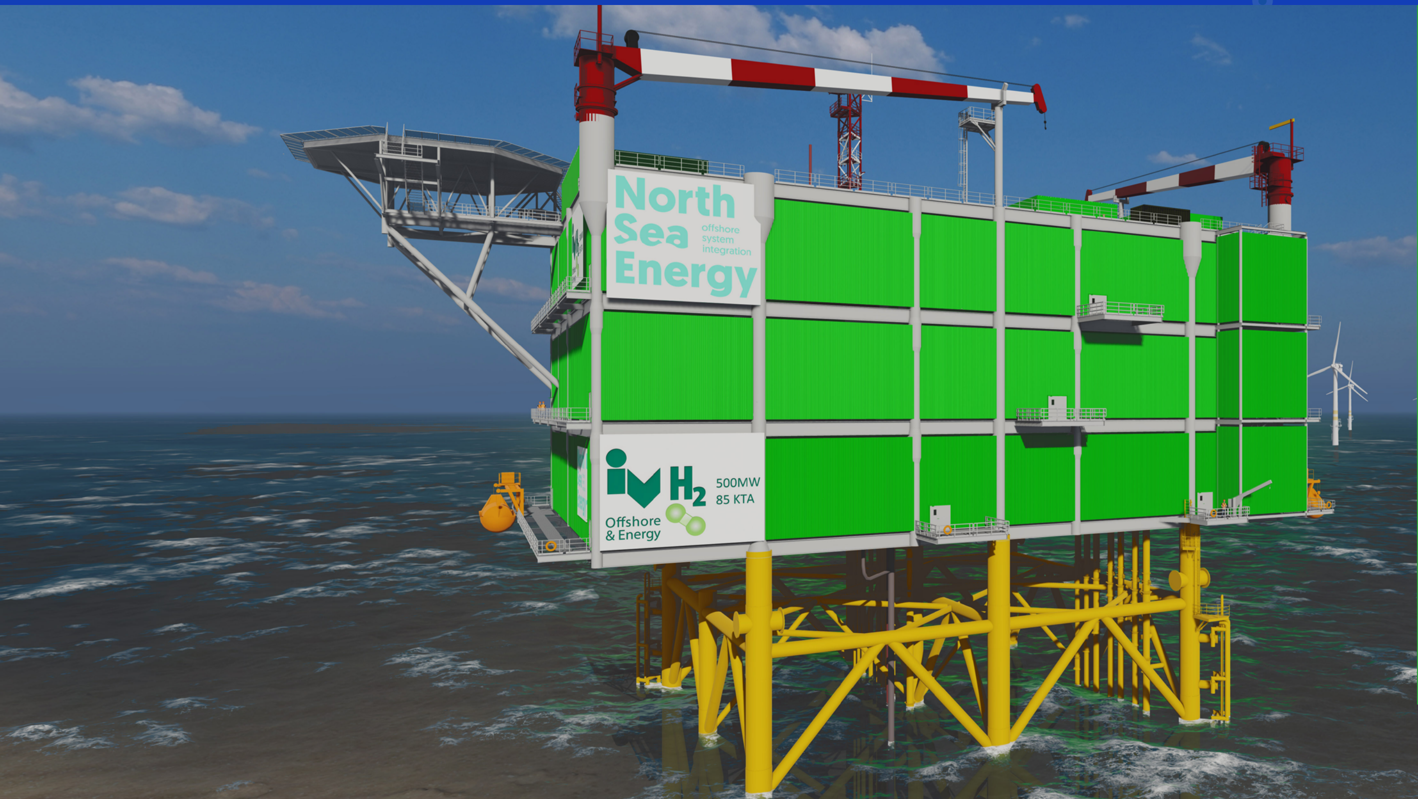
Whitepaper

Offshore hydrogen for unlocking the full energy potential of the North Sea



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TNO innovation for life

Summary

Europe has large ambitions to develop both offshore wind and green hydrogen production as a part of the realization of the climate targets. In Europe's North Seas region, The North Seas Energy Cooperation (NSEC[1]) supports and facilitates the development of the large renewable energy potential in the region. The nine NSEC countries have agreed to reach at least 76 GW of offshore wind by 2030, and 193 GW by 2040, 260 GW of offshore wind energy by 2050[2].

It will be a challenge to incorporate these amounts of electricity into the European energy systems. The use of renewable electricity for water electrolysis provides an additional route to make this possible. Large scale hydrogen production, particularly offshore, is not yet a mature technology, however. TNO advises the NSEC countries to intensify its collaboration on jointly exploiting the North Sea as an energy source on the following topics, with offshore hydrogen production enabling large scale, offshore wind deployment:

1. Innovation and knowledge sharing: A joint approach of North Sea Countries shortens the learning curve for all countries and brings the moment of large scale offshore hydrogen production forward in time.
2. Supply chain security: A joint approach provides clear signals of a high but stable pace of offshore wind and hydrogen deployment to the European offshore wind and electrolyzer manufacturing industry, so that the industry understands the rate of development required to realize the regional, national and European ambitions.
3. Infrastructure: A joint approach allows for an optimally connected infrastructure for onshore and offshore transport and storage of hydrogen to reduce overall systems cost and improve security of supply.
4. Spatial claim and ecological impact: A joint approach on offshore hydrogen allocation can optimize the harvesting of energy at allocated wind farm locations, and can minimize ecological impact related to (construction, operation and decommissioning of) hydrogen production facilities (on- and offshore), and cable or pipeline landing points.
5. Legislation: A joint approach facilitates the development of unambiguous requirements, definitions and standards and common solutions for the possibilities and limitations for offshore hydrogen production that guide Member States, companies, TSOs and DSOs towards a shared goal on the horizon.
6. A common hydrogen market: A joint approach strengthens the foundation of a European hydrogen economy, for regional production and demand, giving industry a sense of political stability and security.

Collaboration is needed to efficiently and effectively bridge the gaps between the European hydrogen ambitions and the current state of play on wind and hydrogen production. By collaborating, we believe that the opportunities above can be fully exploited, and the process of achieving these goals can be accelerated. We propose to evaluate jointly on which topics further efforts in possible collaboration can be intensified.

With this paper, TNO suggests a number of actions to boost this collaboration and proposes a roadmap towards multi-GW scale offshore hydrogen production on the North Sea. In order to reach the ambitions and targets of the EU and NSEC, it is important to start these actions as soon as possible. A potential collaboration model can be the European Research Area Network (ERA-NET) scheme, where several EU member states collaborate on a selected theme.

This work was written in October 2022 by TNO, the Netherlands Organization for Applied Scientific Research. Being a Dutch organization, parts of this document focus more on the North Sea rather than other European seas, but the suggested actions in this paper will be beneficial to all EU countries with large offshore wind potential.

