EXPERT PAPER

The Esbjerg Cooperation

Transforming the North Sea into Europe’s green power plant

The North Sea will be the green power plant of Europe. The rapid expansion of offshore wind energy in particular will be key to achieving our climate targets. But how can the massive expansion of offshore wind power in Europe be achieved quickly and in a manner that is coordinated and sustainable as well as technically and socioeconomically efficient?

In the following, we show how in the future offshore wind will not only be radially connected to the coast, but also via *hybrid interconnectors*, *hydrogen infrastructure* and *offshore energy hubs*.

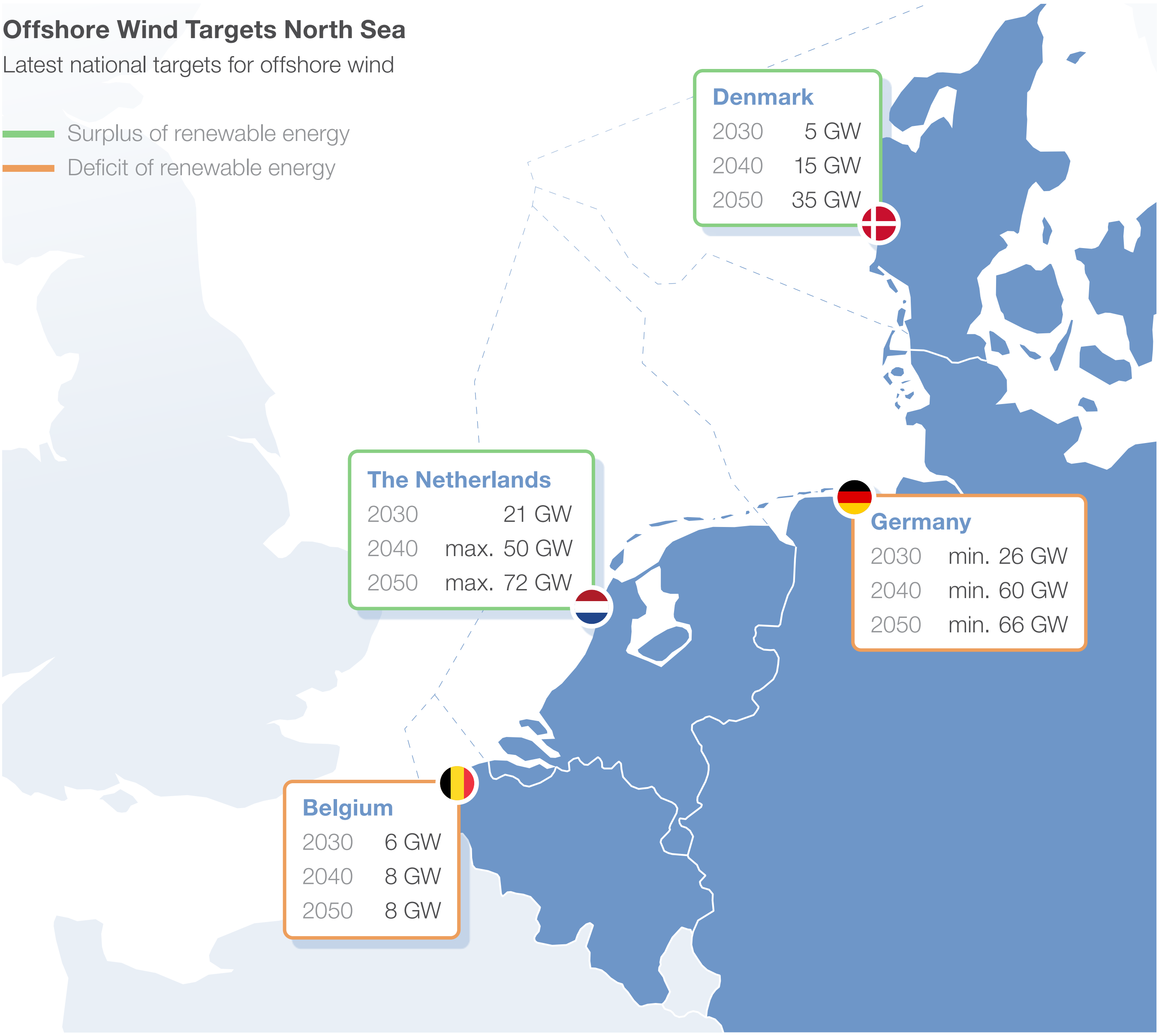
Prompted by efforts to reach climate targets and accelerated by the current energy crisis, more and more thought has been put into offshore infrastructure in the past few years. About a year ago, the *Esbjerg Declaration* – signed by Belgium, Denmark, Germany and the Netherlands – has given a decisive boost to these efforts. We see the *Esbjerg Declaration* as a great opportunity to spur on the development of an interconnected offshore electricity and hydrogen grid in the North Sea.

As leading TSOs we see the time has come for more concrete projects to efficiently integrate offshore wind to meet the growing demand for electricity in Europe and around the North Sea. The time has come to transform the North Sea into Europe's green power plant.

