Study on hydrogen in ports and industrial coastal areas

e4ports-Symposium

November 2023

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

Task	Description	Date
Task 1	Hydrogen demand and market potential	March 2023
Task 2	Hydrogen supply, storage and distribution	March 2023
Task 3	Definition of business models	March 2023
Task 4	Case studies	November 2023
Task 5	Recommendations on R&I, safety regulations, codes and standards and non-technical enablers	September 2023
Task 6	Coalition building	Continuous

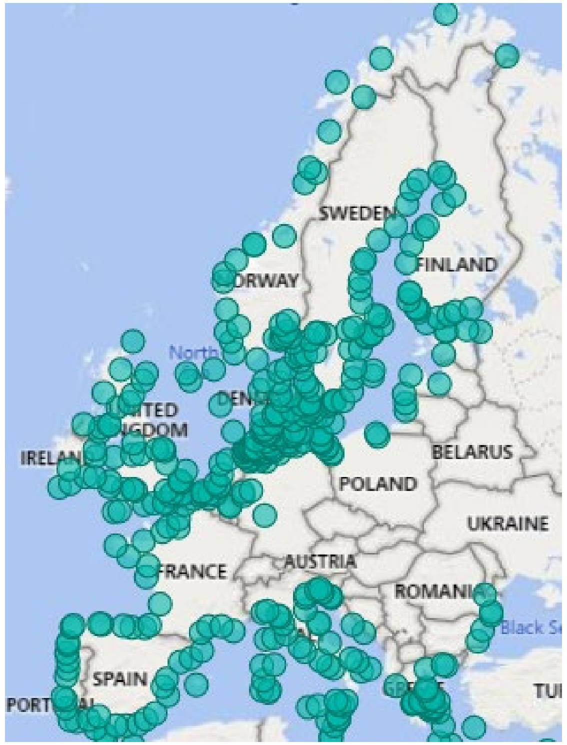
The study feeds into the work of the **Global Hydrogen Ports Coalition**, launched at the latest Clean Energy Ministerial (CEM12). This important international initiative brings together ports from around the world to work together on hydrogen technologies.

* Dates refer to delivery date of final reports

Study on hydrogen in ports and industrial coastal areas: 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

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

Out of scope: pink hydrogen

During the course of the study the **REPowerEU** plan has been published and included in the scope of the study

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*

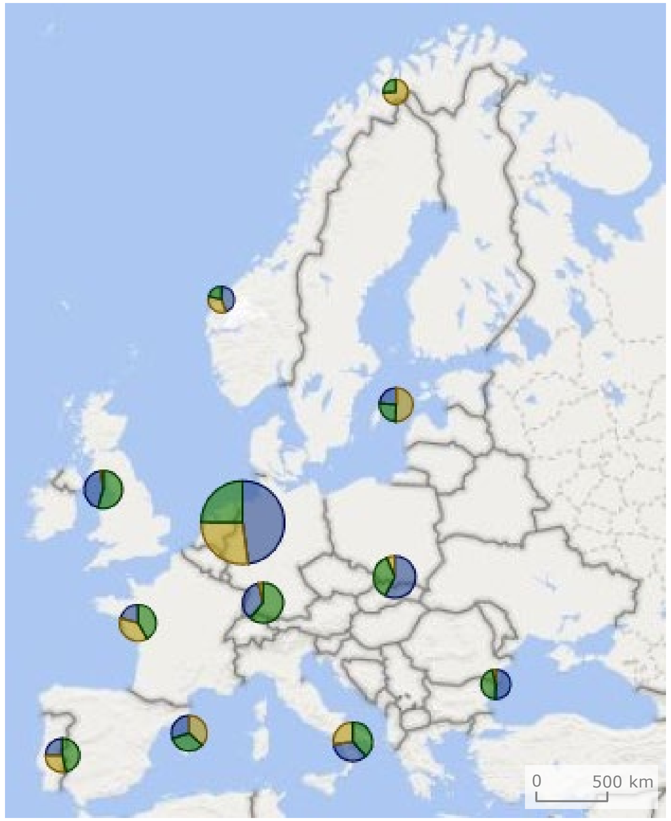
- Port authorities
- Terminal operators
- Shipyard representative
- Ship owner and operators
- City/municipal authorities
- Heavy industries
- Gas infrastructure operator
- Heavy-duty transport
- Hydrogen and renewable energy producers
- European Commission

