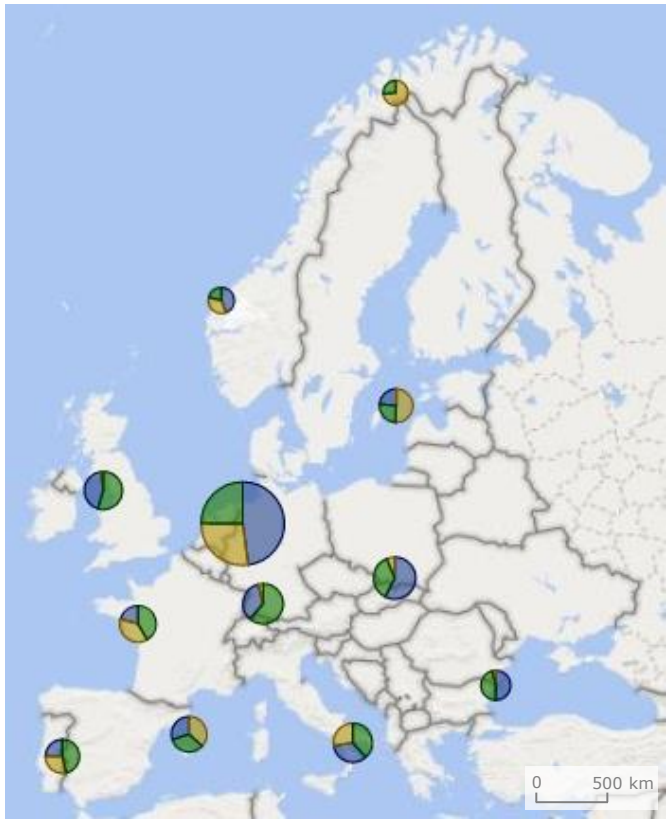
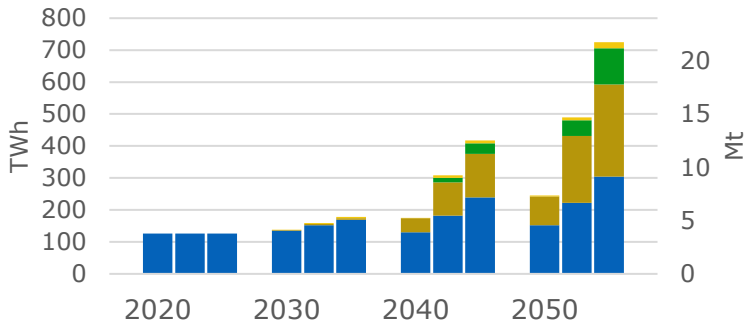
Overview of hydrogen demand projections until 2050 in Europe across all demand subcategories

Hydrogen demand per demand cluster per category – ambitious scenario in 2050

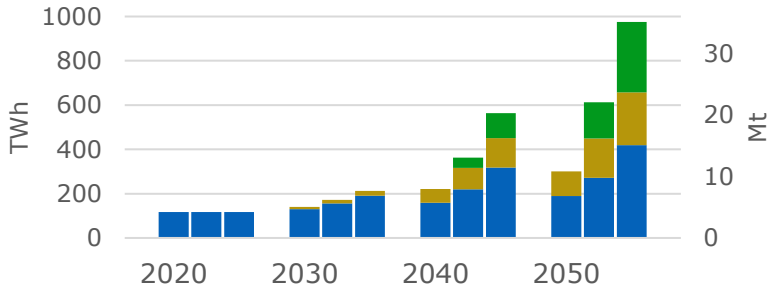


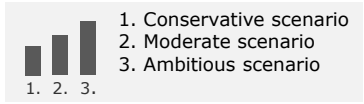
The circles on the map are located in the center of the relevant cluster

Hydrogen demand per category in ports



Hydrogen demand per category outside of ports





Key messages:

- Totals on EU level and per cluster are obtained via **summation of hydrogen demand per individual port and areas outside of ports**
- Low-carbon/renewable hydrogen demand will likely only **start to take off from 2030** onwards. Industry will likely be the first to deploy low-carbon hydrogen, followed by the transport sector and port activities. Finally, buildings in urban areas may adopt hydrogen from 2040 onwards
- In 2030, total hydrogen demand is projected to be between 283 TWh and 389 TWh (8.5 to 11.7 Mt).
- In 2050, total hydrogen demand is projected to be between 545 TWh and 1764 TWh (16.4 to 52.9 Mt).
- By 2050, **industry will likely be the largest demand sector** for low-carbon Hydrogen, followed by transport, urban areas and finally port activities.