I. Accelerate offshore wind and hydrogen

As frontrunners in offshore wind, the four countries of the *Esbjerg Declaration* want to jointly connect 65 GW of offshore wind energy by 2030 and 150 GW by 2050 by establishing interconnected *energy hubs* in the North Sea. In addition, 20 GW of hydrogen production capacity on- and offshore should be developed by 2030. Achieving these goals requires joint planning – now. This is the reason why we point out in the following how an internationally coordinated vision that takes national plans into consideration will unlock a substantial part of Europe's offshore wind potential and enable reaching the objectives of the EU Green Deal, both in terms of timings and volumes.

The combination of radial offshore wind connections, *hybrid interconnectors*, *hydrogen infrastructure* and *energy hubs* could harness the full renewable potential of the North Sea, while more efficiently distributing the green electrons and molecules among European Member States. In addition, it will contribute to bringing countries together – and especially those with uneven potential resources for renewables. If we succeed in ensuring that Europe acts quickly to establish *hybrid interconnectors* more broadly across the North Sea countries, Europe will be able to enjoy more energy independence – and show the world that a sustainable future is possible!



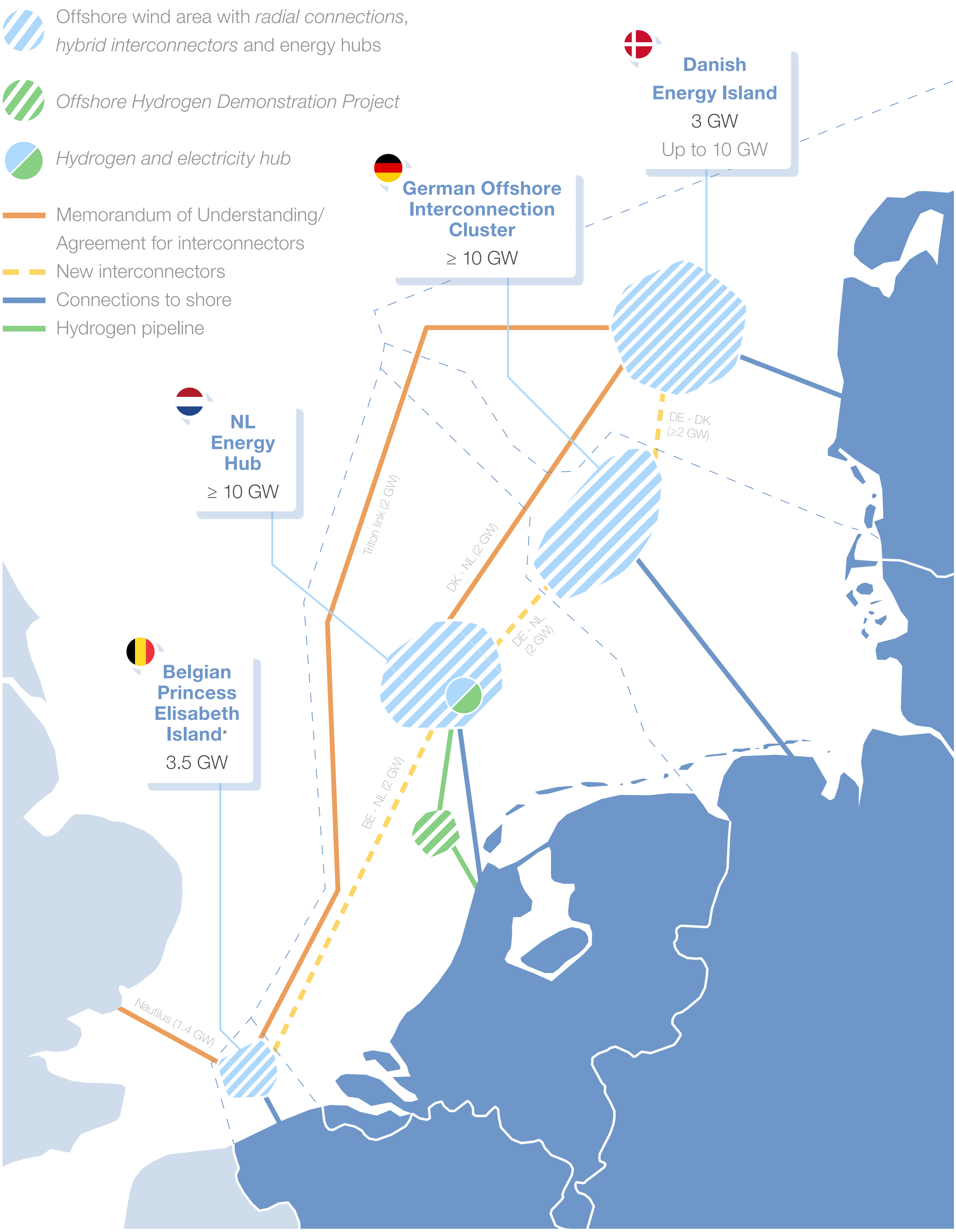
All four countries of the *Esbjerg Declaration* have set national targets for the expansion of offshore wind energy in the North Sea. If they succeed in achieving their individual goals, it will also be possible to achieve the collective goals of the *Esbjerg Declaration*. Preparations are already underway for designating areas for offshore wind, grid connections and hydrogen demonstration projects. Now it is time to push ahead with efforts to plan a European offshore grid in the North Sea.