*Not exhaustive

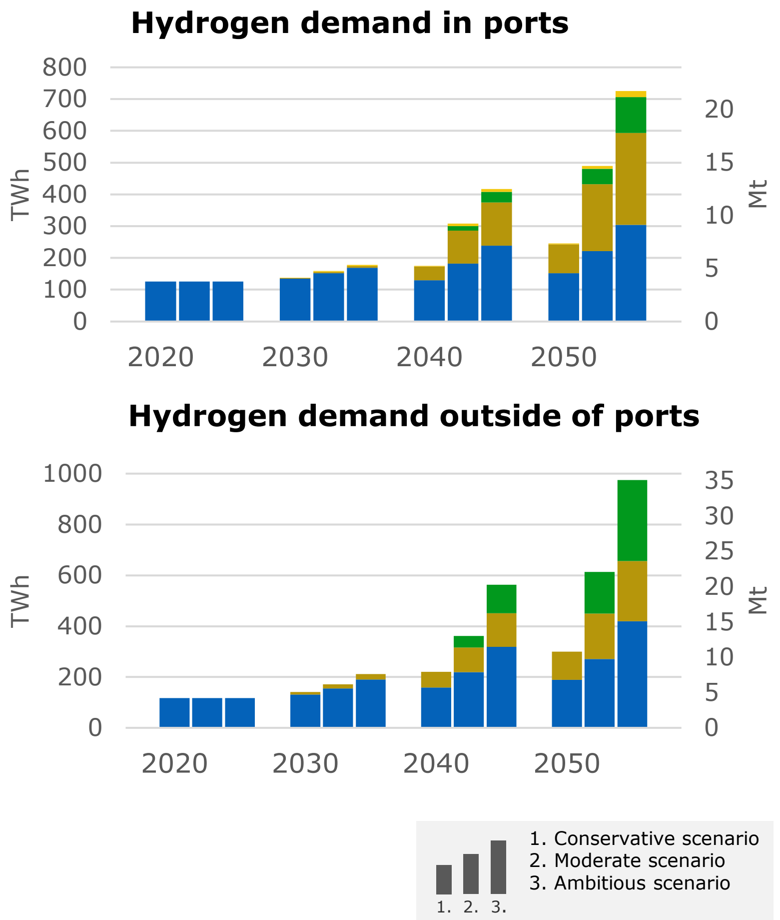
Hydrogen demand
high-level results

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

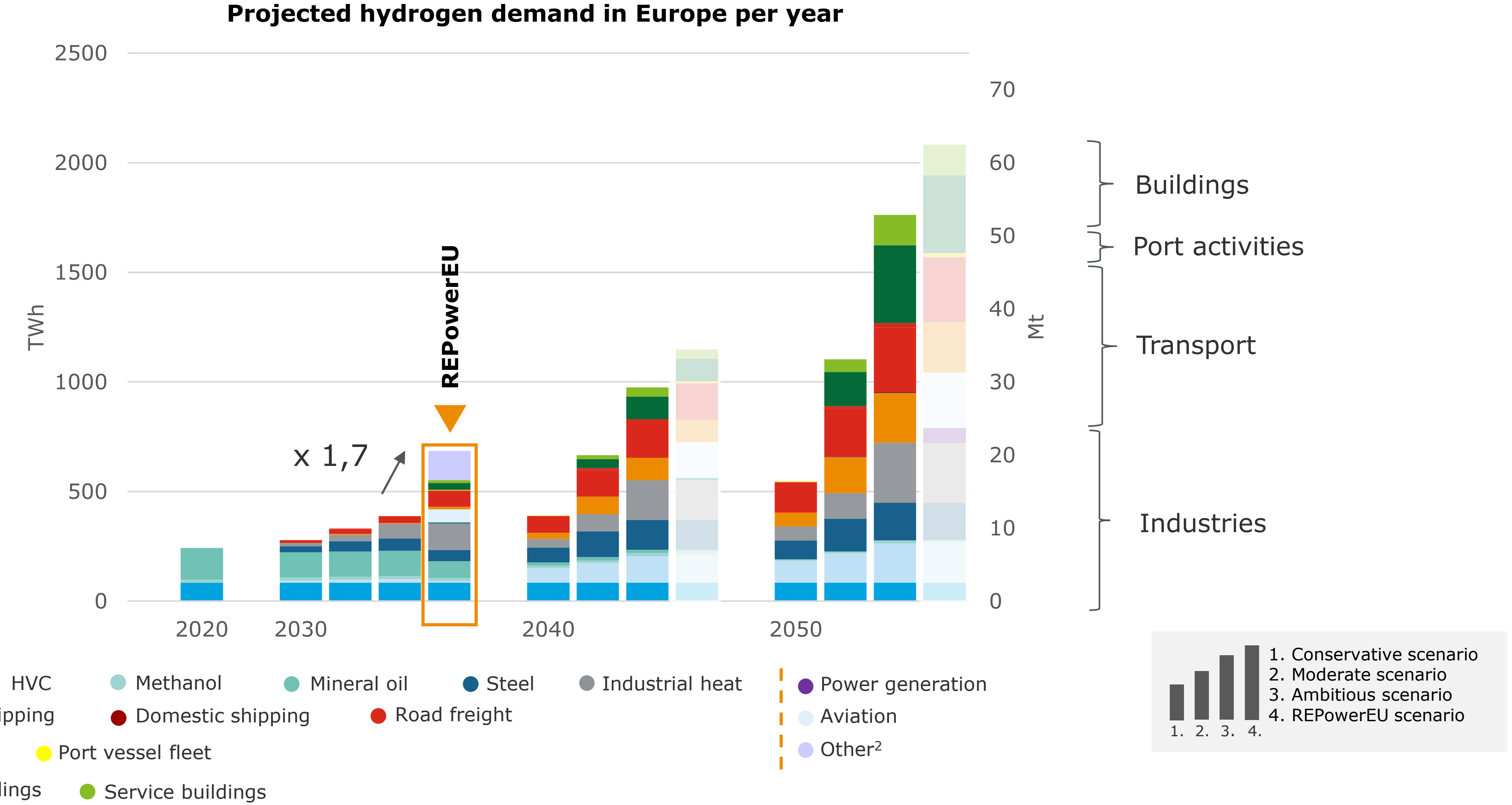


Industry Transport Urban areas Port activities

Key messages:

- Hydrogen demand projections:
  - 2030: between 283 and 389 TWh
  - 2050, between 545 and 1764 TWh
- Mainly driven by industries and the international shipping sector demand for clean hydrogen in the vicinity of **European ports** could reach 730 TWh, or **42% of total hydrogen demand in the EU expected in 2050**. This would represent a six-fold increase compared to the current demand for hydrogen near European ports (126 TWh).
- Clean hydrogen consumption in port areas has the potential to lead to up to 360 Mt of CO2-eq abatement in 2050 (or **8% of total European GHG emissions** in 2019) as well as additional environmental benefits (e.g., reduction of toxic atmospheric emissions, water pollutants, solid waste, and noise emissions).

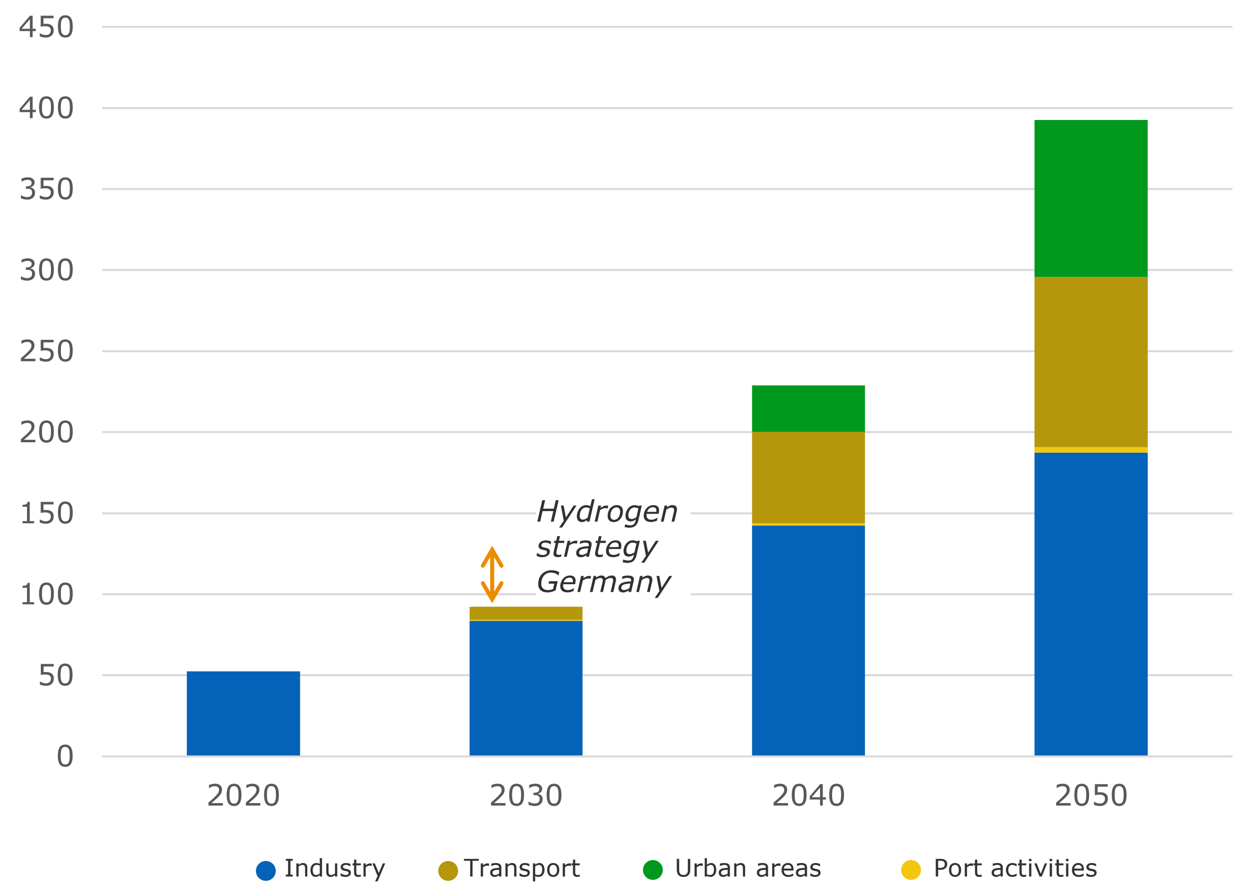
Hydrogen demand in Europe per demand subcategory and scenario for 2020, 2030, 2040 and 2050