1 Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden and the European Commission are currently members of the NSEC.
2 Joint Statement on the North Seas Energy Cooperation – 12 Sept 2022; https://energy.ec.europa.eu/system/files/2022-09/220912_NSEC_Joint_Statement_Dublin_Ministerial.pdf

Offshore hydrogen for unlocking the full energy potential of the North Sea

Contents

1. Introduction

Major EU offshore wind ambition

To help meeting the EU goal of climate neutrality by 2050, the European Commission presented the EU Strategy on Offshore Renewable Energy in November 2020. The nine NSEC countries have agreed to reach at least 76 GW of offshore wind by 2030, and 193 GW by 2040, 260 GW of offshore wind energy by 2050. This will represent more than 85% of the EU-wide ambition of reaching 300 GW by 2050. A large part of this capacity will be realized in the North Sea, as was supported in the declaration that was signed at the Esbjerg Offshore Wind Summit in Denmark, on May 18 2022.

Huge potential for offshore wind energy in the North Sea

The North Sea offers great opportunities for offshore wind energy because of the good wind conditions and the relatively shallow water depth, which are favourable for the installation of fixed bottom wind farms. The North Sea offshore wind potential alone is expected to be well above 300 GW. This potential is of great importance for the decarbonization strategies of the countries bordering the North Sea, and is now increasingly considered strategically important for future energy security for the entire EU.

To exploit this potential, large volumes of variable wind power will have to be incorporated into the energy systems around the North Sea. This will require the development of associated capacities of flexibility options[3] to be able to balance supply and demand.

Hydrogen is needed to unlock the full wind energy potential

The combined potential capacities of offshore and onshore renewable energy from sun and wind is much larger than can be directly absorbed as electricity in the energy systems. Using renewable electricity for water electrolysis provides an additional route to incorporate much larger amounts of renewable energy into the energy systems, rather than if wind and solar were only utilized as sources of electricity. Hydrogen is a very versatile energy carrier. It can be used for the production of electricity again, but it can also be used for non-energy purposes in industry (feedstock and industrial gas) and as a gaseous fuel in various applications that are difficult to electrify.

In addition, electrolysis-based plants can represent a great source of flexibility on the demand side in supporting controlled integration of intermittent electricity supply into the electricity system.

3 Flexibility options include demand-side management measures (creating flexible, manageable demand), energy storage, interconnection of electricity markets and flexible, controllable (preferably zero-emissions) power plants.

Spatial constraints and cost considerations point to offshore hydrogen production

Many of the plans for current and near future development of offshore wind are still based on transporting generated electricity to shore and onshore conversion at the coast. With continued implementation, however, the landing of the many electricity cables is becoming an increasing challenge as well as space requirements for onshore conversion in or near densely built-up industrial areas. In addition, the relatively high costs for electricity infrastructure are an increasing point of attention as wind farms are built further out to sea. Hydrogen offers a more favourable perspective on these points. Hydrogen infrastructure provides a greater capacity per landing point. The costs are lower, and existing natural gas infrastructure may be used. All this points to a clear need and important role for offshore hydrogen production in the near future.

Collaboration is needed to timely and optimally solve the challenges regarding offshore hydrogen

Due to its size, exploitation of the North Sea energy potential through offshore hydrogen is crucial to the realization of European hydrogen and decarbonization ambitions, including the EU 40 GW domestic electrolysis capacity target by 2030. At the moment, offshore hydrogen production is still in its infancy, just like the possible repurposing of offshore natural gas infrastructure for transport of hydrogen, and the offshore underground hydrogen storage which could greatly contribute to flexible energy storage for an integrated system of clean power.
In light of climate ambitions and geopolitical developments, it is important to develop these sources and opportunities as quickly and optimally as possible.

A major effort is needed to exploit the energy potential of the North Sea. The various countries in the region face similar challenges. Joint development increases the chance of rapid and optimal utilization of the potential at the lowest possible cost.

This paper presents the current state of play regarding the developments in offshore hydrogen production, and clarifies how a joint collaboration between the NSEC nations on specific topics can unlock the full potential of the North Sea.

2. State of Play

2.1. The expansion of wind energy in Europe

The NSEC countries and the UK all have ambitious plans with respect to development of offshore wind energy, see Figure 1. The combined ambitions of the NSEC countries show an envisioned installed capacity of 76 GW in 2030. The UK would add an additional 40 GW on the North Sea by 2030. By 2050, the total estimated installed capacity in the EU of offshore wind energy is close to 300 GW and the EU countries around the southern part of the North Sea agreed to supply 50% of that, hence 150 GW. Total installed capacity at the North Sea in 2050 is currently predicted to be over 300 GW.