II. Initial offshore grid in the North Sea

We propose taking a gradual approach that starts with identifying initial projects for an offshore grid consisting of *hybrid interconnectors*, *hydrogen infrastructure* and *offshore energy hubs* in the North Sea by around 2035. Such an approach will incorporate projects that are already being assessed, add new ones and offer the option to connect more countries to the grid, which could eventually evolve into an advanced offshore energy system for the whole North Sea area.

Initial offshore grid

Cross border projects in mid 2030s time horizon



Connections to shore are a graphically simplified representation of multiple connections to shore.
Offshore wind areas are a graphically simplified representation of potentially separate or coupled wind farm areas.

* As next steps, further investigations with relation to the interaction with the Princess Elisabeth Island, the foreseen increase of Belgian offshore renewable energy generation to 8 GW by 2040 and the onshore grid are to be launched and to be complemented by a cost-benefit analysis.

The energy hubs and islands

Denmark
Denmark is a frontrunner in establishing two of the world's first energy islands. The two energy islands in North and Baltic Sea which are scheduled to be completed in the beginning of the 2030s and will together be able to supply 6 GW of power. The energy island in the North Sea will have an initial capacity of 3 GW increasing to 10 GW going towards 2040.

Belgium
Belgium will develop a world's first artificial energy island called "Princess Elisabeth Island". Planned in 2026, the island will facilitate the connection of 3.5 GW domestic offshore wind by 2030. The island will also enable efficient sharing of those and other renewables in and around the North Sea, starting with additional interconnections to United Kingdom (Nautilus in 2030) and to Denmark (TritonLink in 2031-2032). Towards 2035, it is even envisaged to combine these interconnections in one common electrical node offshore, allowing new and more efficient paths between offshore wind production and demand.

Germany
With the "German *Offshore Interconnection Cluster*", more than 10 GW will be available for international connection between 2032 and 2036. The interconnection cluster can be implemented flexibly, modularly and building on the radial offshore connection systems, depending on how the national plans are updated. Furthermore, a wind area will be tendered during 2023/2024 with the special emphasis on offshore hydrogen production.

The Netherlands
Some initial hub demonstration projects, such as a full electrical hub as well as a hybrid 500 MW hydrogen conversion hub, are expected to enter operation in the early 2030s. In addition to these first hub demonstration projects, the Dutch Ministry of Economic Affairs and Climate Policy is preparing an infrastructure plan for the establishment of a large-scale hub, approximately 150 km up North from the Dutch coastline. One main objective of these efforts will be on developing this area into a large-scale *energy hub* which have the capacity between 20 to 30 GW offshore wind.

The interconnections

- DK – BE (MoA signed)
- DK – NL (MoU signed)
- DK – DE (new)
- DE – NL (new)
- NL – BE (new)

All these connections have been identified based on recent studies as well as political agreements. Once realised, we will be able to create synergies, achieve a higher utilisation of offshore wind yields, offer a variety of congestion management options, and ensure better economic returns for the society from the offshore energy and improved utilisation of the invested assets. Together we can harvest the energy of offshore wind in an optimal and cross-border fashion. Together, we can build and operate a standardised offshore grid like the one we already have onshore.

- **Accelerate offshore wind**
  Delivering grid infrastructure to support the ambition of the North Sea's countries to accelerate offshore wind integration. This would spread the huge investment need, giving wind developers clear opportunities and long-term investment signals.

- **Win-win situation for the participating countries**
  Creating synergies from uneven distributed potential of offshore wind, generation, and electricity demand between neighbouring countries. Countries whose generation of renewables exceeds their national demand ("long") can export their untapped electricity to connected countries whose own potential of renewables does not cover national demand ("short"). This creates a win-win situation for the participating countries: the exporter benefiting from an increase in producers' surplus and the importer benefiting from an increase in consumers' surplus due to access to low-priced, green electricity, leading to an overall net increase in European socio-economic welfare.

- **Additional access to dispatchable power**
  The total electricity demand is expected to increase over the coming decades. This can be served for a large extent by additional renewable power production. However this is not always possible due to periods with less wind and solar production, resulting in a need for flexibilities such as additional dispatchable power generation, more flexible demand or energy storage units as well as additional infrastructure for spatial balancing. Wind production profiles from the various areas in the North Sea are partly uncorrelated. By interconnecting the countries and windfarms with the proposed infrastructure, a higher direct supply of renewable power can be brought to the different markets. This will not only increase the penetration of green electrons in the final power demand, but this will also result in a lower requirement to invest in additional dispatchable power generation within the different countries.

- **Higher economic return of the offshore energy**
  By connecting different countries and price zones, the wind energy will be directed to a maximum to those areas with the highest prices.