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. (1) Hydrogen demand in international shipping was added on top of the communicated REPowerEU hydrogen demand of 20 Mt, due to studies2 showing hydrogen is no-regret option for shipping in 2030. (2) This category includes part of the ammonia/hydrogen derivatives imports defined in the REPowerEU communication

Overview of hydrogen demand projections until 2050 in Germany

Hydrogen demand in Germany for the ambitious scenario



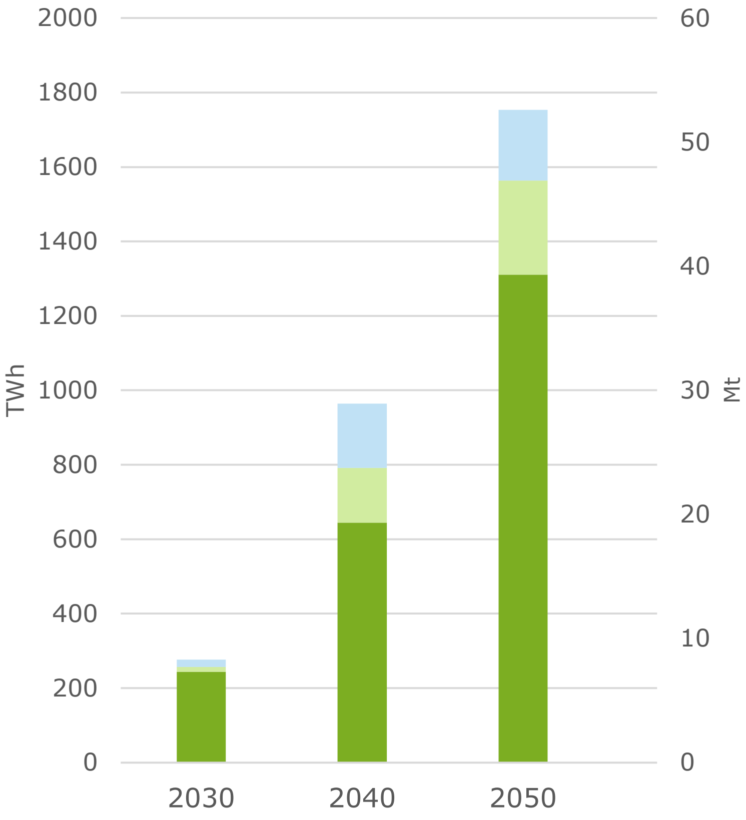
Key messages:

- In **2030**, total hydrogen demand is projected to be up to **~ 92 TWh** (about 2.8 Mt)
- In 2050, total hydrogen demand is projected to be up to ~ 392 TWh (about 12 Mt)
- By 2050, the **industry** (mainly HVC, industrial heat and steel) **will likely be the largest demand sector** for renewable and low-carbon hydrogen, followed by transport sector, potentially urban areas and finally port activities.
- REFERENCE: Projected hydrogen demand in Germany's national hydrogen strategy (BMWK's):
    - **2030: 95-130 TWh**
    - 2045: 290-440 TWh industry, conversion sector 80-100 TWh & a role in transport and potentially buildings

Hydrogen supply
high-level results

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



Key messages:

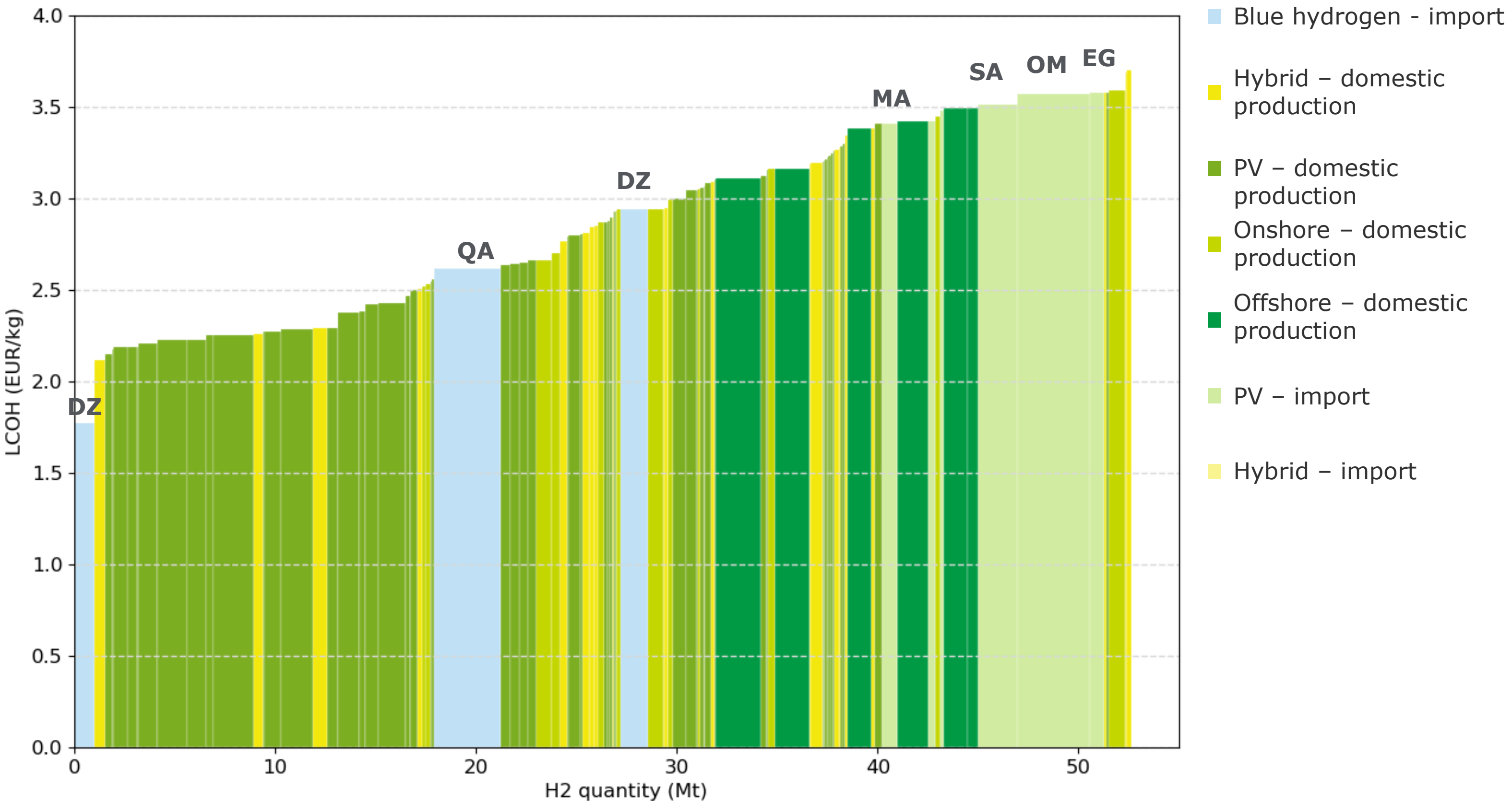
- In the **base scenario**, most of the hydrogen is projected to be supplied by local European production. Split **local production vs. import** is expected to be **75% - 25%** by 2050, while in 2030, imports are expected to be less than 10%
- By 2050 the **majority of imported hydrogen is green** (60%) 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.