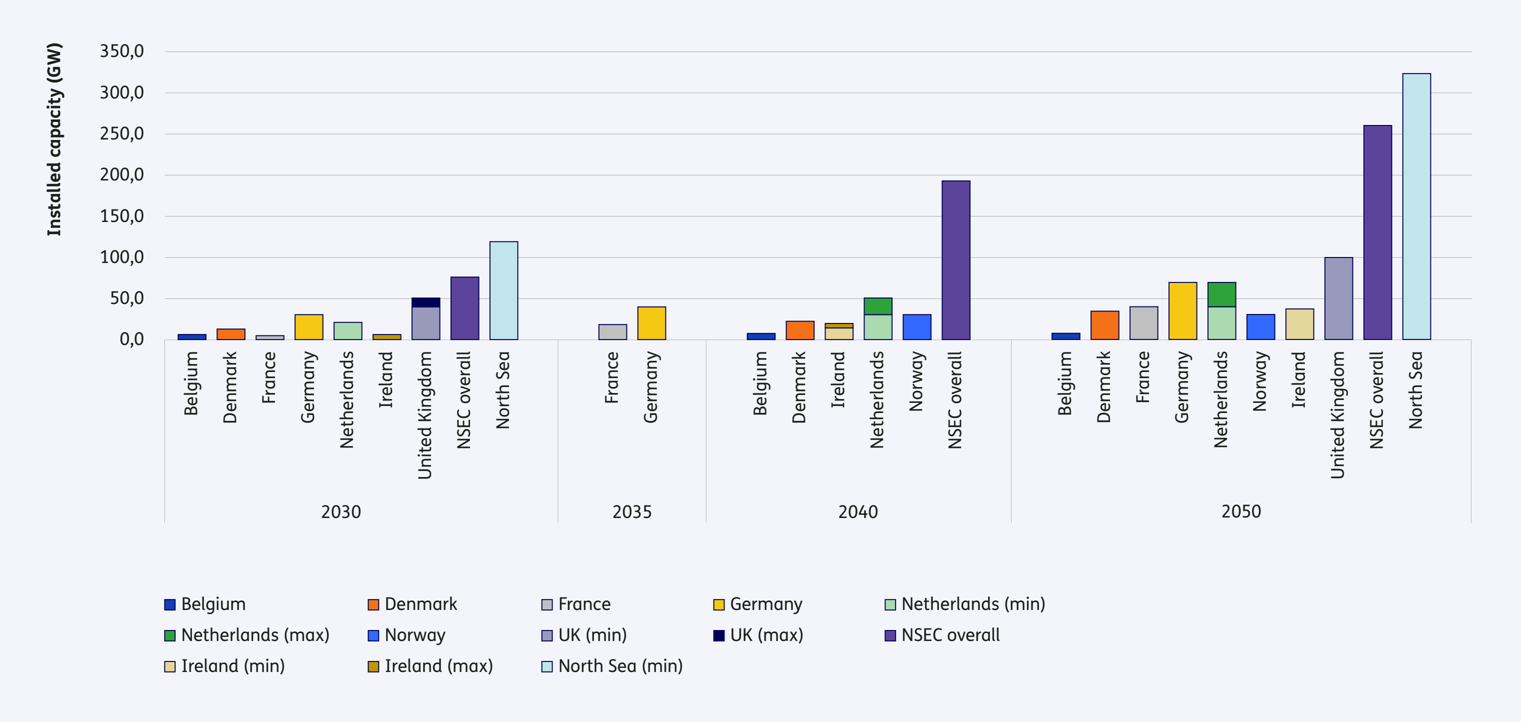


Figure 1. Predictions of installed capacities of offshore wind in Europe[4]

4 North Sea Energy 2022, published 7 November 2022 (North Sea Energy (north-sea-energy.eu).

2.2. Peak demands require investments in capacity and balancing of the grid

In the Netherlands, there are also large expansions foreseen for the onshore development of renewable energy generation next to the plans for offshore wind developments. Based on the Dutch climate agreement, for example, the target for electricity generation from onshore wind is 35 TWh which means at least 10 GW of onshore wind capacity. A comparable target is mentioned for solar PV, for which at least an additional installed capacity of 25 GW is required. The peak generation capacity of renewables (onshore and offshore wind and solar PV) will therefore increase with about 50 to 60 GW. On the demand side, the current peak demand in the Netherlands is between 15 and 20 GW. For the Netherlands it is foreseen that the electricity demand in 2030 could increase by 3 to 9 GW (average demand), due to electrification of industrial processes[5].

Other sources predict smaller increments in electricity demand due to energy conservation actions[6].

The large increments in peak production compared to peak demands will require significant investments in the capacity and balancing of the grid. It is questionable to what extent the capacity of the grid can be increased at acceptable costs. Additional flexible demand will allow effective balancing of the grid.

All in all, the possibilities for increasing electricity production in North Sea countries are more apparent than the possibilities of increasing electricity consumption. Conversion of part of the produced electricity to hydrogen will therefore allow for unlocking the full potential of energy production at the North Sea.

2.3. Hydrogen ambitions for the North Sea

Present offshore green hydrogen production capacity is still limited. There are a few pilot projects starting up, which have a capacities of kW to a MW scale. In the Netherlands, the PosHYdon[7] project comprises the demonstration of operating a 1 MW electrolyser on a platform near the coast of The Hague. The Aquaventus consortium in Germany has the ambition of 10 GW by 2035 starting with shorter term AquaSector at 300 MW capacity (2028) and AquaPrimus prototypes at the 14 MW scale (2025). The Danish government has agreed to build two “energy islands” with a minimum capacity of 2x2 GW (wind electricity) and intends to convert low-carbon electricity from the energy islands to green hydrogen which could be further processed into fuels[8]. Also in the UK consortia are working towards the first offshore (floating) hydrogen wind turbines in the ‘Hydrogen Turbine 1’and ‘Dylan’ projects[9, 10].

The REPowerEU plan’s ambition is to produce 10 million tonnes and import 10 million tonnes of renewable hydrogen in the EU by 2030[11]. The strategy of the European Commission to reach that goal is to implement 65 to 80 GW of dedicated hydrogen production, which will be onshore as well as offshore, see Figure 2.

Besides the green energy supply from wind turbines, the supply of electrolysers (and its supporting supply chain) is essential in reaching these targets. The European Commission and 20 industry CEOs signed a Joint Declaration[12] whereby industry committed to a tenfold increase of its electrolyser manufacturing capacities by 2025. This is required to be able to produce the amounts of hydrogen set as target in the March 2022 REPowerEU Communication.

5 Routekaart elektrificatie van de industrie, in 2030 30 - 80 TWh additionele elektriciteitsvraag.
6 6 IEA World Energy outlook (2019).
7 Poshydon | Green Hydrogen Energy.
8 https://www.iea.org/policies/11562 energy-island-project-in-the-north-sea.
9 New Floating Wind-to-Hydrogen Project Proposed in UK | Offshore Wind.
10 World’s first hydrogen-producing offshore wind turbine gets £9.3million funding boost - Vattenfall.
11 REPowerEU Plan - https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF.
12 Electrolyser Summit Joint Declaration, 05/05/2022, https://ec.europa.eu/docsroom/documents/50014.

Once hydrogen is produced offshore, it will be transported to shore and beyond in a pipeline network on the North Sea, consisting of newbuild pipelines, possibly in combination with repurposed existing pipelines that are currently used for natural gas transport. The current state of play and ambitions for onshore hydrogen networks are rather well defined and studied[13].

For offshore hydrogen networks, however, the plans and ambitions are still at a very basic level.

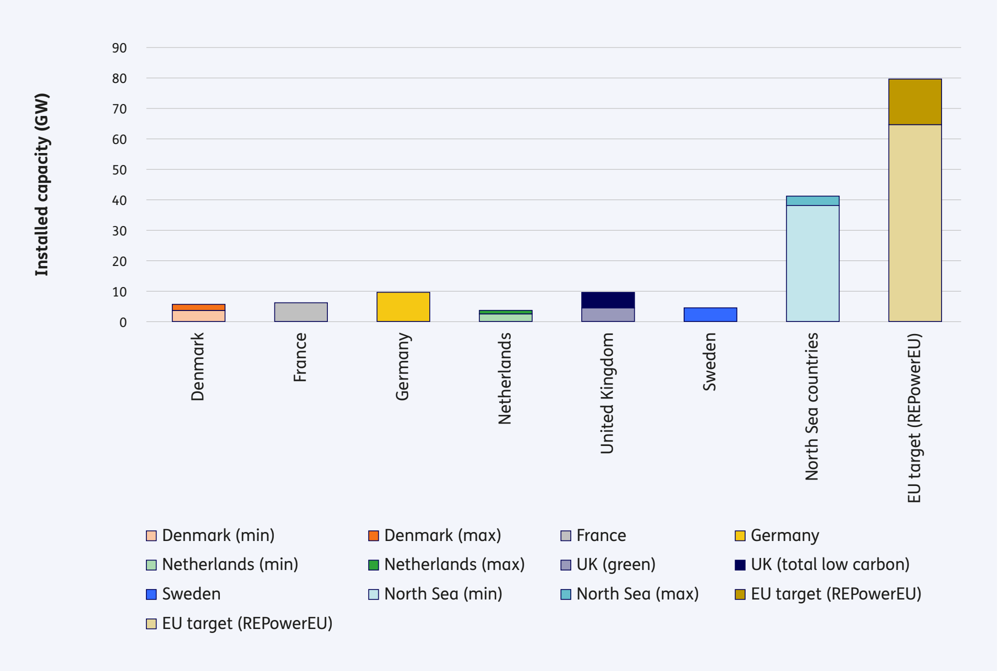


Figure 2. Predicted installed capacity for hydrogen production for 2030[14].