Industry Transport Urban areas Port activities

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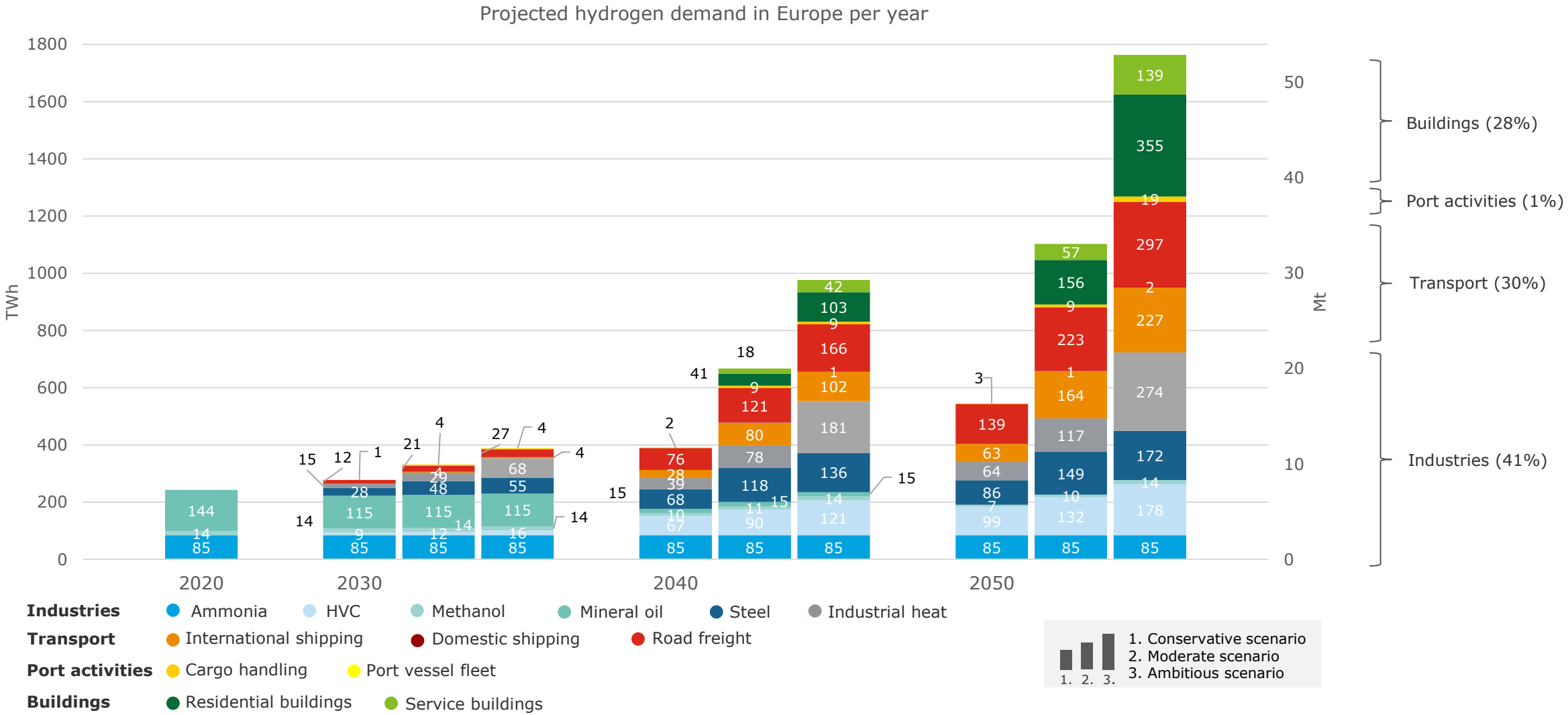
Hydrogen demand in Europe per demand subcategory and scenario for 2020, 2030, 2040 and 2050



Note: The large differences in estimates of future hydrogen demand reflect the great degree of uncertainty that currently exists in the adoption of hydrogen as a replacement for fossil fuels in some sectors, notably the 'Buildings' sectors (heating of residential and service buildings). For all the other sectors in scope of this study (industries, transport and port activities), all three scenarios foresee a role for hydrogen, at least to some extent.

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Hydrogen supply
high-level results

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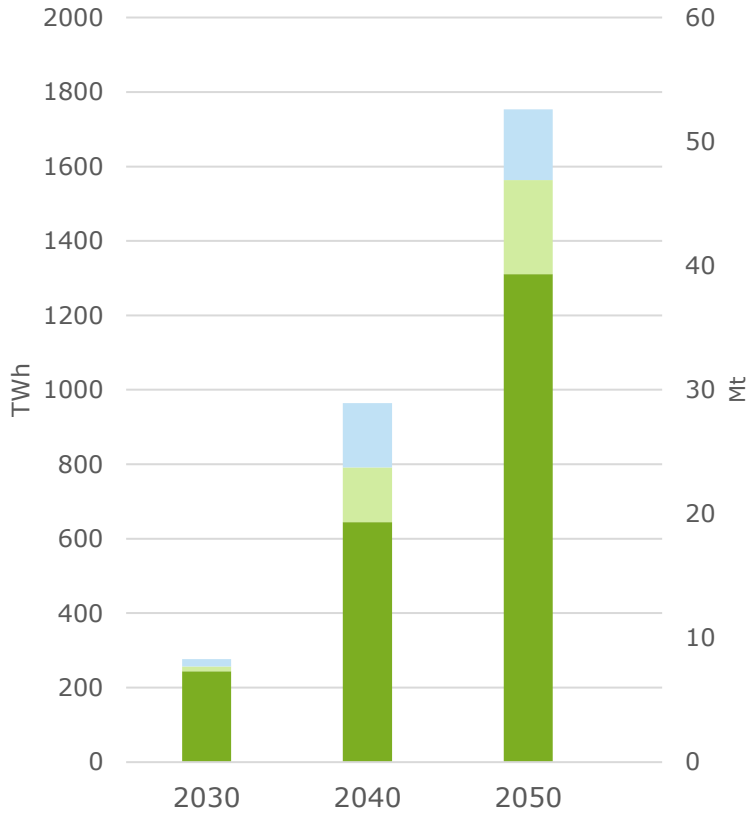
The base scenario[1] evolves to a 75% - 25% split of local production vs. import of hydrogen by 2050, with important variation between clusters…

Local hydrogen production vs. import per cluster per type – base scenario in 2050

Local hydrogen production vs. hydrogen import



Key messages:

- In the **base scenario**, most of the hydrogen is projected to be supplied by local European production. Split **local production vs. import** is expected to be **75% - 25%** by 2050, while in 2030, imports are expected to be less than 10%
- By 2050 the **majority of imported hydrogen is green** (60%) however the balance green vs. blue only sways to green after 2040.
- Most clusters rely almost completely on local European production for their hydrogen supply however, this is not the case for all clusters. The **largest demand cluster** *Belgium, Netherlands, Denmark and North of Germany* **relies for over 40% of its supply on import**, whereas the clusters *Western Mediterranean coast* and *Eastern Central Europe* rely for over 50% of their supply on import.

Note: (1) The ambitious scenario is the default demand scenario for which supply is matched, unless stated otherwise. (2) Turquoise hydrogen via pyrolysis was also considered an option in the model, however, LCOH was higher than for GHR and thus not an outcome of the model.