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

… 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:

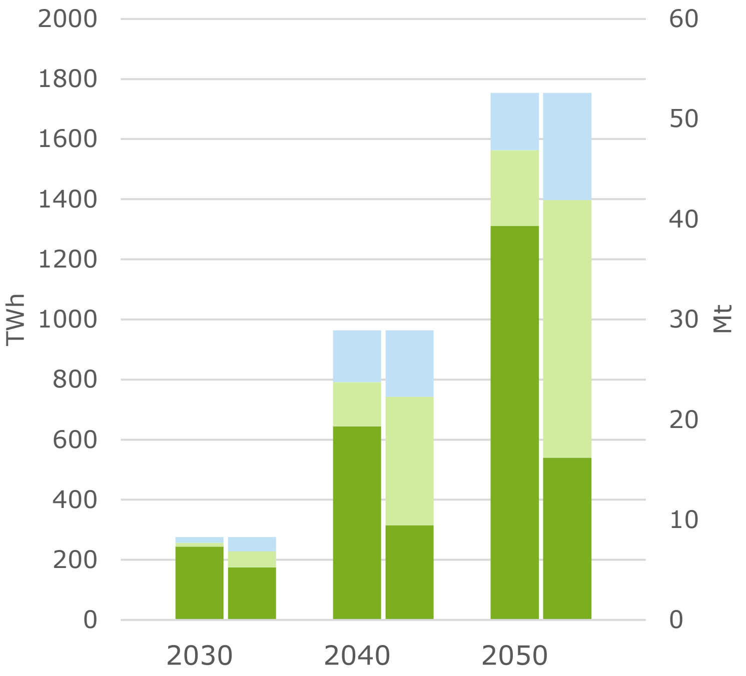
- **Local PV and hybrid systems** are the most cost-effective hydrogen sources and have the possibility to provide **at least 15 Mt of hydrogen** at a **cost lower than 2,5 EUR/kg**
- Further, local hydrogen supply is based on other onshore wind, PV and hybrid systems at a cost between 2,1 and 3,3 EUR/kg 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.

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

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:

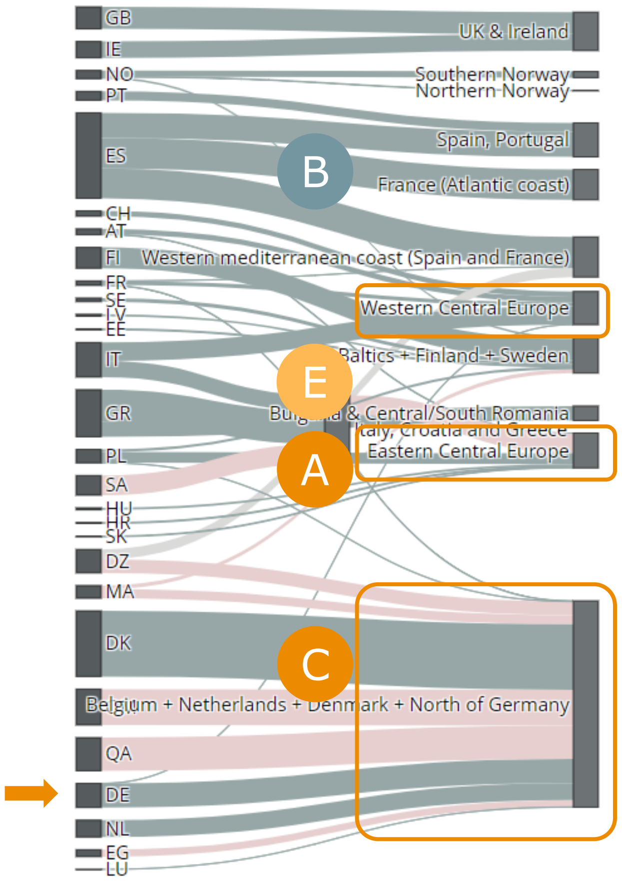
- In the **increased import supply scenario**, where local European renewables are expected to be deployed slower than in the base supply scenario, there is a significant shift from local European hydrogen production to more import. Split **local production vs. import** is expected to be **30% - 70%** 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

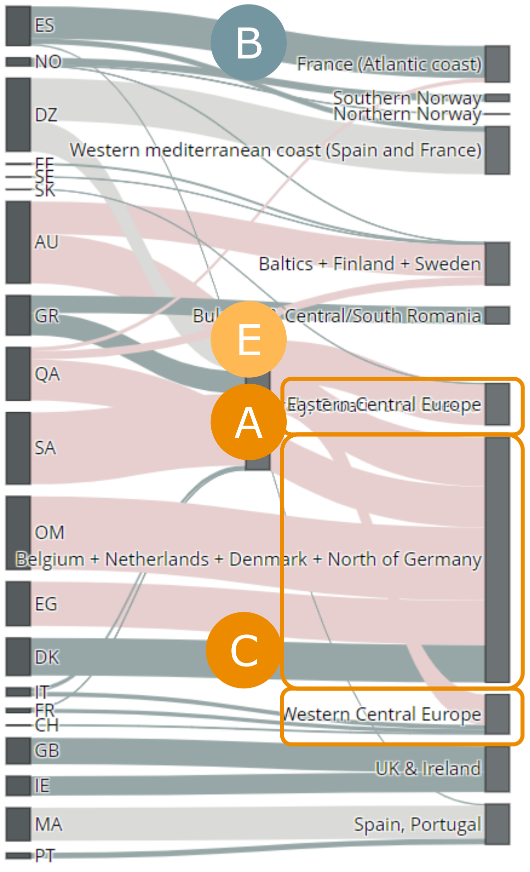
Note: (1) E.g. Belgium (or Belgian ports) are signing memorandums of understanding (MoUs) with Oman, Namibia and Chili; the Netherlands (or ports in the Netherlands) with the United Arab Emirates (Africa-focused); Germany with Australia

The projected need for specific corridors largely aligns with the communicated corridors in European Hydrogen Backbone vision

Base supply scenario in 2050



Increased import supply scenario in 2050



Maritime import Pipeline import Intra European transport

Comparison to identified corridors in European Hydrogen Backbone vision[1]