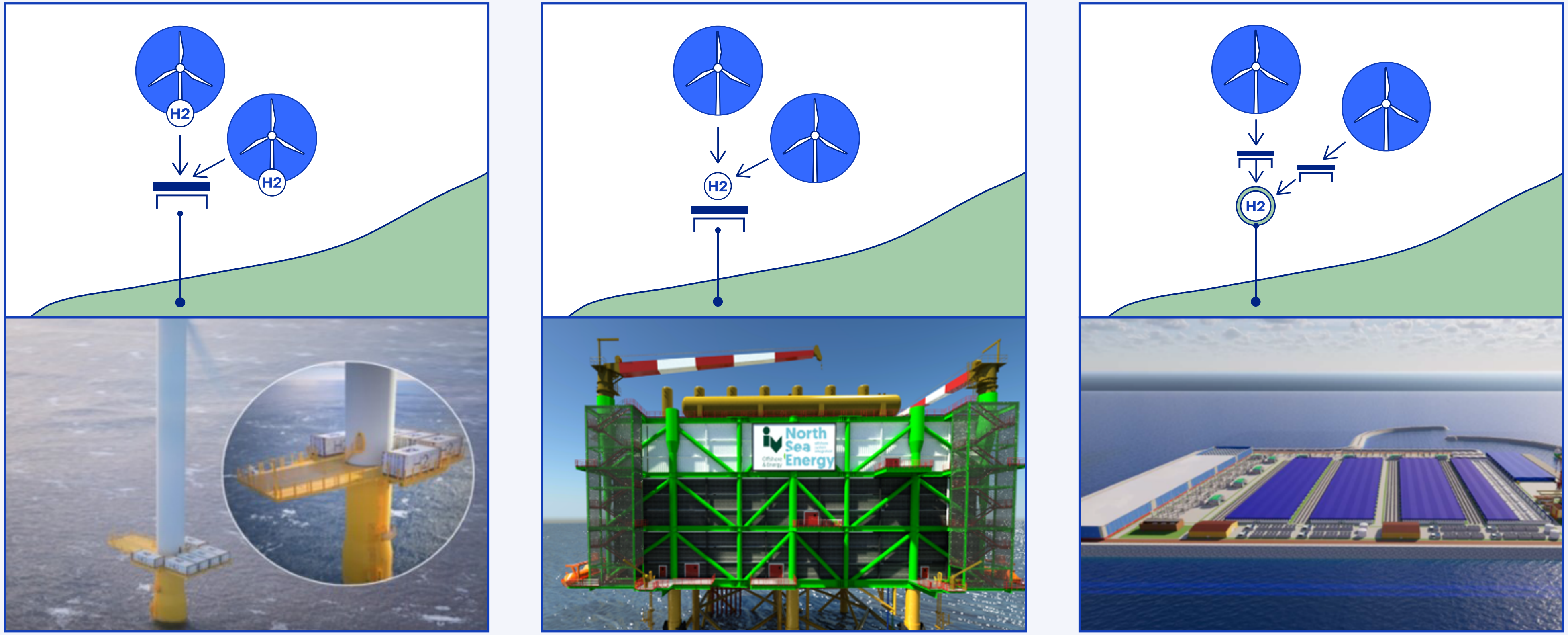
2.4. Offshore Hydrogen Production

There are several concepts of offshore hydrogen production. Most frequently investigated concepts are shown schematically in Figure 3:

a. decentralized (in-turbine or at-turbine) electrolysers at MW scale. This concept implies that the wind turbines are only connected by means of hydrogen pipelines.
b. large scale electrolysers on a platform, on a central location in the wind farm. In this case the turbines are connected to an electrical substation which is interconnected to an electrolyser platform.
c. large scale electrolysers on an energy island that combines the power of one or multiple wind farms. This concept implies that the wind farm has a conventional substation that collects the electrical power and transmits it to an energy island where the electrolysis takes place.

Each concept has benefits and disadvantages that depend on several criteria such as size, location, electrical system requirements. This document discusses offshore produced hydrogen in general and therefore does not favour one concept over the other.

13 European Hydrogen Backbone – a European infrastructure vision covering 28 countries, April 2022.
14 North Sea Energy 2022, published 7 November 2022 (North Sea Energy (north-sea-energy.eu).



a) Electrolysis at the turbine, scale 15 – 20 MW

b) Electrolysis on wind farm level, scale 300 – 500 MW

c) Electrolysis on energy island, scale Multi GW

Figure 3. Three concepts of offshore wind combined with electrolysis[15].

15 https://cleantechnica.com/2021/12/09/love-blooms-when-green-hydrogen-meets-offshore-wind-turbines/

3. The benefits of a joint approach

Comparing the ambitions to the current state of play, it is apparent that huge steps will have to be made to reach our ambitions. Bridging these gaps on short notice is essential, and can be done more effectively when working together. This is explained in the next section of this document.

3.1. Innovation

It is technically possible to move from MW to GW scale offshore hydrogen production within a decade. With the projects mentioned above, and with the ambitions under Hydrogen ambitions for the North Sea, the NSEC countries already represent an impressive portfolio of offshore hydrogen production concepts. This opens up unique cross-border and technology learning possibilities within a portfolio of Research, Development & Deployment (RD&D) initiatives for offshore hydrogen production concepts. However, without collaboration and knowledge sharing between countries, the overall ambitions and timelines are considered very challenging. With more intensified collaboration, we can learn simultaneously and important benefits can be achieved.

The benefit of working on an NSEC level will be to shorten learning curves for all countries at the same time, and thereby bring the moment of large scale offshore hydrogen production forward in time. This can be achieved through a common innovation program with the aim of accelerating offshore hydrogen in the NSEC countries and the EU.

When working together, it is anticipated that large benefits can be achieved compared to working in parallel, for example:

1. Fast-track learning for multiple concepts, centralized and decentralised, in parallel in pre-competitive environment from MW to GW scale;
2. Lower net learning (RD&D) cost with shared learning curves across sectors and countries;
3. Faster de-risking, standardization and shorter time to (bankable) market for new offshore hydrogen production concepts;
4. Knowledge and experience sharing between RD&D projects allows the build-up of expertise, experience and human capital faster to support large scale and repetitive implementation post-2030. Lessons to be learned on all facets of technology implementation: technical, environmental, safety, market, financial, institutional and stakeholder perspectives;
5. A pathway to the required cost reduction that is associated with new innovations, economies of scale and economy of numbers as they need to materialize to deliver the ambition of offshore hydrogen;
6. Establishing a frontrunner position on offshore hydrogen production with unique regional expertise and supply chain capacity, which creates jobs and an export position towards other parts of the globe with very similar challenges and opportunities.