- **Higher utilisation of the invested assets**
  Combining offshore connection systems with links between countries will ensure a higher utilisation of the invested assets. In times with low wind infeed, the cables will be used for cross border power exchange between countries.

- **Delivering redundancy**
  In case of a failure in an offshore connection system, the electricity can be transported by the other connected systems instead of a curtailment of the wind park and therefore contributes to a higher utilisation of the offshore wind by delivering redundancy.

- **Efficient integration**
  In case of overloads in the onshore grid, the offshore wind infeed can be transported to the best available onshore grid connection point near the electricity demand. Additionally, electricity can be transported from one onshore grid connection point to another using the offshore link to relieve the onshore grid. Both the use of hubs as well as offshore interconnections create efficient dispatch opportunities and offer a variety of congestion management opportunities. Thereby these may reduce the need for additional measures in the onshore grid.

III. Hydrogen as part of the plan

Hydrogen also plays an important role in the development of the North Sea into Europe's largest green power plant. Hydrogen and electricity grids should be planned and operated in an integrated way - both onshore and offshore. This involves on- and offshore hydrogen production next to import on the one hand and a hydrogen grid with storage capacities on the other. Hydrogen production should ideally be placed where we have a surplus of renewables in order to develop an efficient and integrated energy system.

The initial offshore grid proposed here contains the first concrete projects that make it possible to further develop and demonstrate the hydrogen technology offshore[1], potentially through the Dutch Hydrogen Demonstration Hub or the Danish Energy Island. These demonstration projects should derisk future investments and pave the way for large scale hydrogen production capacities in a later stage, while developing the *energy hubs*. Additionally, Denmark and the Netherlands are exploring how to connect both projects in future and make it a an integral part of the future meshed hydrogen grid in the North Sea. Note that equally in Belgium and Germany there are developments on hydrogen offshore infrastructure. In the Federal Hydrogen Strategy, Belgium has the 2030 ambition to connect its import hub to neighbouring countries via the open-access hydrogen network in order to realise its international positioning as an import and transit hub for renewable energy in Europe. In Germany, the first offshore hydrogen production site is expected to be tendered in 2023/2024. The pipeline connecting this site to the shore may become a cornerstone of an open-access hydrogen grid in the German part of the North Sea, which will also allow for hydrogen imports from other North Sea countries in the future.

In order to scale up after 2030, offshore hydrogen production needs to be developed around 2030. The advantages of grid-integrated offshore hydrogen production are related to possibly higher utilisation of the off- and onshore electricity grid, lower overall investment requirement under certain conditions, less coastal crossings and less spatial constraints onshore while developing receiving terminals and onshore hydrogen production. To scale *hydrogen infrastructure* successfully spatial planning needs a long term, integrated perspective and economic models need to financially derisk first users.

IV. Framework conditions

In order for the vision of an initial offshore grid with *hybrid interconnectors*, *hydrogen infrastructure* and *energy hubs* in the North Sea to become a reality, we will need to see adjustments to the technical, regulatory and market frameworks that will accelerate projects and speed up the decarbonisation of society. For example, we need to harmonise the technical standards and enable interoperability of our projects; we would welcome additional, incentivising support for innovation and anticipatory design costs; we advocate the adoption of a planning and evaluation approach that encompasses a broader offshore

[1] Further information on the development of hydrogen: https://ehb.eu/files/downloads/ehb-report-220428-17h00-interactive-1.pdf

grid and related compensation for all impacts on the natural environment on a sea-basin scale; and we believe that planning and permitting procedures should be expedited for both the generation and the transmission elements. In short, we need innovative solutions, lean and workable approaches, and – crucially – a higher pace of realisation. While the framework conditions are being clarified in detail, we offer to already work on the implementation of the initial offshore grid in order not to lose any time and to tap the future potential of offshore wind.

Regulatory conditions & governance

- **Cost sharing & financing support**
  Hybrid interconnectors and *energy hubs* are a particularly prominent case for projects with spread benefits – in other words, while the benefit to the hosting countries might not be sufficient, the overall benefit to Europe's socio-economic welfare from these projects outweighs their projected cost. This is especially true for the reduction of CO_2 emissions considering that CO_2 does not know national boundaries. Accordingly, the relevance of a feasible cost-sharing framework will gain importance with such projects in the pipeline.

  This has also been recognised by the EU legislators, whose revised Trans-European Networks for Energy (TEN-E) regulation calls on the European Commission to formulate a new guideline for sea basin cost benefit analysis and cost sharing by 2024. This guideline is supposed to specify a robust framework for the fair distribution of costs among all Member States benefitting from a sea basin. The TSOs associated with the *Esbjerg Declaration* welcome these developments and recommend a workable approach to avoid burdensome administration. They are necessary to ensure that all benefits and first mover effects are taken into account.