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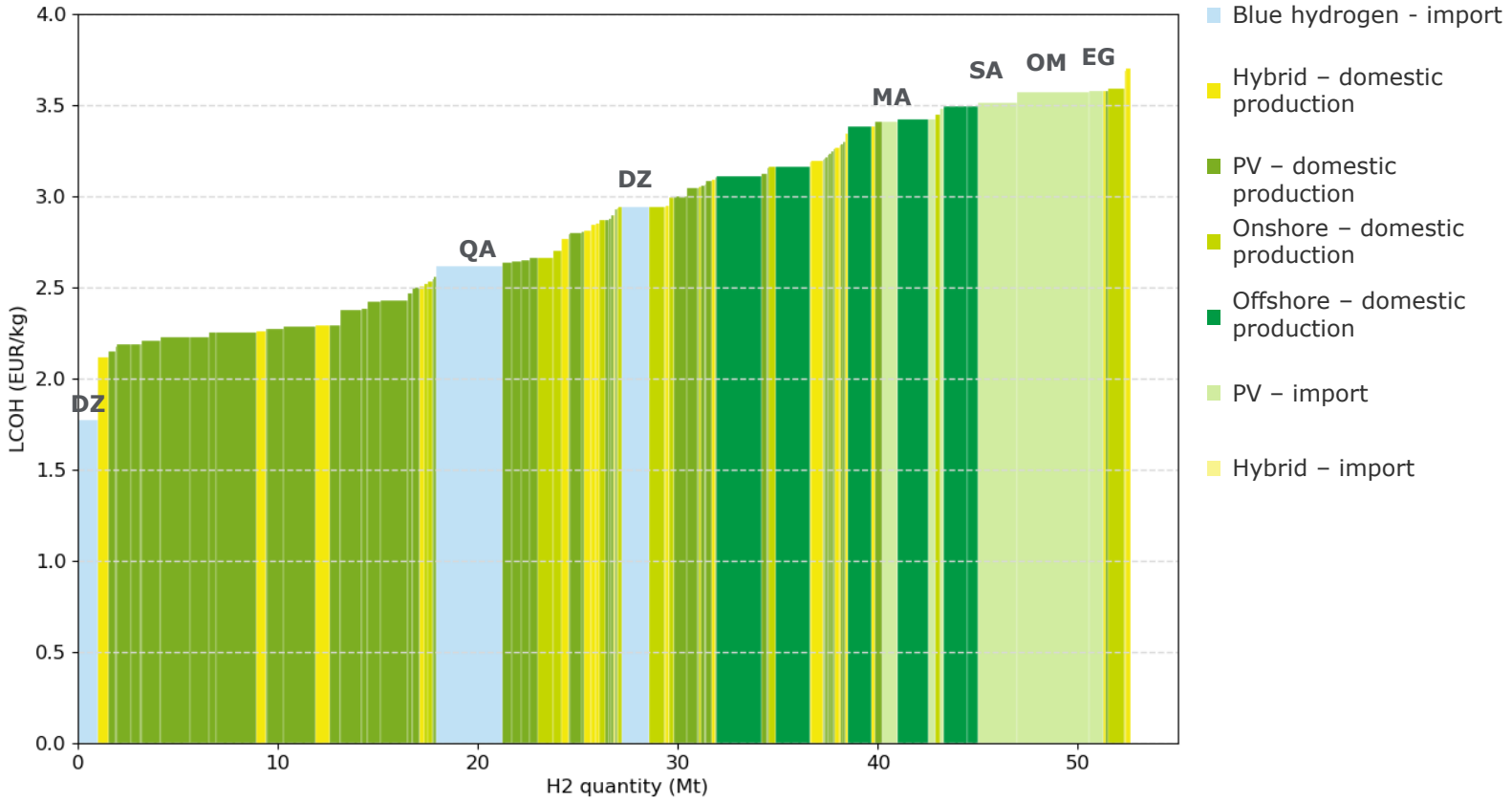
… for which the cheaper local production and blue imports are complemented with more expensive local production and green imports

Merit order curve hydrogen supply – base scenario in 2050



Key messages:

- **Local PV and hybrid systems** are the most cost-effective hydrogen sources and have the possibility to provide **at least 15 Mt of hydrogen** at a **cost lower than 2,5 EUR/kg**
- Further, local hydrogen supply is based on other onshore wind, PV and hybrid systems at a cost between 2,1 and 3,3 EUR/kg and **offshore wind** at a cost between **3 and 3,5 EUR/kg**
- **Blue hydrogen imports** are expected from Algeria and Qatar at a **cost below 3 EUR/kg**
- **Green hydrogen imports** are expected from Morocco, Oman, Saudi Arabia and Egypt at around **3,5 EUR/kg**. The hydrogen supply model assumes consumption of hydrogen, however in many cases the carrier used for transport, such as **ammonia**, can be used directly **without conversion to hydrogen**. Avoiding this conversion step makes the **import case significantly more competitive** (cost reduction of 0,4[2] to 0,8[3] EUR/kg) for sectors where direct offtake of these carriers is expected (e.g. shipping). We refer to ongoing initiatives such as HyPort Dugm or HyEx where ammonia will be imported from Oman and Chili, respectively.
- Finally, we note that the range of LCOH is relatively narrow and change in cost assumptions can cause reshuffling of the merit order curve.

Note: (1) Hybrid systems: wind onshore + PV. (2) Hydrogen import coalition. (3) Own cost assumption, cf. appendix

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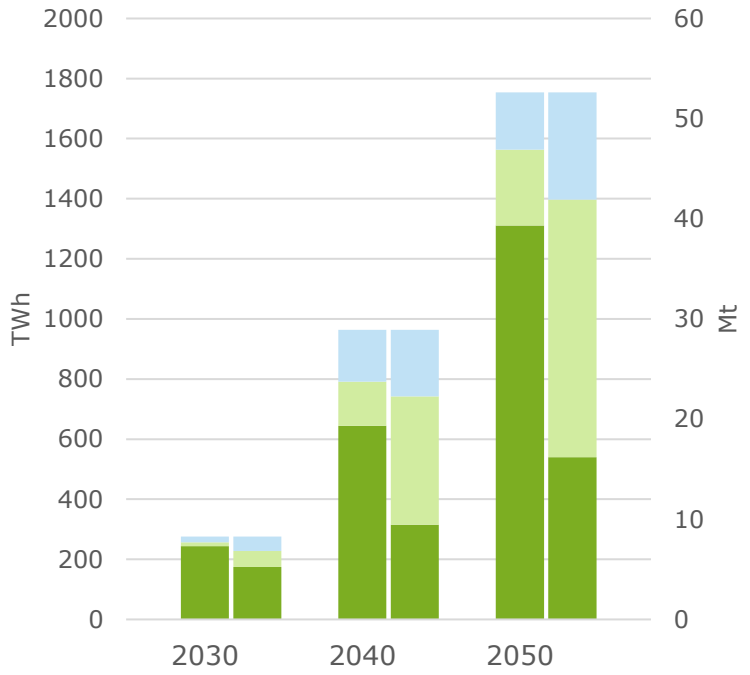
In the increased import supply scenario, with constrained EU renewables deployment, there is a significant shift to 70% hydrogen imports …