3.2. Supply chain security

The energy transition requires very high and sustained installation rates for renewable energy production, transport, storage and demand in the next decades, both onshore and offshore. For offshore wind, WindEurope[16] has estimated a required growth in installation rate from 3 GW now to 20 GW per year in 2030 for offshore wind, in their 450 GW vision[17]. For the North Sea countries this boils down to consenting and installation rates with a maximum of 10 GW per year.

The supply chain for electrolysers is currently not at par with the offshore wind sector, but it is growing fast and announcements have been made on planned factories for manufacturing and assembling electrolysers with GW/yr output. European electrolyser manufacturers have set the objective to a tenfold increase in electrolyser manufacturing capacity from 1.75 GW to 17.5 GW by 2025, and to "further increase that capacity by 2030 in line with projected demand for renewable and low-carbon hydrogen"[18].

There are some important challenges that need attention when securing the output of this supply chain:

- The mobilization of private and governmental financing for these supply chains is needed to mitigate risks and reduce bottlenecks in the various parts of the value chain.
- The (monitoring of) implementation of Responsible Business Conduct standards, such as the OECD Guidelines for Multinational Enterprises, across the supply chains can help gain and retain a social license to operate. In addition, effort and innovation shall be put in a sustainable and circular supply chain. An example where this is critical is for further development of electrolyses, where material scarcity could be an important bottleneck depending on the electrolyser technology of choice. IRENA[19] states that "current production of iridium and platinum for PEM electrolysers will only support an estimated 3 GW-7.5 GW annual manufacturing capacity". This against a backdrop of supply chain requirement of 100 GW by 2030, globally.
- Market demand on medium size. The current projects are still at kW to multi MW scale. The plans and ambitions are at GW scale in the NSEC countries and on EU level. The required cost reduction that is associated with economies of scale needs to materialize.
- Immaturity of technology and technical risks of manufacturing. There is no experience with offshore hydrogen production; centralized or decentralised. The projects announced for offshore hydrogen production are at pilot to demonstration level. In the supply chain this means that there is no standardization yet or notion of dominant design features.

The benefit of working on an NSEC level will be that the countries could provide clear signals to the (discrete manufacturing) industry of a high and stable pace of offshore wind and hydrogen deployment so that they understand the rate of development required to deliver the regional ambitions. The mobilization of private and governmental financing for these supply chains is needed to reduce bottlenecks in the various parts of the value chain. Jointly there is a much better position for the countries to secure the supply chain and develop a frontrunner position for the region as a whole, attracting production industries to settle in the region, creating jobs, know-how and export opportunities.

16 https://windeurope.org/about-wind/reports/our-energy-our-future/#explore.
17 From 2019, including the UK.
18 18 https://ec.europa.eu/docsroom/documents/50014/attachments/1 translations/en/renditions/native.
19 IRENA (2020), Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5oC Climate Goal, International Renewable Energy Agency, Abu Dhabi.

3.3. Infrastructure & hubs

The development of offshore hydrogen production and the required infrastructure can alleviate the expansion of the offshore and onshore electricity grid. Next to financial gains this could also represent avoiding delays due to long grid-expansion procedures and timelines onshore.

The benefit of working on an NSEC level will be that it allows for connecting infrastructure on- and offshore for transport and storage of hydrogen to reduce overall systems cost and improve security of supply.

The NSEC countries have the benefit of being one of the starting nucleus of the European Hydrogen Backbone (EHB) (see Figure 4)[20]. The plans for a hydrogen network with new and repurposed pipelines are being shaped on- and offshore. For the offshore infrastructure, plans are being developed and feasibility studies are performed to create offshore hubs with interconnected platforms, islands or other offshore structures that host hydrogen production capacity and allow for cross-border connection of both electricity and hydrogen infrastructure.

A clear benefit is that most of the NSEC countries have an extensive infrastructure already in place for the transport of hydrocarbons offshore. The option to repurpose these offshore gas pipelines could bring further cost reductions in comparison with new pipelines or an all-electric offshore grid[21]. The repurpose of pipelines is technically possible, but for case-specific conclusions this warrants detailed scrutiny of the state of the infrastructure via inspections[22]. International cooperation on reducing the cost of developing offshore hydrogen infrastructure by repurposing legacy hydrocarbon infrastructure would yield benefits to all North Sea countries.

Landing offshore wind in the form of hydrogen would also alleviate electricity grid congestion near landing points that has already resulted in high curtailment and related costs in Germany[23] over the past years and is expected to remain an issue if grid reinforcement or other flexibility measures are delayed. Next to project and system cost reduction, an offshore hydrogen backbone could also reduce the development lead time for the offshore energy system, as permitting lead times may be long for offshore electricity grid development and onshore grid tie-in and enforcement.

20 "The European Hydrogen Backbone (EHB) initiative consists of a group of thirty-one energy infrastructure operators, united through a shared vision of a climate-neutral Europe enabled by a thriving renewable and low-carbon hydrogen market." https://ehb.eu/.
21 Re-Stream project reports: "For both CO2 and H2 transport, 53% to 82% of cost reduction can be achieved with around 2 MEUR/km cost reduction for offshore cases and 1 MEUR/km for onshore cases." https://www.concawe.eu/wp-content/uploads/Re-stream-final-report_Oct2021.pdf
22 https://north-sea-energy.eu/static/3e19bcb9aa57735fe1bbc423ca22d5e7/FINAL-North-Sea-Energy-Unlocking-potential-of-the-North-Sea-program-findings-2020.pdf
23 https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/Monitoringbericht_Energie2021.pdf?__blob=publicationFile&v=7.