  In addition to cost sharing between countries, EU funding has proven to be a decisive factor when realising projects of European benefit beyond the hosting countries' territory. It is reasonable to expect more projects in the future when the cost burden is shared according to the benefits. Additionally, part of the investment costs could be covered by EU funding sources to reflect additional socioeconomic benefits at the European level. The Connecting Europe Facility for Energy is a particularly prominent fund that deserves more resources in the upcoming budgeting phases. However, it is important to make sure that EU funding is eligible in all national regulatory frameworks to avoid creating misaligned incentives.

- **Anticipatory investments & regulatory incentives for innovation**
  Hybrid interconnectors, hydrogen infrastructure and *energy hubs* are innovative in multiple ways. In addition to being international projects involving several countries, they combine the development and integration of offshore wind power, interconnection capacity and hydrogen. These new characteristics have in common the fact that their full potential can only be realised by subsequentially developing individual projects into a meshed grid in the long term. More specifically, rather than requiring just

one step, the vision of a meshed offshore grid can only be achieved by taking an iterative approach that goes from having (a) offshore wind parks that are only directly connected to the shore to (b) offshore wind farms that are connected both radially to shore and to each other to (c) *offshore energy hubs*. This means that expandability needs to be taken into account (i.e. when the initial *radial connection* to shore is planned). In practice this will mean that investments (e.g. for a larger platform or additional assets) need to be approved as so called "anticipatory investments" to enable planning security.

Furthermore, the current regulatory frameworks at both the EU and national levels lack suitable incentives for TSOs to devote resources to these kinds of "anticipatory investments" including those in new or to-be-developed technology. Investing in novel projects, such as a *hybrid interconnector* or *energy hub*, comes with challenges that are currently not fully covered by the regulatory framework.

- Input-based incentives should reduce the downside risk of innovation. For example, these could be project specific subsidies or approved budgets for research and development.
- In addition, test-field regulations outside the strict confine of the existing regulatory framework could give more room for testing innovations. We therefore welcome the suggestion to establish 'regulatory sandboxes'. However, while these could kick-start pilot projects aimed at developing innovative solutions, they are not fit to incentivise the kind of large-scale investments that will be needed to develop an offshore grid in the North Sea. Furthermore, if the tested innovations prove beneficial to the end consumer, this should be factored into the regulatory return for TSOs.
- Output-based incentives linked to the value added by the innovation would encourage TSOs to boost their own investment volumes. For example, TSOs could get a share of the value added by their innovation or an "innovation bonus" stipulated by the regulator.

Regarding implementation, it is crucial that the incentives on anticipatory investments and innovation are aligned in the legislations of various countries involved. Indeed, the development of *hybrid interconnectors*, *hydrogen infrastructure* and *energy hubs* in the North Sea can only succeed, if all Member States work together and their TSOs are incentivized to develop projects to the same degree. Thus, the massive offshore build-out can only succeed if anticipatory investments and incentives for innovative solutions are recognized in the regulatory framework and aligned internationally.

- **Market conditions for hybrid interconnectors and energy hubs**
  If *hybrid interconnectors* and *energy hubs* are to be developed in a way that ensures a stable, predictable and reliable investment climate for all stakeholders involved, there is a need for clarity regarding the market design. Efficient integration of large amounts of offshore wind energy will require a market design that considers the physical constraints of the grid so as to ensure both efficient access for all market participants.

Securing a conducive investment climate is inevitable for the ramp up of offshore wind. A fair remuneration for all investors needs to be ensured, in line with the risks every party has to take in a given project connecting offshore wind farms to *hybrid interconnectors*. To ensure a well-functioning market, we need specific and transparent revenue streams for the transmission and generator side. For transmission system operators, this is ensured via a regulated return while congestion income contributes further to maintaining and further developing interconnector capacities or lowering the grid tariffs, and thus the end consumer bill. For offshore wind park developers, well-designed contract for difference mechanisms can be a feasible solution to ensure revenue stabilization. All support mechanisms should be as technologically neutral as possible and follow the same taxonomy.

At present there are two main concepts for how an offshore market design can be configured: the Home Market (HM) setup and the Offshore Bidding Zone (OBZ) setup. For certain configurations, some parties are considering a HM setup which may then require robust and longterm exemptions from the so called "*70% rule*". On the other hand, for the OBZ setup, more clarity is needed on how it can be configured (e.g. size, number, boundaries) to ensure adequate stability and, consequently, how interconnection capacity between these bidding zones is allocated. Both solutions have been analysed and evaluated using various criteria. While the HM setup is still applicable for *radial connections*, the OBZ setup seems the most promising concept for future offshore hybrid projects when considering the efficiency of markets and system integration. In addition, the European Commission has expressed its preference for OBZs for the efficient integration of offshore wind power. ACER and CEER also support the EC's offshore strategy. The choice between an OBZ and HM set-up will have an impact on the cost-benefit-analysis used to determine placement of electrolysis capacities. In an OBZ, prices are expected to correlate to the exporting countries rather than the importing countries, resulting in lower prices compared to a rather importing Home Market.

To achieve the efficiency gains from the OBZ, the allocation of offshore wind volumes and interconnector capacity needs to happen simultaneously. This requires the interconnectors to be part of an *implicit market coupling*. Only in this way offshore wind and interconnector capacity are in its most effective way put into competition to achieve the best solution from economic welfare perspective. *Implicit market coupling* should be the target model when developing offshore wind.