H2 local hydrogen production vs import per cluster per source – increased import supply scenario in 2050

Local European hydrogen production vs hydrogen import



The left bar in each year is the base scenario, while the right bar is the increased import scenario

Key messages:

- In the **increased import supply scenario**, where local European renewables are expected to be deployed slower than in the base supply scenario, there is a significant shift from local European hydrogen production to more import. Split **local production vs. import** is expected to be **40% - 60%** by 2050, in 2030, imports are expected to be already more than 35%.
- By 2050 the **imported hydrogen is predominantly green** (70%), this is already the case in 2030.
- A significant variety exists amongst clusters in split local production vs. import as well as the type of hydrogen imported.
- The **largest demand cluster** *Belgium, Netherlands, Denmark and North of Germany* **relies for about 80% of its supply on import**. Correspondingly, these countries are signing MoUs for hydrogen import[1].

Green hydrogen - domestic Green hydrogen - import Blue hydrogen - import

Note: (1) E.g. Belgium (or Belgian ports) are signing memorandums of understanding (MoUs) with Oman, Namibia and Chili; The Netherlands (or ports in the Netherlands) with the United Arab Emirates and Chariot (Africa-focused); Denmark with Australia

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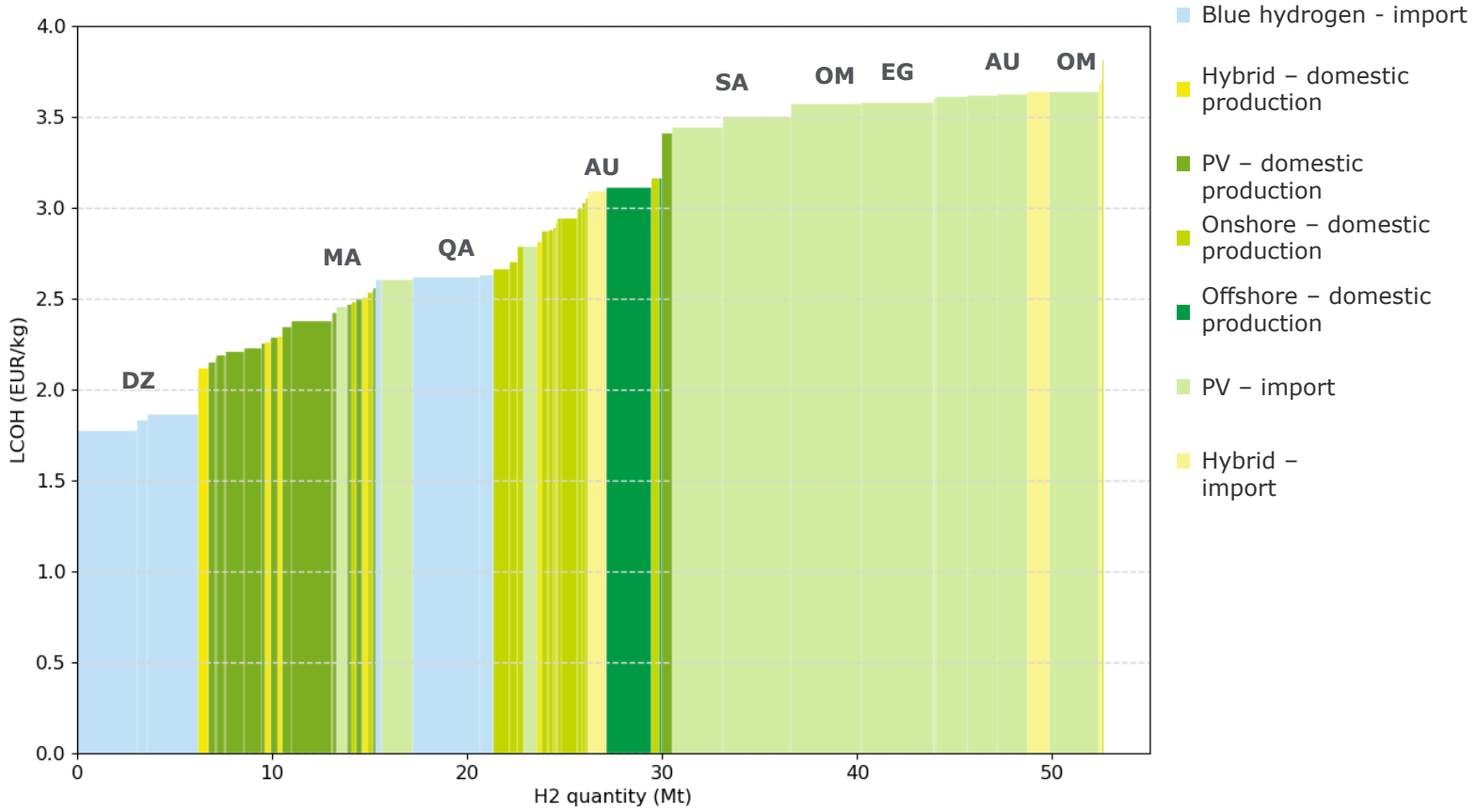
… for which Europe will need to significantly tap into more other foreign sources, mainly imports from North Africa and the Middle East

Merit order curve hydrogen supply – increased import scenario in 2050



Key messages:

- Local hydrogen supply is coming from wind onshore, PV, hybrid and wind offshore systems. **Around 10 Mt** of green hydrogen is produced **locally at a cost lower than 2,5 EUR/kg**
- **Larger share of blue hydrogen** is imported from Algeria and Qatar at a cost below and around 2,5 EUR/kg.
- **More green hydrogen** is **imported from North Africa** (Morocco, Egypt), **Middle East** (Oman, Saudi Arabia) and even **Australia**. The **maximum LCOH of around 3,5 EUR/kg is similar to the base supply scenario but the ramp-up is much steeper** with plateaus of green imports.
- Note that other regions with favourable conditions for wind and sun such as Chili, Namibia and South Africa may supply to the global hydrogen market and become competitive, especially at increasing demand levels and depending on capacity factor, transport distance, local infrastructure, etc. At the projected hydrogen demand, the willingness-to-pay for hydrogen imported from outside of Europe is up to ~3.5 EUR/kg.
- The same remark with regards to the direct offtake of ammonia or methanol, corresponding to about 15% of the demand, or 8 Mt, is valid here, favouring the import case.