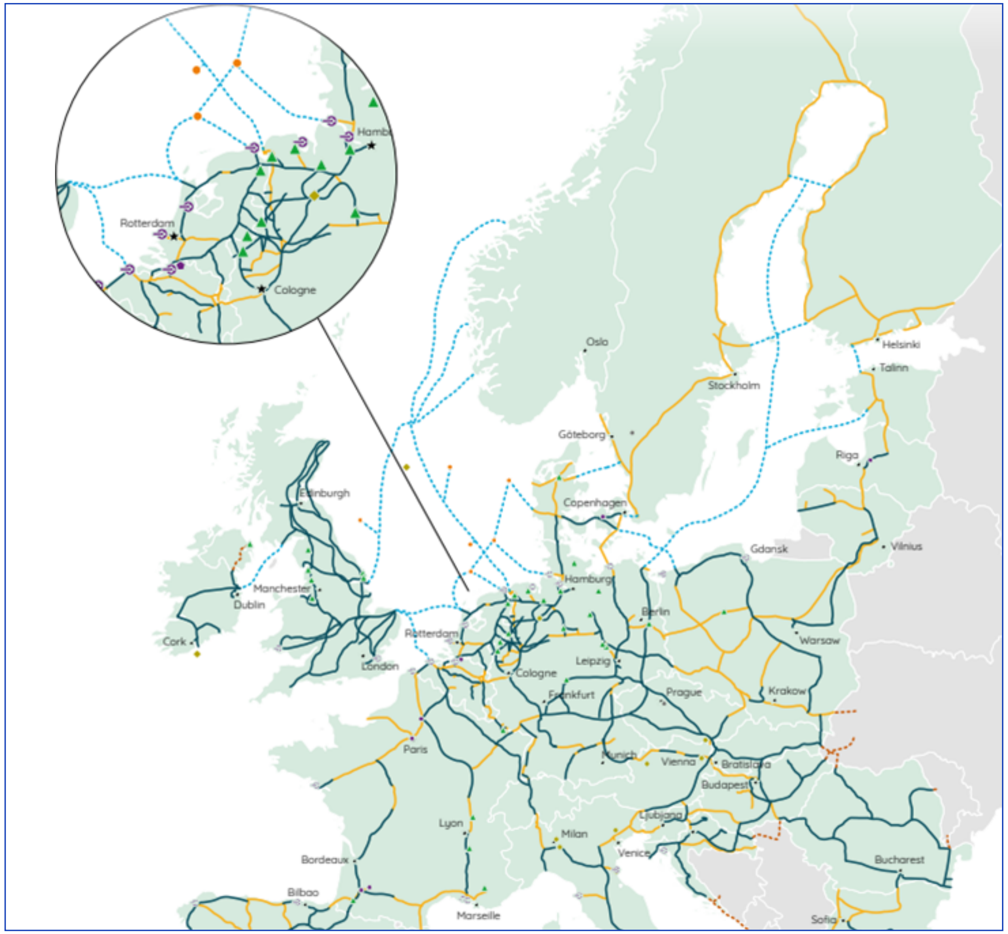


Figure 4. Vision on European hydrogen backbone towards 2040 with notional development of offshore transport network and hubs. Source European Hydrogen Backbone initiative.

3.4. Spatial claim and ecological impact

Space is a critical element in the energy transition; both on- and offshore. An optimal balance needs to be found between various offshore functionalities, such as ecology, shipping, fishing, tourism and defence. As offshore wind is growing fast, it is becoming a major consideration in maritime spatial planning, but also in planning for onshore landing points and onshore grid connections.

Currently, there is increasing attention to the (cumulative) ecological impact of offshore wind development. However, there is a sheer lack of data given the current phase in the learning curve of offshore hydrogen production. Research and monitoring is needed of (preparations of) pilot and demonstration projects to identify the impact, risks and best practices of offshore hydrogen production. This will provide actionable insights on the ecological benefits and downsides of the different production methods (in turbine, platform or island).

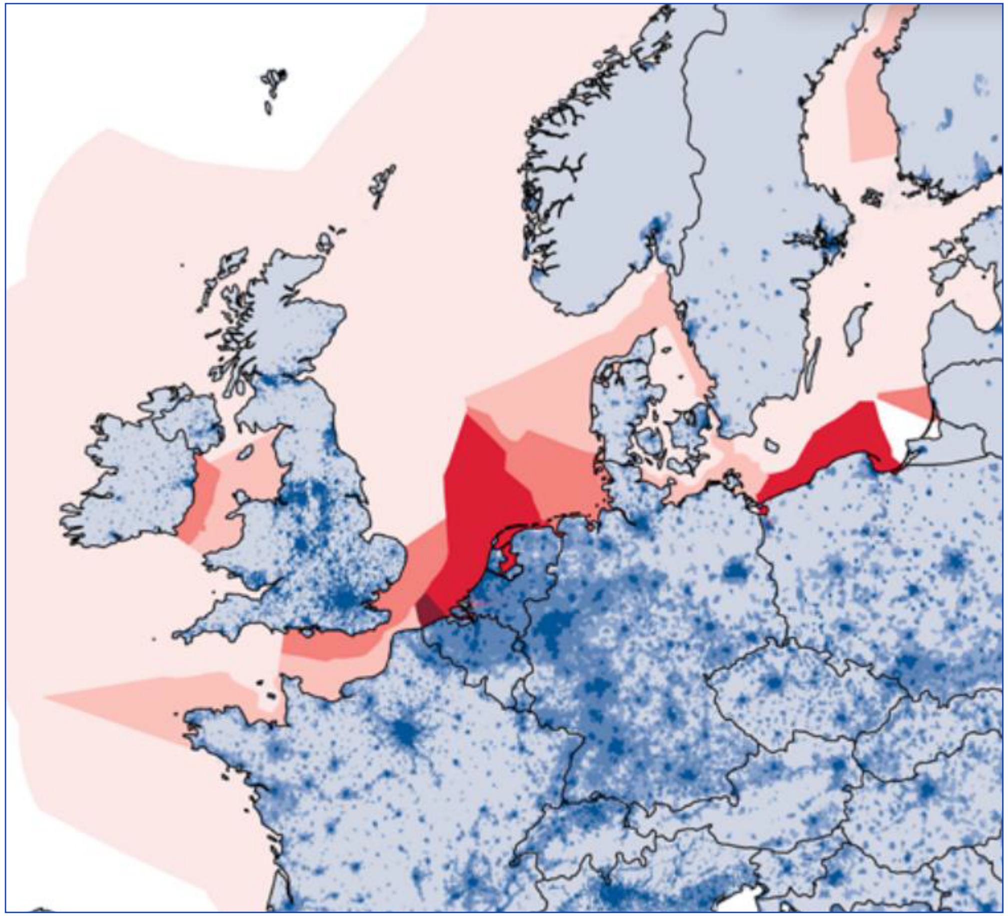
This requires attention to all phases of offshore hydrogen projects including baseline monitoring, construction, operation, decommissioning and post-abandonment stewardship. Specific research topics raised in current research programs include brine disposal from offshore electrolysis, oxygen disposal and dispersion, cooling water needs and disposal, innovative construction and decommissioning techniques and enhanced (automated) monitoring of direct and cumulative effects of offshore structures on North Sea ecology. Responsible business conduct, with a dedicated focus on circularity and sustainability shall be demanded and well monitored for offshore hydrogen production developments.

A more flexible energy system with offshore hydrogen production helps to reduce curtailment. In theory also less installed offshore capacity is thus required to meet the same energy needs; as there is lower loss of energy production. This may therefore alleviate spatial pressure for nature and other maritime use functions of the North Sea A rough calculation shows that it is possible to avoid 30 TWh curtailment[24] with offshore hydrogen production. This could avoid the installation of roughly 6 GW of offshore wind, which would otherwise have claimed approximately 900-1200 km2 (about one third of the Belgium total sea area[25]). The competition for offshore space may be further alleviated by combining various uses of the North Sea, which improves the balance between energy production, food production and ecological value.