Technical conditions

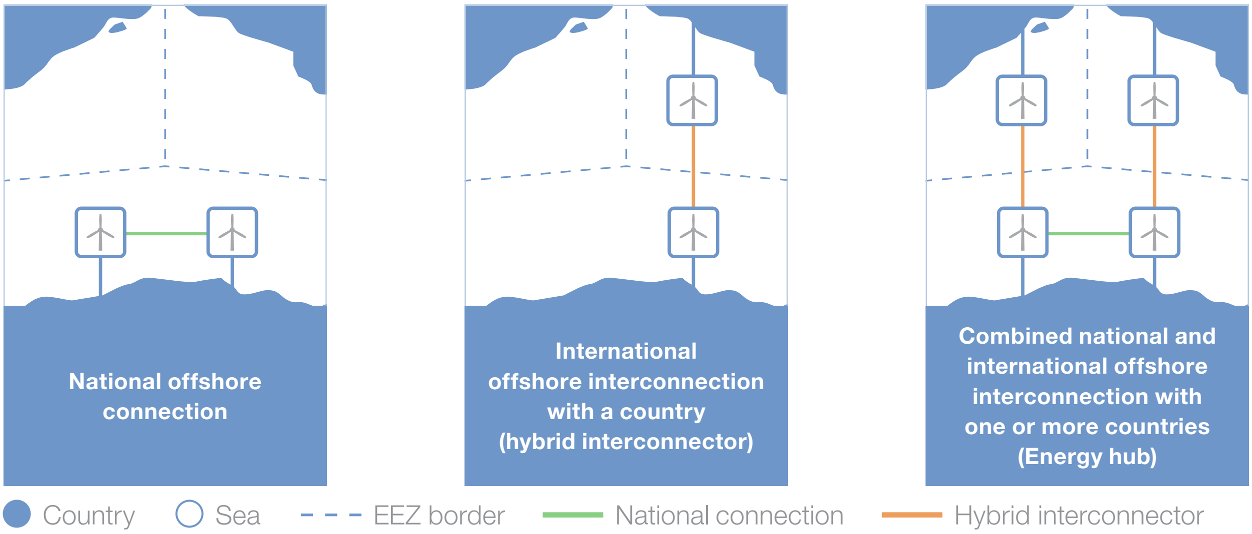
- **Multi-Terminal HVDC**
  The key to unlocking the potential of the North Sea by enabling offshore grids, is to make use of multi-terminal *HVDC* systems. This is especially true when going above the 3 GW level with respect to the available primary control reserve in continental Europe. For a first approach, two additional *HVDC* connections per platform have been proposed based on today's state of the art 525 kV voltage level and 2 GW transmission capacity.

- **Multi-Vendor HVDC**
  A basic precondition for the realisation of resource- and cost-efficient offshore expansion and the establishment of *offshore energy hubs* is interoperability – in terms of both technology and vendors. Meeting this technological prerequisite will facilitate an accelerated and efficient coupling of various market areas by enabling the construction or expansion of a *HVDC* grid featuring interoperable components from multiple suppliers, which in turn will prevent projects being "locked-in" with a single supplier. Ultimately, a multi-terminal- and multi-vendor-ready platform will boost competition, lower costs, and distribute manufacturing efficiently.

  The European Horizon 2020 funded projects READY4DC and InterOPERA are the initial steps to develop the standards for a multi-terminal and multi-vendor approach. Both projects do not only focus on developing technical standards but also about agreeing on the procurement, commercial, legal and regulatory frameworks that will facilitate the tendering, building and operation of full-scale *HVDC* multi-terminal, multi-vendor applications anticipated by 2030. At a minimum, we need a harmonisation of standards and a reliable development path for grid operators and manufactures.

- **Availability of innovative technologies and fallback concepts**
  To make the initial offshore grid of the *Esbjerg Declaration* countries scalable and connectable in the long term, we need new technologies, e.g. a *DC* fault separation device, to overcome limitations that result from existing grid planning requirements, e.g. primary reserve and other constraints for system stability. This includes the specification of interfaces between converters and *DC fault separation devices* and the harmonisation of the functionalities of various *DC fault separation device* technologies, e.g. for selective fault isolation in future offshore grids. In our initial Esbjerg topology, we aim to push the market to develop the innovative technologies needed.

  When planning with such technologies, we will define technical and planning fallback concepts to ensure that the ambitious political goals for offshore wind expansion are not endangered at any point. This is why we have already thought about fallback concepts when developing the topology, for example as follows:



- **Hydrogen**
  Offshore hydrogen production requires special attention be paid to electricity grid friendly placement and operation of electrolysers to match the production profile. Additionally, there is a need to establish the system integration with the 2 GW power conversion platforms, the power supply and brine treatment. In all likelihood, the most critical factor will be the supply chain for the platforms and the electrolyser stacks, which will need to be developed in order to ensure the required production volumes.