Note: (1) Hybrid systems: Wind onshore + Solar PV. (2) Since an economic optimum is sought for the complete timeperiod 2030 to 2050, the LCOH of imports per location cannot be directly compared between the scenarios in a certain year, rather all years should be taken into account when comparing the cost and quantity per location

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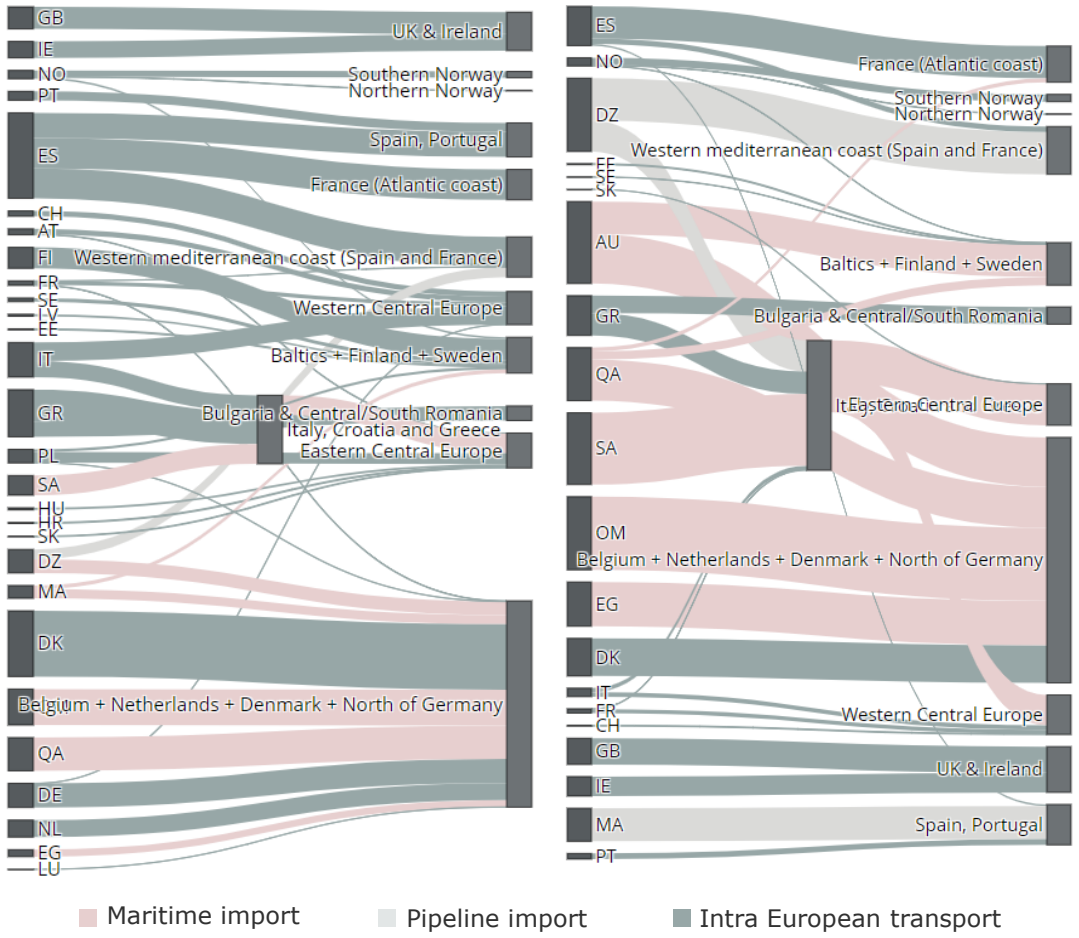
In the increased import scenario, required transport infrastructure will be more focused on import than on distributing locally produced hydrogen

Base supply scenario in 2050

Increased import supply scenario in 2050



Key messages:

- It is projected that locally produced hydrogen will mostly be supplied to countries within the same cluster. In this case there will be **hydrogen transport infrastructure required within a cluster**. For the cluster *Belgium, Netherlands, Denmark and North of Germany,* there will be infrastructure required to transport **offshore energy from the North Sea to the mainland**.
- There are some exceptions where countries will export to other European countries not located within their cluster. If this is the case, a pipeline connection between the clusters should be in place. In our analysis, it is projected that **Spain will supply hydrogen to France**. The **hinterland clusters** (*Eastern central Europe* and *Western central Europe*) are projected to be supplied **via the cluster *Italy, Croatia and Greece*** with hydrogen coming from Saudi-Arabia, next to hydrogen being produced directly in the cluster.
- In the base supply scenario, **imports from Algeria** are the only projected imports from outside of Europe via pipeline. The other countries will export to Europe via ship.
- In the **increased import supply scenario**, next to pipeline import from Algeria, hydrogen is also projected to be imported via pipeline from **Morocco** to Spain and Portugal. Also, there will be less hydrogen produced from offshore wind, thus the corridor required between the mainland and the North Sea will be more limited, there is only a connection projected via Denmark.

Notes: (1) Country codes can be found in glossary at the end of the report. (2) for data concerning the other years, we refer to the Power BI dashboards.

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Detailed insights via dashboards