The benefit of working on an NSEC level will be to be equipped with a broader range of possibilities to make more efficient and conscient spatial plans for the limited sea area. This can improve the balance for the different offshore uses of the European seas and the local ecology. Innovation and knowledge sharing (mentioned under 'Innovation') on ecology will contribute to the benefits on an NSEC level as well.

TNO advises to coordinate national maritime spatial plans (MSP) at the level of each sea basin.Within that coordinated effort a strategic spatial vision for offshore wind and hydrogen infrastructure could help to find an optimal balance between various functionalities, such as ecology, shipping, fishing and tourism. Ultimately this could result in scenario development and spatial planning of plot space for offshore hydrogen production, transport and storage. But such an effort will require major cross-border cooperation and planning. An additional benefit could be that ecological impacts might also be reduced with such a coordinated effort as species management transcends national boundaries and requires cross jurisdictional cooperation[26].

24 Rafael Martínez-Gordón, Manuel Sánchez-Diéguez, Amirhossein Fattahi, Germán Morales-España, Jos Sijm, André Faaij, Modelling a highly decarbonised North Sea energy system in 2050: A multinational approach,. Advances in Applied Energy, Volume 5, 2022, https://doi.org/10.1016/j.adapen.2021.100080.
25 Assuming 5000 full load hours and 5-7 MW/km2.
26 Gușatu, L.F., Menegon, S., Depellegrin, D. et al. Spatial and temporal analysis of cumulative environmental effects of offshore wind farms in the North Sea basin. Sci Rep 11, 10125 (2021). https://doi.org/10.1038/s41598-021-89537-1



Area taken up by offshore wind in 2050

□ < 5% □ 5-10% □ 10-15% □ 15-20% □ 20-35%

Population density

□ Low □ Mid □ High

Figure 5. Spatial claim of offshore wind in 2050 by percentage of total sea area, as can be found in WindEurope's 450 GW vision for offshore wind by 2050 (published November 2019)[27].

27 https://windeurope.org/about-wind/reports/our-energy-our-future/#explore

3.5. Aligned regulatory framework

An enabling market design and regulatory framework is needed for offshore hydrogen production, transport and storage. For offshore hydrogen production, the legal regime under which projects should and could be permitted is yet to be clarified and may vary between member states. Gaps between the innovation and development needs for offshore hydrogen production and the current regulatory regimes should be resolved. The support of investments and operation of offshore hydrogen production pilots, demonstration and early commercial projects require an enabling market design to move through the learning curve on one hand, yet also provide a level playing field for the market on the other hand.

This needs to be established on short notice, to align the national and EU legislative and policy frameworks. Learning from designing and applying regulatory frameworks on hydrogen production from offshore wind and sharing these between countries is thus essential and will deliver very important benefits for cross-border infrastructure and market development.

The benefit of working on an NSEC level will be to more rapidly obtain an aligned legal and policy support regime for offshore hydrogen production, transport and storage. Future, international projects that have interconnections between countries will require a clear basis to materialize. Legal analyses on offshore hydrogen[28, 29] indicate that synergies could be found in the following items:

- Alignment and best practice sharing on offshore wind tendering procedures, to support and enable offshore hydrogen production, transport and storage. This is important for providing a level playing field, increase deployment speed and aligning the timing of tendering.
- Alignment on national regulatory regimes, to provide the legal certainty necessary to sufficiently support the conversion of wind energy to hydrogen at sea. This is needed to avoid delay in project planning and permitting, especially in cross-border projects.
- Successful development of hydrogen conversion activities in the North Sea requires that coastal states ensure that hydrogen is a part of their national policy strategy and Marine Spatial Plans.
- Integrated and long term planning for offshore and onshore hydrogen and electricity systems is needed to avoid delay in projects, lower stresses on supply chains and provide a level of certainty for long term investment in infrastructure.
- Harmonization of national and EU gas quality standards by specifying homogenous blending levels is needed in the case when offshore produced hydrogen is transported to shore in a mixture with offshore produced natural gas.
- Harmonised guidelines on state aid for offshore hydrogen production, transport, storage and conversion for demand.
- Guidance regarding the permitting itself (i.e., technical and/or financial capability of the applicant) and/or safety requirements and explicit references to Power to Gas in its environmental and safety laws.
- Specifically for offshore infrastructure (transport and storage), a clear, predictable regulatory framework on procedures and guidance regarding potential repurposing of legacy infrastructure, third-party access, investment regimes, and network tariff structures to adequately value/price transport and storage.

28 North Sea Energy. Regulatory Framework: Legal Challenges and Incentives for Developing Hydrogen Offshore. 2020. Available via link.
29 European Commission, Directorate-General for Energy, Breitschopf, B., Zheng, L., Plaisir, M., et al., The role of renewable H_2 import & storage to scale up the EU deployment of renewable H_2 : report, 2022, https://data.europa.eu/doi/10.2833/727785.

3.6. A common hydrogen market and benefits to the energy system

Offshore hydrogen production contributes to stability and flexibility of the energy system. It provides more stable and better market conditions for integrating variable renewable energy sources. As a result, EU offshore hydrogen production also contributes to improving energy security in European energy markets and reduces the dependency on other parts of the world.

The benefit of working on an NSEC level will be that a larger common hydrogen market could be developed, compared to what can be expected from import and onshore production per country. The current demand in hydrogen in the four countries that signed the Esbjerg declaration is already around 3.5 Mt of hydrogen per year (see Figure 6); and almost 5 Mt per year when taking a perspective from the countries with a North Sea coastline.

Collaboration and market integration likely results in better utilization of infrastructure, reduce the risk of stranded assets and increases security of supply for hydrogen off takers, next to a higher accessible market volume for hydrogen producers[30].

A delicate balance is needed between the deployment of offshore wind along with other renewable sources and the deployment of electrolysis assets[31]. If too many hydrogen production facilities will be built in a short period of time, it may increase electricity demand and prices to such extent that investments in new electrolysers will become uneconomic. New renewable energy production facilities will have to be installed, up to a point where electricity prices have dropped to a point that electrolysers have a sustainable business case again.

These 'stop-and-go' investment cycles can strain the offshore energy value chains and delay the energy transition. A cross-border orchestrated roll-out of offshore wind and hydrogen assets can mitigate these intermittent investment cycles further, as the relative contribution of a single electrolyser asset to the European market will be smaller than to a national market.

30 Hy3 – Large-scale Hydrogen Production from Offshore Wind to Decarbonise the Dutch and German Industry. Deutsche Energie-Agentur GmbH (dena), TNO and Forschungszentrum Jülich. 2022, Accessible via Hy3.eu
31 https://north-sea-energy.eu.