- **System operation**
  To operate future *DC* offshore grids in a secure, reliable, and efficient manner, new system operation concepts are required. This includes and addresses for example the definition of responsibilities between the individual system operators, determining the degree of automation and the development of grid controllers which assure, that the new technologies work in an optimal way in the multi-terminal system, thereby enabling the desired degree of overall operability. Since the concepts of system operation are closely related to the technical design of the grid, we will develop and coordinate the new multi-terminal technologies and operational concepts with one another and at an early planning stage.

Spatial and environmental conditions

- **Offshore grid & nature**
  The massive expansion of offshore wind will most likely have a lasting impact on the local habitat, which will have a knock-on effect on species populations and biodiversity. Marine mammals and parts of the bird populations in the North Sea will also be impacted. It is important to view these potential environmental impacts on a sea basin scale, as well as across project and country borders. We should seek to shift from an approach that only considers individual projects to one that encompasses a broader offshore grid and related compensation for all impacts on the natural environment. This includes designing technical concepts for a portfolio of grid connections with a lower environmental footprint but also, where proven to be more efficient, opting for meshed grids to limit environmental impacts on sea basins. Early stakeholder involvement to define joint compensation projects remains a further key element – just like the joint development of a “nature inclusive design”.

- **Planning & permitting procedures**
  To build out at the planned scale and pace, countries around the North Sea will need to cooperate cross-border on a sea basin scale as well as introduce more efficient permitting processes – including for grid investments. The TSOs associated with the *Esbjerg Declaration* welcome the EU Energy Council’s decision to create an emergency framework that introduces the concept of “projects of overriding public interest”. Recognizing that this Council regulation is limited in its application for a period of 18 months, we count on the legislators to create a stable framework beyond the emergency regulation in upcoming negotiations, addressing both renewable generation and transmission grid projects alike.

- **Transmission infrastructure lead approach**
  The path towards interconnected offshore grids will entail a sequential build-out and a TSO-led bottom-up process. In order to maintain a holistic perspective, it will be crucial to allocate clear responsibilities for the grid planning. Existing electricity and gas TSOs are well set to ensure an efficient build-out that is appropriate for the development of the onshore grids while also leading to an integrated energy system. Coordinated and systematic approaches for offshore infrastructure planning (e.g. TEN-E), which are building on well-established processes, can facilitate the completion of such tasks by allowing them to proceed swiftly. In order to ensure progress, the complexity, additional interfaces and risks of hybrid interconnectors, hydrogen infrastructure and *energy hubs* must be reduced by structuring them based on their individual market roles. Generation and transmission activities are legally separated and carried out by respectively generation and transmission entities. A clear separation of responsibilities will enable both parties to most efficiently put their individual expertise to use where needed. More specifically, a so-called "transmission infrastructure lead approach" will facilitate efficient planning by taking various constraints into account, such as geospatial ones (including suitable cable and pipeline corridors and landfalls, as well as the onshore grid impact and the consequently suitable grid connection point). In doing so, this approach will provide clarity for the wind developers and minimise total investment costs and therefore the impacts on society. Such an approach should also be supported by governments and regulatory entities.

- **Consideration of different uses of the North Sea**
  When planning interconnections in the North Sea one must keep in mind that this part of the North Sea is currently home to cables from offshore wind farms and offshore grid connection systems as well as other interconnectors, pipelines from oil and gas installations and telecommunication cables. Any interconnectors as part of an offshore *energy hub* will be required to cross existing subsea infrastructure. This will pose a potential risk to any future project, and a common approach to manage these risks should be prepared among the involved North Sea countries. Furthermore, different use forms of the North Sea like shipping routes, nature conservation areas and military areas for marine exercises have to be considered while planning an offshore grid. Multiple usage (co-usage) of the limited space at sea will be key for a successful realisation of future offshore grid projects in Europe.

V. Outlook

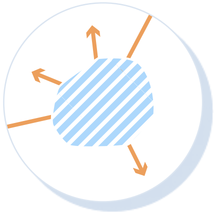
The goals of the *Esbjerg Declaration* are only the beginning: if we look at the potential of offshore wind that the North Sea can offer Europe, until 2050 we are talking about 300 GW. Almost all North Sea countries have set ambitious targets for the expansion of offshore wind by 2050.

The initial offshore grid as we are proposing here is the first step towards realizing the vision of jointly tapped wind potential in the North Sea. It can be expanded to include connections to other countries, integrating electricity and hydrogen in the early stages. For the vision to become reality, it now needs strong political support. This means creating the necessary framework conditions, but above all it means creating independent and robust supply chains. Cooperation at all levels and close exchange between all actors in the supply chains are the key to success for a sustainable and independent energy supply for Europe. Complementary to offshore grid developments, the necessary timely and adequate onshore grid developments - both cross-border as internal reinforcements - are equally required in order to ensure overall optimal system integration.