main functionalities

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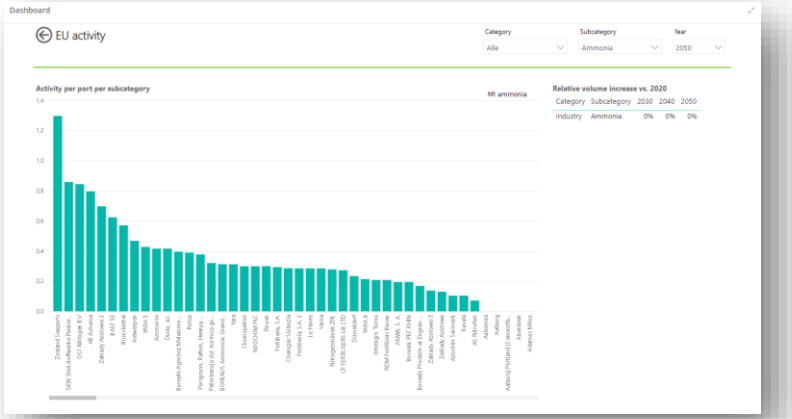
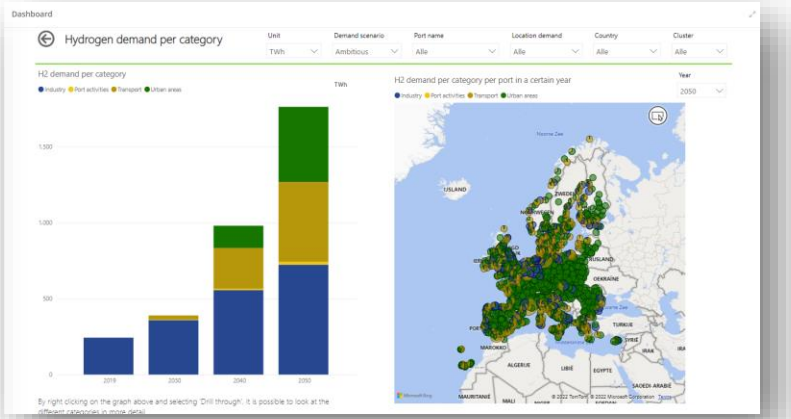
Detailed insights via dashboards

Overall perspective: hydrogen demand and related CO_2 abatement

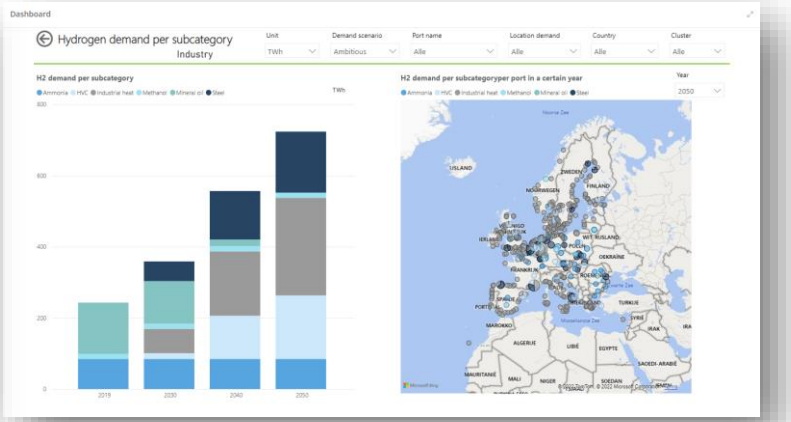
EU activity



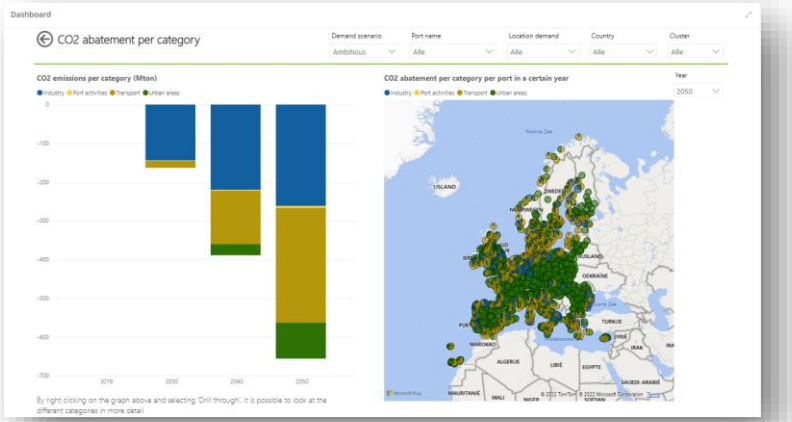
Hydrogen demand per category



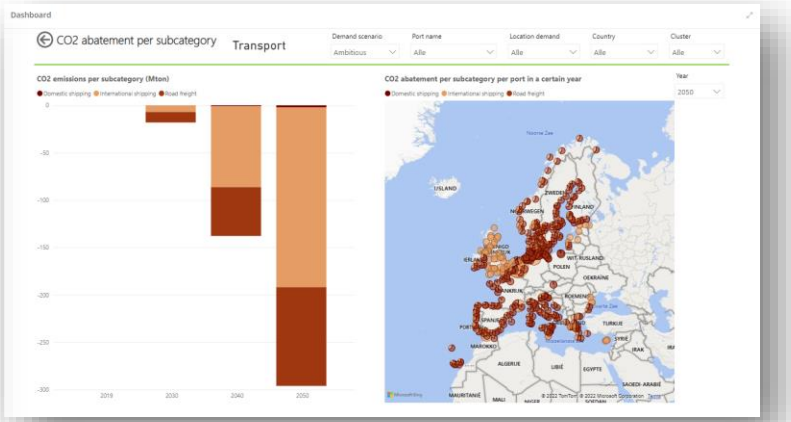
Hydrogen demand per subcategory



CO_2 abatement potential per category



CO_2 abatement potential per subcategory



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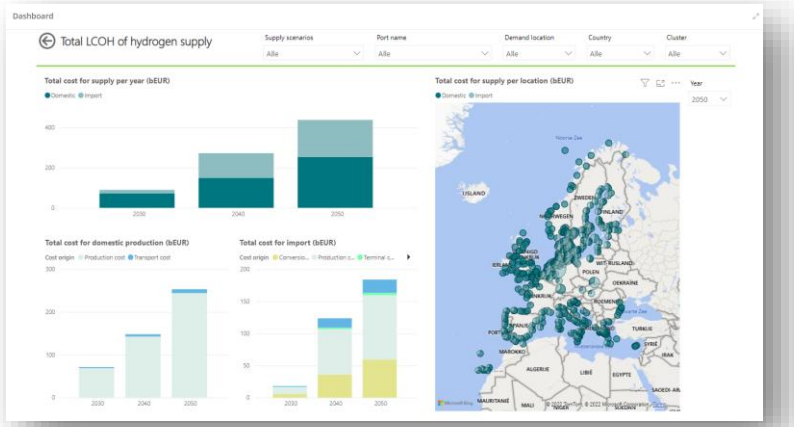
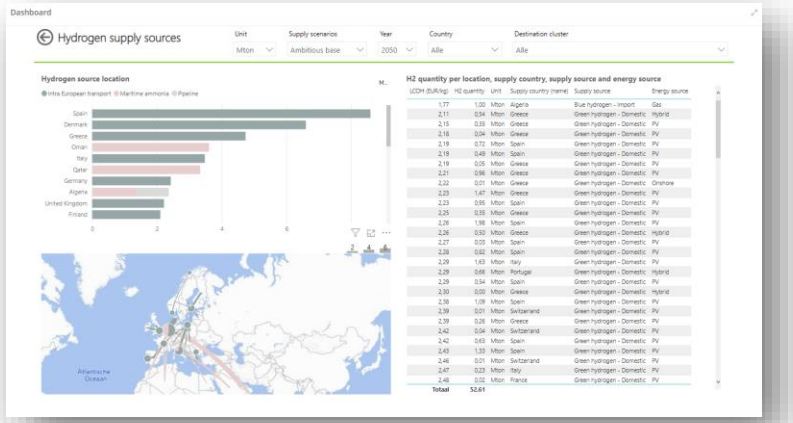
Detailed insights via dashboards