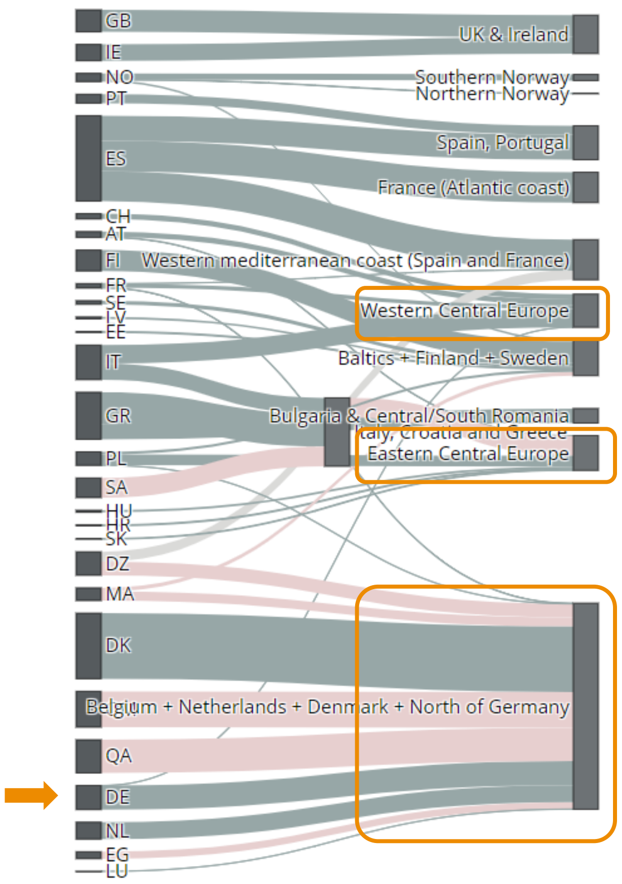
- To deliver the hydrogen demand and supply targets set by the REPowerEU plan, five large-scale pipeline corridors are envisaged by European Hydrogen Backbone initiative:
  - Corridor A: North Africa and Southern Europe (from Algeria through Italy to Central Europe)
  - Corridor B: Southwest Europe and North Europe
  - Corridor C: North Sea
  - Corridor D: Nordic and Baltic regions
  - Corridor E: East and South-East Europe

- From our economical analysis, it can be concluded that there is indeed a **projected need for corridor A, B, C and E.** It should be noted that our analysis is an economic optimization and does not take into account other factors such as policy initiatives.

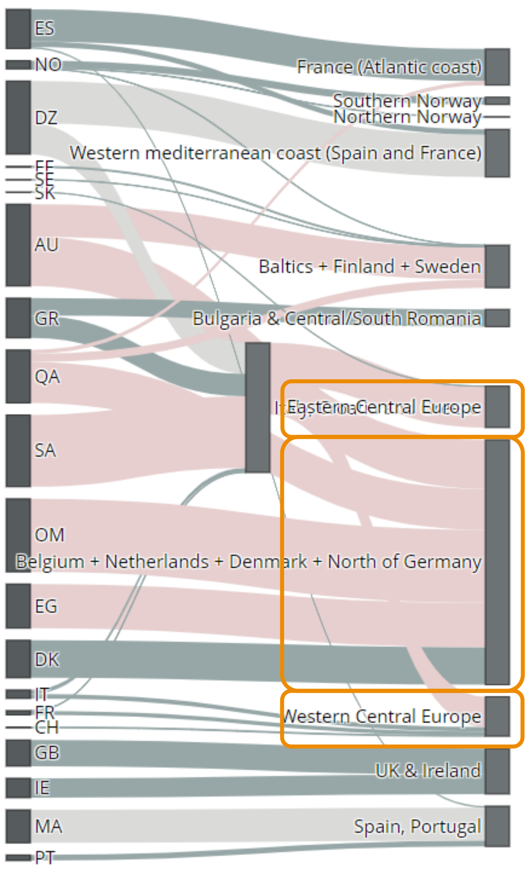
Sources and notes: (1) Guidehouse, *Five hydrogen supply corridors for Europe in 2030*, 2022. (2) Country codes can be found in glossary at the end of the report

The projected need for specific corridors largely aligns with the communicated corridors in European Hydrogen Backbone vision

Base supply scenario in 2050



Increased import supply scenario in 2050



Maritime import   Pipeline import   Intra European transport

Key messages:

- Germany's hydrogen demand is projected to by supplied partially by **local production** for a small part (~13% in 2030, corresponding to **12 TWh**, corresponding 5.7 GW electrolysis capacity and ~20% in 2050), or not at all in the increased import scenario
- It is projected that Germany will **import**:
    - Via pipeline, from amongst others, directly, **Denmark** or transited via **Belgium, the Netherlands, Italy**, coming from outside of Europe (pipeline/ship: **Algeria, Morocco**, ship, cf. below)
    - Via ship from countries outside of Europe, mostly countries in the **North of Africa or Middle East**. However, also other options such as **Australia** are possible
- **LCOH range: 2030: 2.9 – 5 EUR/kg**, 2050: 2.6 – 3.5 EUR/kg
- REFERENCE: Germany's national hydrogen strategy:
- **Local production: 25 TWh**, 10 GW electrolysis capacity
- **Import** strategy (to be released): pipeline: Norway, the Netherlands, Belgium, Denmark, France, Morocco, Algeria, Tunisia, the United Kingdom and Ukraine, ship: Australia, Saudi Arabia, the United Arab Emirates, South Africa, Namibia and Chile

Sources and notes: (1) Guidehouse, *Five hydrogen supply corridors for Europe in 2030*, 2022. (2) Country codes can be found in glossary at the end of the report