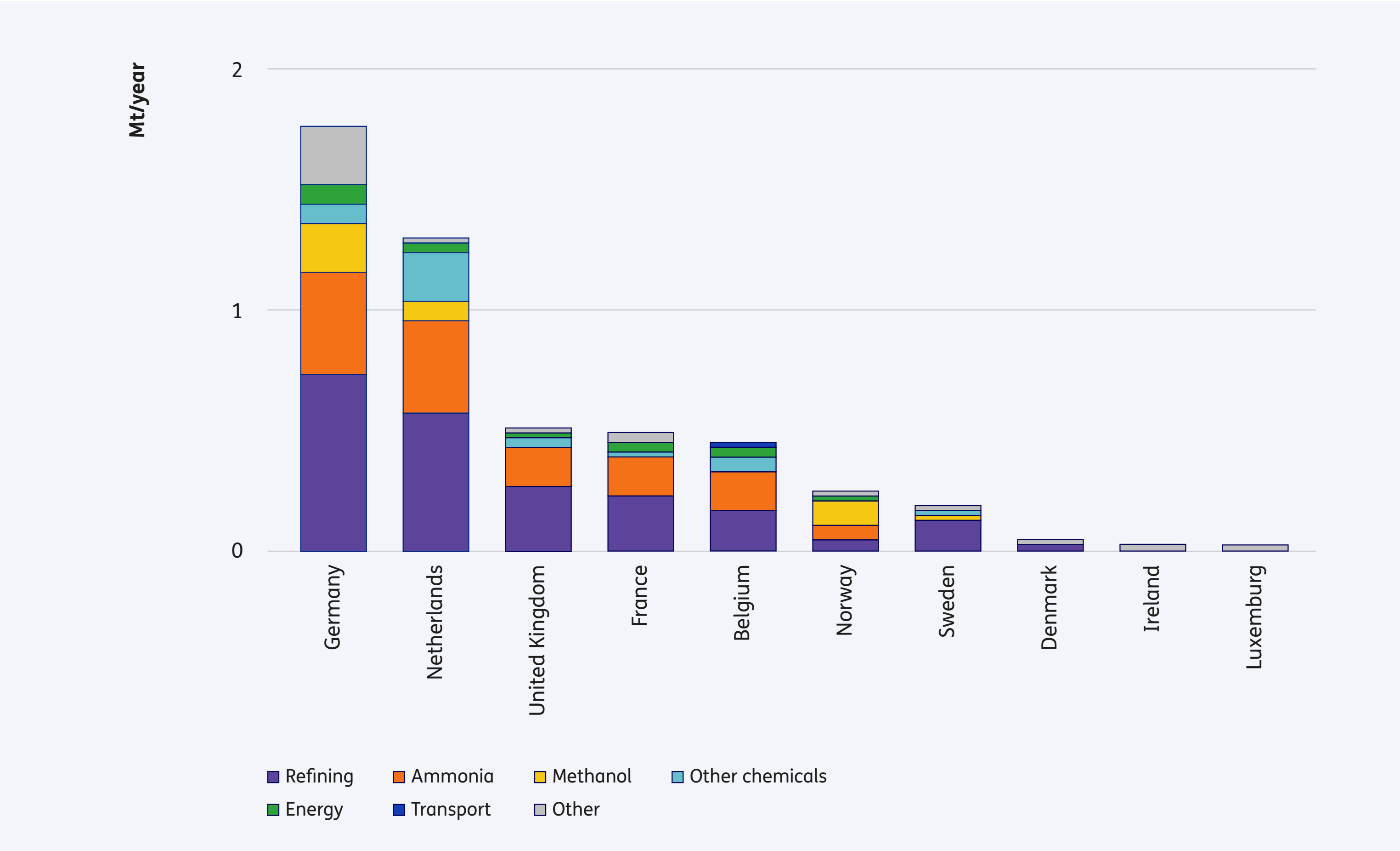


Figure 6. Current hydrogen demand by sector and country. Source Fuel cells and Hydrogen observatory[32].

32 Hydrogen Demand | FCHObservatory

4. Conclusion - Making it possible

To efficiently and effectively bridge the gaps between the European hydrogen ambitions and the current state of play, we see opportunities for jointly exploiting the wind energy at the European Seas using offshore hydrogen production, on the following topics:

1. Innovation: Many steps will still have to be taken in order to have large scale offshore hydrogen production in 2030, and known and unknown challenges will have to be overcome. A joint approach steepens the learning curve for all countries, and brings the moment of large scale offshore hydrogen production forward in time. A potential collaboration model can be the European Research Area Network (ERA-NET) scheme.
2. Supply chain security: A joint approach provides clear signals to the European (discrete manufacturing) industry of a high but stable pace of offshore wind and hydrogen deployment so that they understand the rate of development required to deliver the regional, national and European ambitions.
3. A common hydrogen market: A joint approach on offshore hydrogen production strengthens the foundation of a European hydrogen economy, for production and demand, giving industry a sense of political stability and security. This improves the chance of acceptable return on investments of offshore wind to hydrogen projects and, vice versa, may accelerate larger natural gas consuming industry to switch to hydrogen.
4. Infrastructure: A joint approach allows for an optimally connected infrastructure for onshore and offshore transport and storage of hydrogen to reduce overall systems cost and improve security of supply.
5. Spatial claim and ecological impact: A joint approach can optimize the harvesting of energy at allocated wind farm locations, and can minimize ecological impact when it comes to (the number of) landing points.
6. Common regulatory framework: A joint approach clarifies standards, requirements, limitations and possibilities for offshore hydrogen production and transport, to move countries, companies, DSO's and TSO's towards the same point on the horizon.

By collaborating, we believe these opportunities can be harvested optimally, and the process of reaching these targets can be accelerated. We propose to evaluate jointly on which topics further efforts in possible collaboration can be intensified. Possible topics are foreseen to be:

1. Determine a roadmap towards a multi-GW scale offshore hydrogen producing North Sea. Identify what demonstrations and scale ups are to be required in order to meet the ambitions of these nations.
2. Identify methods to incentivize offshore wind and electrolysis in a similar and balanced way on a European level, to provide basis for a stable growth of offshore hydrogen production, yet considering other functions of the North Sea, such as shipping, fishing and ecology.
3. Define of a joint vision on infrastructure, to aim for an optimized grid determined by trade-offs on a multi-national level, for an offshore hydrogen backbone, (the reuse of) pipeline infrastructure, landing locations and connecting locations between nations.
4. Setup a common innovation program, where we aim to learn on European level and study options/concepts in different countries, instead of each country by itself. This includes combining tenders, knowledge dissemination, particularly on demonstration projects supported by subsidy schemes. ERA NET is considered an appropriate instrument for collaboration.
5. Strive for alignment on European legislation, standards and policy, that also focusses on offshore production, transport and storage of hydrogen.

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