Overall perspective: hydrogen supply and required infrastructure

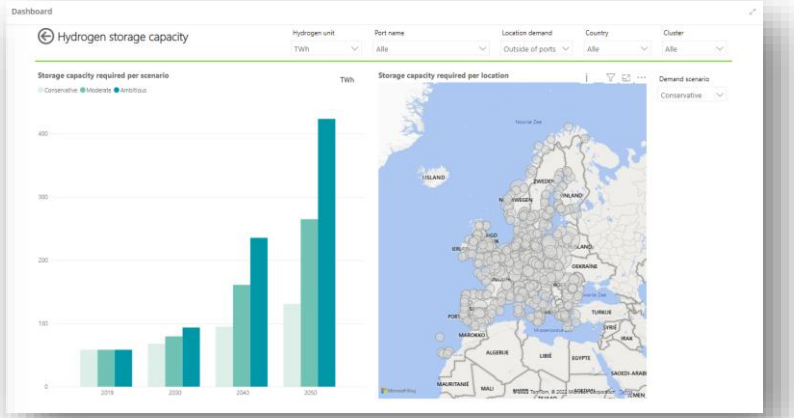
LCOH supply



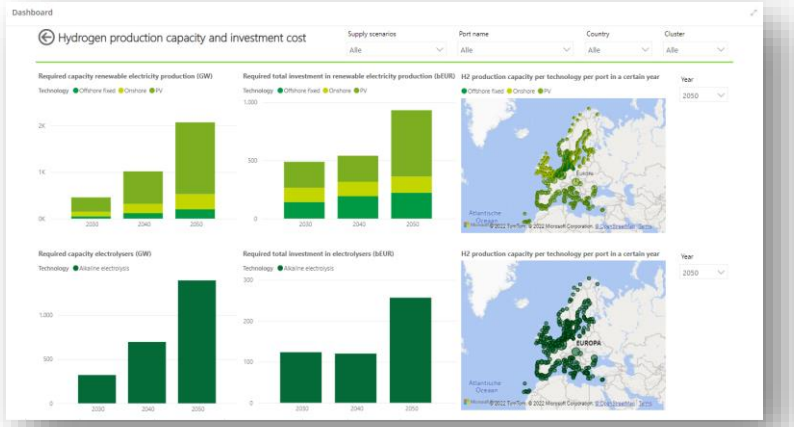
Supply sources



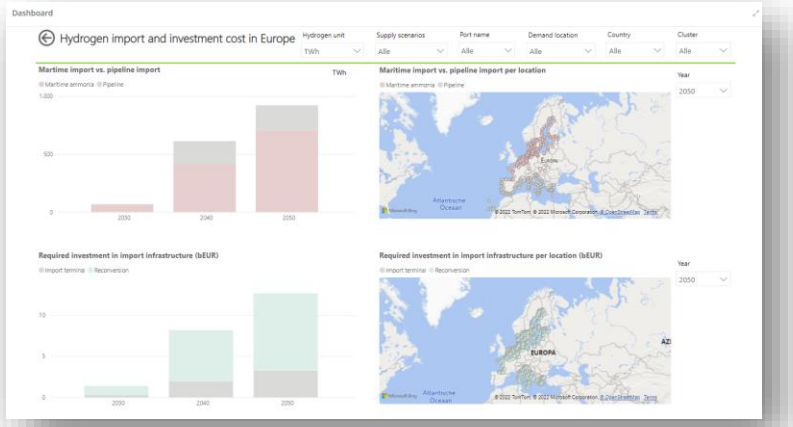
Storage capacity



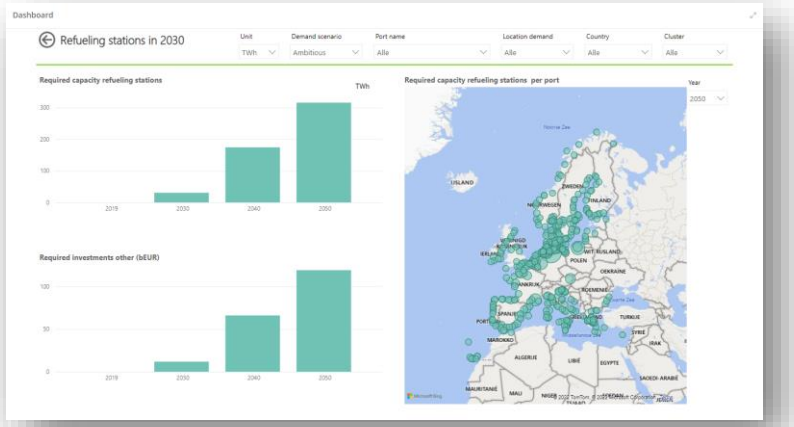
Production capacity and investments



Import capacity and investments



Refueling stations capacity



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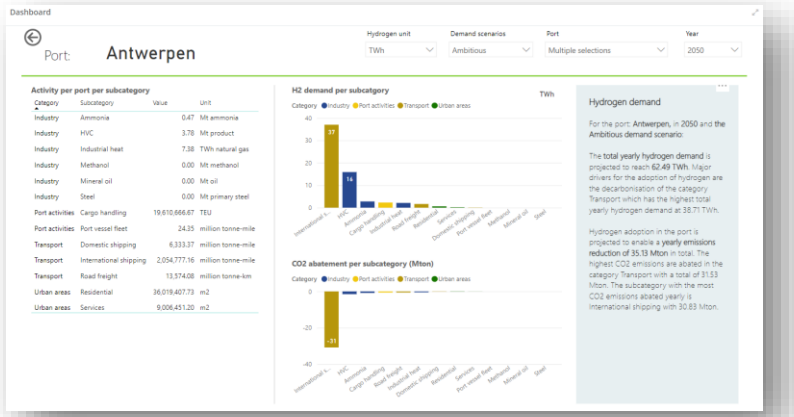
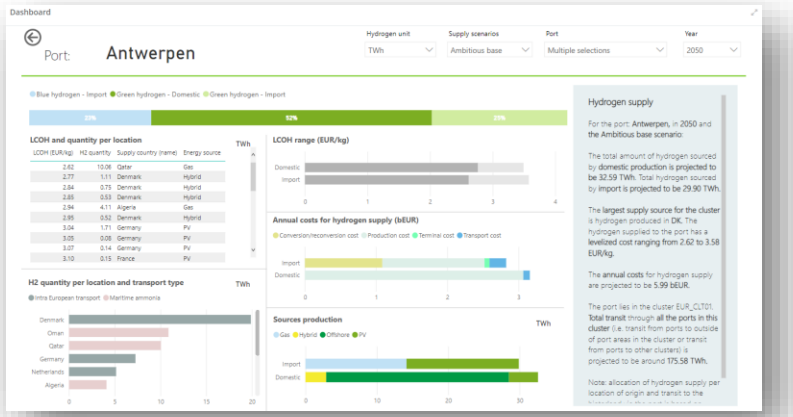
Individual port perspective: hydrogen demand, supply and investments

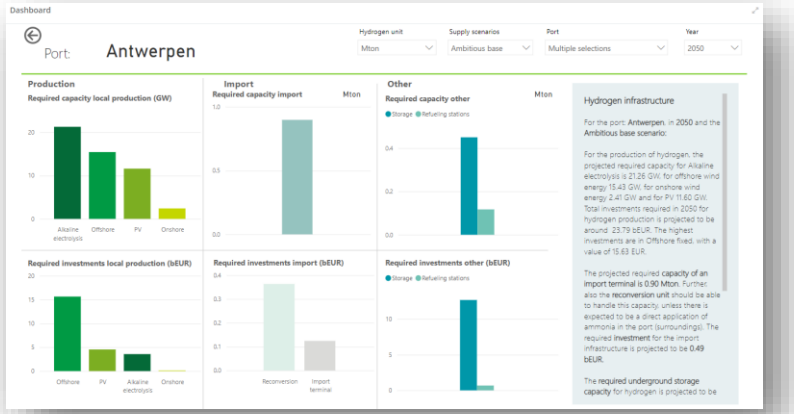