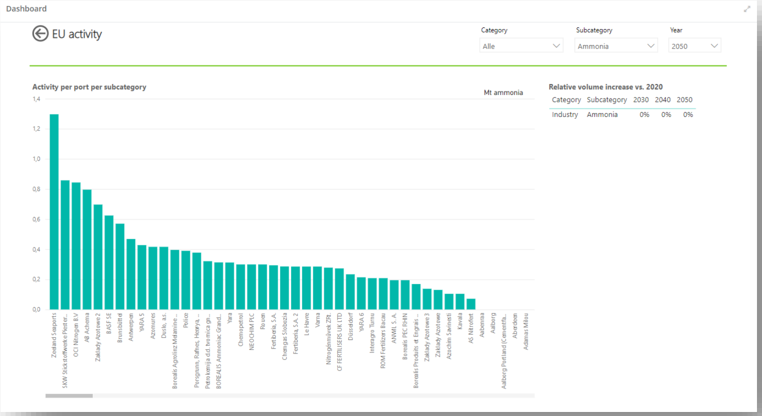
Detailed insights via dashboards

main functionalities

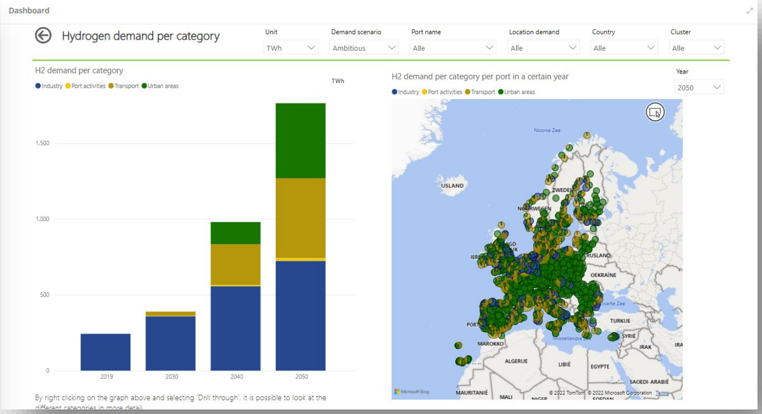
Detailed insights via dashboards

Overall perspective: hydrogen demand and related CO_2 abatement

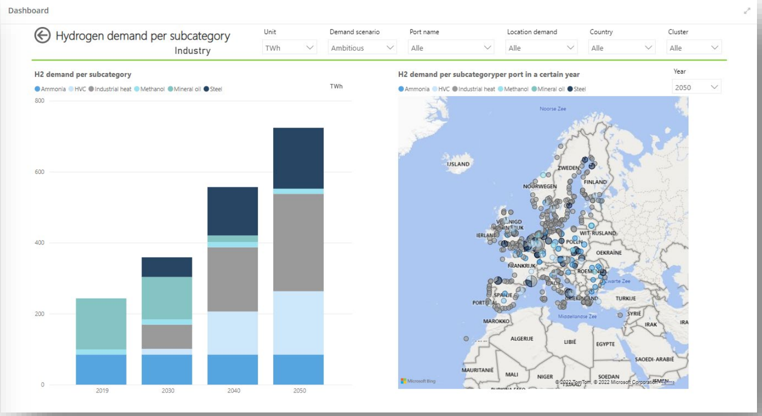
EU activity



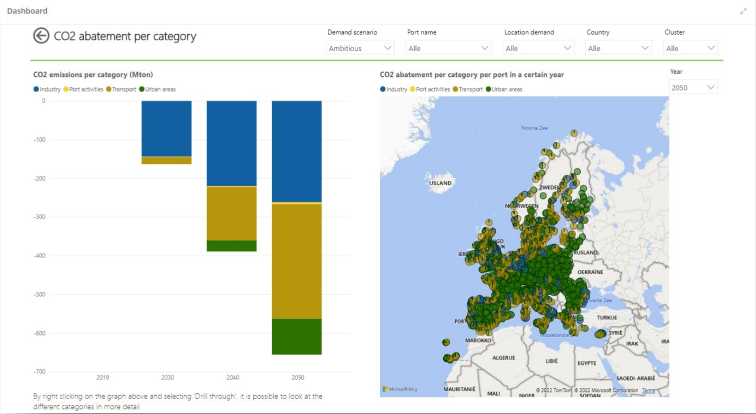
Hydrogen demand per category



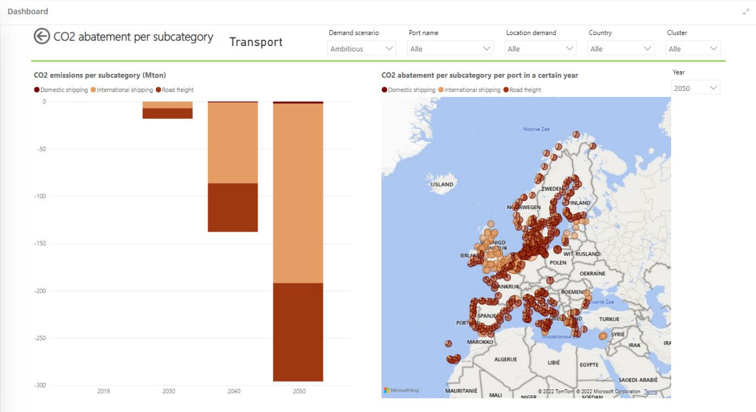
Hydrogen demand per subcategory



CO_2 abatement potential per category

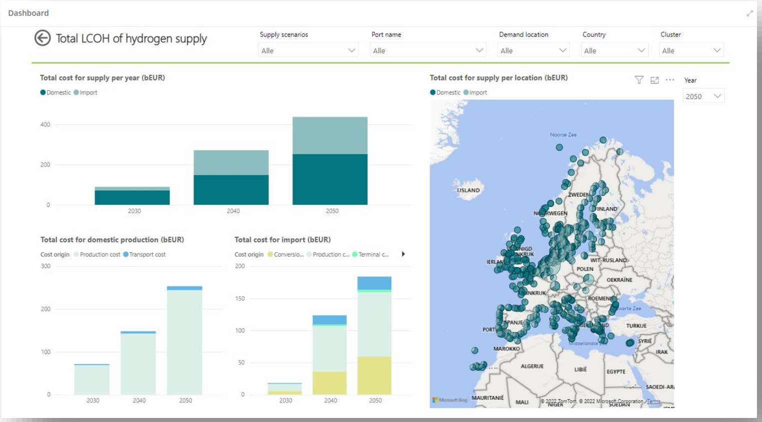


CO_2 abatement potential per subcategory

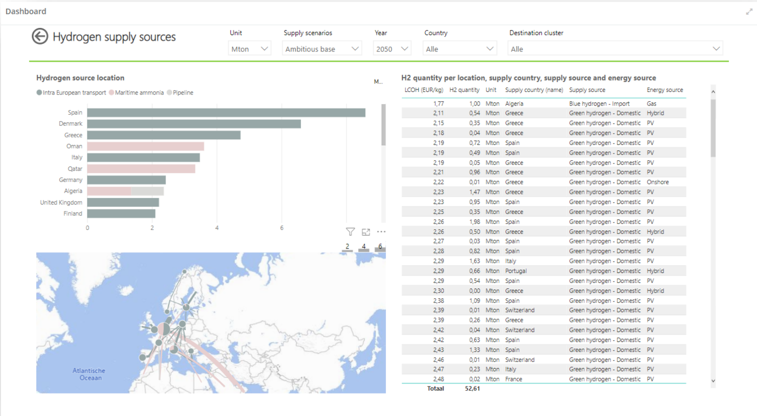


Overall perspective: hydrogen supply and required infrastructure

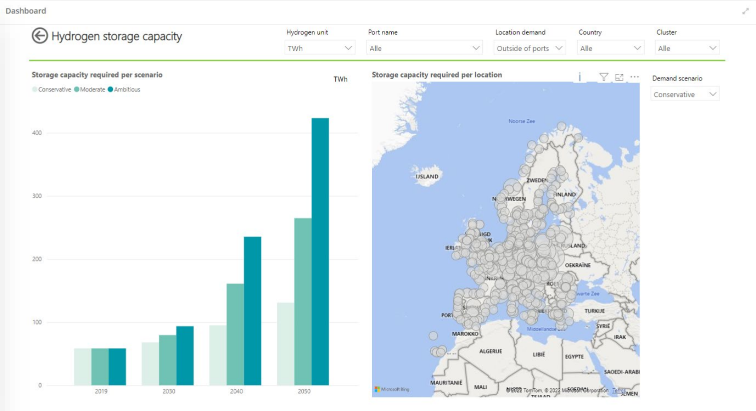
LCOH supply



Supply sources

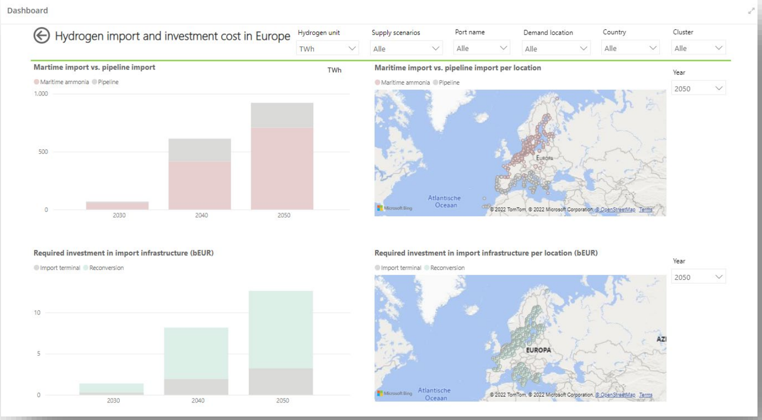


Storage capacity

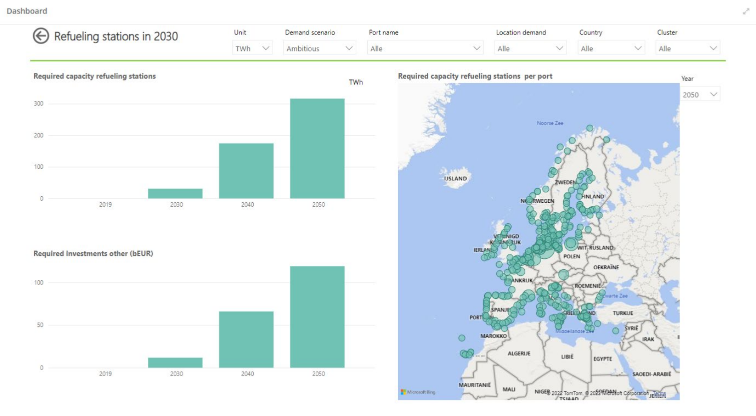


Production capacity and investments

Import capacity and investments



Refueling stations capacity



Policy recommendations
high-level results

This study provides a three-level analysis for each of the hydrogen-related activities and infrastructure expected to be developed in port areas

R&I challenges

Assessment of current **technological challenges,** identification of **areas of priority for R&I** projects and **recommendations on R&I objectives** and millstones (e.g., cost target, research timeline)

Safety challenges

Identification of **gaps** in **safety regulations, codes** and **standards** and **recommendations** on safety regulations, codes and standards to update or develop.

Non-technical (policy, regulatory, strategic, etc.) challenges

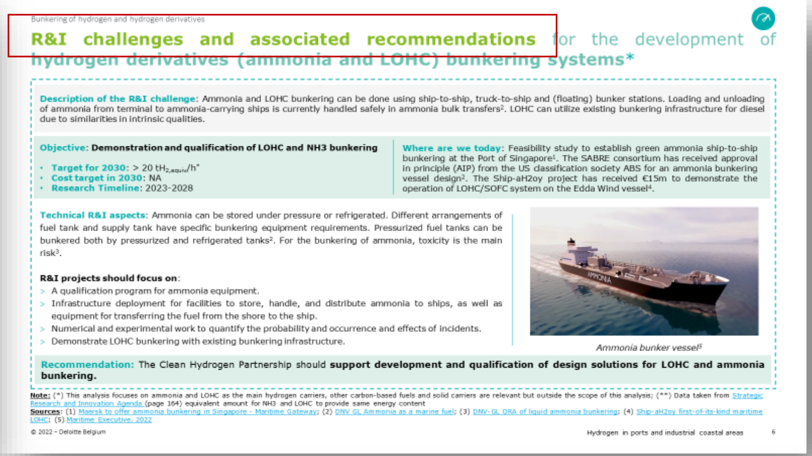
Identification of **non-technical (policy, regulatory, strategic, etc.)** and **recommendations** on these non-technical challenges.

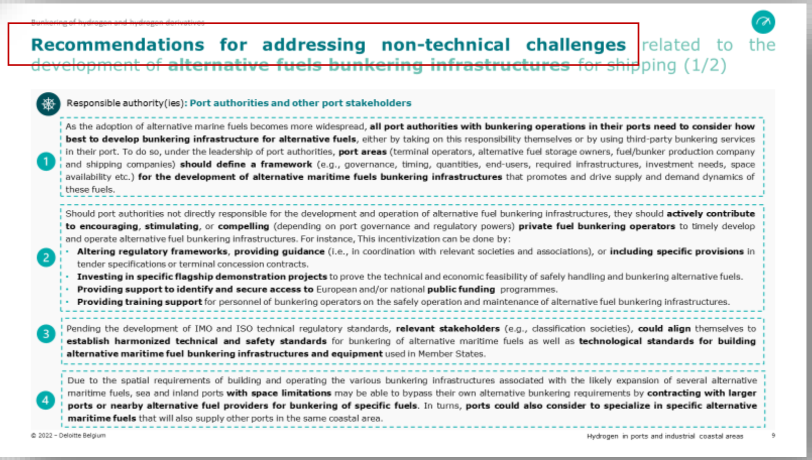
Key recommendations to **port authorities and other port stakeholders**

Key recommendations to **EU Member States (national governments)**

Key recommendations to **the European Union**

Illustrative example of the structure of the analysis for one step of the hydrogen value chain in EU port areas





Prioritization of R&I challenges for the development of hydrogen and hydrogen carriers-related activities and infrastructure in port areas

In the port	
Import terminals of hydrogen in EU ports	High
Import terminals of hydrogen carriers in EU ports	Low
Bunkering of hydrogen and hydrogen derivatives	Medium
Use of hydrogen and hydrogen-based fuels in the maritime sector	High
Use of hydrogen and hydrogen carriers in cold ironing	Low
Use of hydrogen and hydrogen carriers in port equipment	Low

In the vicinity of the port	
Renewable hydrogen production	Medium
Surface hydrogen storage solutions	Medium
Surface hydrogen derivatives storage solutions	Low
Conversion of imported hydrogen carriers into hydrogen	High
Multimodal land-based hydrogen refueling stations	Medium
Transport of hydrogen and derivatives from ports to users	Medium

In the wider setting of the port area	
Deep sea transport of hydrogen via tankers	High
Deep sea transport of hydrogen carriers via tankers	Low
Hydrogen storage in underground geological formations	Low

Prioritization of challenges:

High Medium Low

Prioritization of safety challenges for the development of hydrogen and hydrogen carriers-related activities and infrastructure in port areas

In the port

- Import terminals of hydrogen and hydrogen carriers in EU ports
- Bunkering of hydrogen and hydrogen derivatives
- Use of hydrogen and hydrogen-based fuels in the maritime sector
- Use of hydrogen and hydrogen carriers in cold ironing
- Use of hydrogen and hydrogen carriers in port equipment

In the vicinity of the port

- Renewable hydrogen production
- Surface hydrogen and derivatives storage solutions
- Conversion of imported hydrogen carriers into hydrogen
- Multimodal land-based hydrogen refueling stations
- Transport of hydrogen and derivatives from ports to users

In the wider setting of the port area

- Deep sea transport of hydrogen and hydrogen carriers via tankers
- Hydrogen storage in underground geological formations

Prioritization of challenges:

High Medium Low

Prioritization non-technical challenges (policy, regulatory, governance, strategic) for the development of hydrogen and hydrogen carriers-related activities and infrastructure in port areas

Challenge	Priority
Governance of hydrogen and hydrogen carrier-related activities and infrastructure in port areas	High

In the port

Challenge	Priority
Import terminals of hydrogen and hydrogen carriers in EU ports	High
Bunkering of hydrogen and hydrogen derivatives	High
Use of hydrogen and hydrogen-based fuels in the maritime sector	High
Use of hydrogen and hydrogen carriers in cold ironing	Low
Use of hydrogen and hydrogen carriers in port equipment	Low

In the vicinity of the port

Challenge	Priority
Renewable hydrogen production	High
Surface hydrogen and derivatives storage solutions	Medium
Conversion of imported hydrogen carriers into hydrogen	Medium
Multimodal land-based hydrogen refueling stations	Medium
Transport of hydrogen and derivatives from ports to users	Medium

In the wider setting of the port area

Challenge	Priority
Deep sea transport of hydrogen and hydrogen carriers via tankers	Medium
Hydrogen storage in underground geological formations	Medium

Prioritization of challenges:

High Medium Low

Key recommendations to port authorities and other port stakeholders

Step 1: Assess and formulate a strategy

1. **Assess** the **societal relevance** and the **techno-economic rationale**
2. **Acquire** a comprehensive understanding of the **power and interest of all stakeholders**
3. **Set up** a multi-stakeholder hydrogen **working group**
4. **Develop** a clear **roadmap** with key milestones, conditions and organizational structure

Step 2: Engage with stakeholders

5. **Engage** with the competent **regulatory authorities**
6. **Build partnerships** between the port authority, key other relevant port-related stakeholders and neighboring connecting ports.
7. (*Assist national governments in establishing strong and resilient strategic partnerships with exporting countries*)

Step 3: Invest and incentivize

8. **(Co-)invest** in specific flagship demonstration projects
9. **Incentivize** relevant port-related stakeholders to timely develop and/or operate hydrogen (carrier)-related activities and infrastructure.