Hydrogen demand per port



Hydrogen supply per port



Hydrogen investments per port



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Next steps and Q&A

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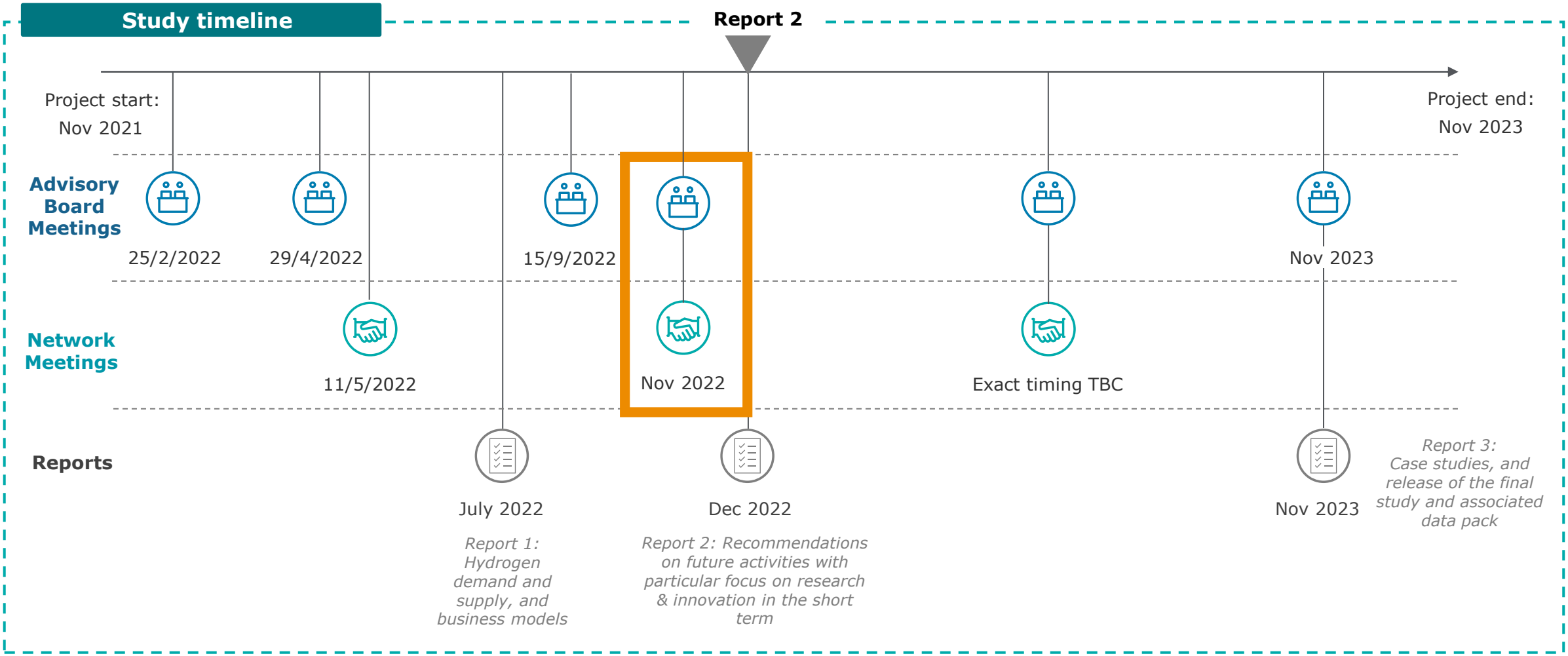
Join us at our second Network Meeting on 23 November 2022 in Brussels, during which the main results of the report will be presented and discussed



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Questions

Q&A

Registration link second European Hydrogen Ports Network event on 23 November 2022 in Brussels

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