Key recommendations to EU Member States (national governments)

Providing the enabling environment

1. **Specify the role of ports in the national H2 strategy** (including short-, medium- and long-term timelines, quantitative milestones, required infrastructure and investment needs).

2. **Work** towards the development of **integrated cross-border hydrogen valleys involving several maritime and inland ports**.

3. **Mitigate** the risk of delays in developing infrastructures due to a potential **lack of social and public acceptance**.

4. Mandate that all under construction or planned **LNG terminals and large-scale storage tanks** are **designed considering later conversion** to LH2 or hydrogen carriers (e.g., ammonia).

5. Define an appropriate **policy and regulatory framework** for the **design and operation** of hydrogen and hydrogen carriers infrastructures **in port areas**.

6. **Address** the growing **concern** over the **lack of availability of freshwater** supplies needed by electrolysis facilities.

Investing and incentivizing

1. **Maximize support for EU companies** in the design, construction and retrofitting of zero-emission ships, hydrogen and hydrogen carrier tankers and associated maritime equipment.

2. Allocate **public funding** to pioneers in the EU port areas that are **launching investments in R&I and also in market-ready projects** at all steps of the hydrogen value chain in a port environment.

Key recommendations to the institutions of the European Union

Providing the enabling environment

1. Encourage the **IMO to adapt existing** and **develop regulations** and **technical** and **safety standards** for
   - the sea-based transportation of hydrogen;
   - import terminals of hydrogen and LOHC;
   - the bunkering of hydrogen and hydrogen-based fuels;
   - the utilization of hydrogen and hydrogen-based fuels in deep-see and short-sea applications.

2. **Encourage the ISO** to **adapt existing** and **develop new standards and protocols** (e.g., on LNG to liquified hydrogen and compressed/refrigerated ammonia; vehicle on-board hydrogen storage, tank characteristics, port equipment vehicles, etc.).

3. **Work with the relevant regulatory and standardization authorities** (e.g., CCNR and CESNI & CEN and CENELEC) to develop harmonized EU-wide regulations, clear guidelines to Member States on administrative practices and permitting procedures, as well as technical and safety standards.

4. **Support the development of testing and certification protocols** for various processes and activities involving hydrogen

Investing and incentivizing

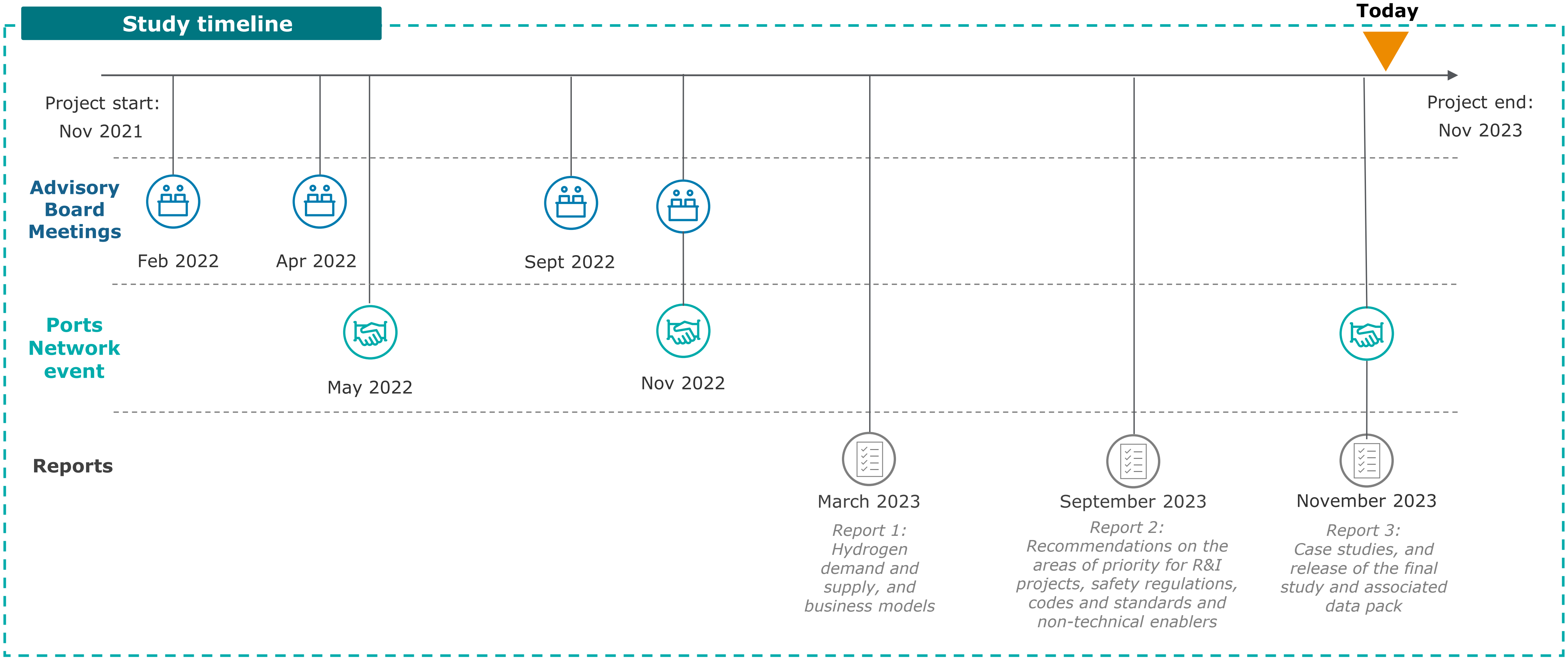
1. **Maximize support for EU companies** in the design, construction and retrofitting of zero-emission ships, hydrogen and hydrogen carrier tankers and associated maritime equipment.

2. Complementary to national funding programs, **allocate public funding to R&I and market-ready projects** aiming at demonstrating or decreasing the cost of import, production, storage, conversion, refueling and end-use of hydrogen (carriers) in a port environment.

3. Support in **clarifying** whether (and if so, under what specific conditions) it is technically and economically **feasible to convert existing LNG** terminals into **LH2, ammonia** and **LOHC** terminals.

Next steps and Q&A

Project timeline



Questions

Access our reports

Q&A

Registration link to last European Hydrogen Ports Network event, 21 November 2023 in Brussels

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