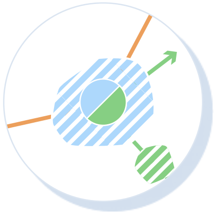
The TSOs will continue to work closely together to support policy targets and drive further development of the initial offshore grid. The TSO group is open to additional members, to engage in other initiatives such as the NSEC, and will work together to translate ideas for specific projects into national and international planning tools. Now is the time to establish the first concrete projects.

Additional potential for hybrid interconnectors, hydrogen infrastructure and energy hubs

Further expand and designate new offshore wind areas to meet the 2050 targets.



Further interconnect the various wind areas and countries around the North Sea and beyond (i.e. United Kingdom, Norway, France, Ireland, and more).



Further integrate hydrogen and electricity via *energy hubs* while developing a meshed offshore hydrogen pipeline system.

Glossary

70% Rule

The current EU legal framework (Internal Energy Market Regulation, Art. 16), introduced by the Clean Energy Package in 2019, states the obligation towards electricity TSOs to make at least 70% of the transmission capacity of interconnectors and internal critical network elements available to the market for cross-border trade between Bidding Zones.

Electricity grid friendly electrolysers

Electrolysers will consume large quantities of electricity to produce green hydrogen. Both spacial placement as well as the operating mode of these electrolysers are important drivers to enable an overall efficient energy system. Spacial placement of the electrolyser will have an effect on the required additional electricity grid reinforcements. With regards of operating modes, electrolysers should operate in a flexible manner while matching the surplus profile of renewables in the electricity system. This enables to effectively decarbonize both the electricity and non-electricity sector. In periods with renewable surplus production, green hydrogen will be produced on top of the regular electricity demand. Designing the energy system with these principles on placement and operation will avoid curtailment, will optimize congestion management and allow the energy system to be cost- and energy-efficient.

Esbjerg Declaration

In a joint declaration the heads of government of Belgium, Denmark, Germany and the Netherlands, together with President of the European Commission highlighted the role of home-grown North Sea offshore wind in strengthening the EU's energy security. In May 2022, they pledged to expand the combined North Sea offshore wind capacity of the four countries to 65 GW by 2030 and 150 GW by 2050. The role of interconnecting the future offshore grid is emphasized.

HVAC or short AC

High Voltage Alternating Current – is a type of electrical current, in which the direction of the flow of electrons switches back and forth at regular intervals - in Europe at the frequency of 50 Hz.

HVDC or short DC

High Voltage Direct Current – is electrical current which flows consistently in one direction. It is mainly used for long distance transmission.

HVDC Fault Separation Devices

Fault Separation Devices like HVDC Circuit breakers are crucial to interconnect more than 4 GW wind generation. For radial HVDC lines, DC-breakers are not necessary, as the HVDC converters are capable of going into "blocking" mode when there is a fault on the line, e.g. a fault on the DC cable. However, as more DC connections are required on the multi-terminal HVDC busbar to expand to more "hubs" and/or more lines, DC breakers are essential for protecting each additional DC connection. This is to ensure that in case of a fault on any of the DC connection, the faulted connection should be isolated from the rest of multi-terminal HVDC system as quickly as possible, to ensure that the rest of the multi-terminal HVDC system remains stable and in operation.

Hybrid Interconnector
Transmission line with hybrid (two or more) functionalities: transmission of cross-border flows between Bidding Zones as well as grid integration of offshore produced electricity. Hybrid interconnectors can be installed between two Bidding Zones or between Offshore Energy Hubs.

Hydrogen Infrastructure
Electrolysers, compressors, treatment equipment, storages and pipelines are technical hydrogen infrastructure that enable production, storage and transport of hydrogen. It can be developed on- and offshore and is most ideally highly integrated into the electricity system.

Implicit Market Coupling
Implicit market coupling is a mechanism used in the European energy market to increase cross-border trading and improve price convergence between different countries' energy markets. It involves the automatic matching of bids and offers across interconnected markets, without the need for explicit coordination between market operators.

North Seas Energy Cooperation (NSEC)
The North Seas Energy Cooperation (NSEC) supports and facilitates the development of the offshore grid and the large renewable energy potential in the region. Members are Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway and Sweden. Due to an agreement between the NSEC member States, UK and the Commission in December 2023 the UK has become "observer" of the NSEC.

Offshore Energy Hub
Offshore infrastructure collecting the energy produced by one or more offshore wind farms and connecting to on- or offshore transmission and/or P2X facilities. Currently these hubs are defined in mainly 2 to 3 GW steps. A hub can consist of several platforms or an artificial island and/or a combination of these foundations.

Offshore Interconnection Cluster
Geographic area, where interconnected offshore platforms and hubs are foreseen to be located or already in planning. These areas are dedicated to the production of energy in Maritime Spatial Plans.

Radial connection
Direct grid connection of offshore wind parks to the onshore grid.

50HERTZ TRANSMISSION GMBH

Heidestraße 2	+49 (0)30 5150-0
10557 Berlin	info@50hertz.com
Germany	www.50hertz.com

AMPRION GMBH

Robert-Schuman-Straße 7	+49 (0)231 5849-0
44263 Dortmund	info@amprion.net
Germany	www.amprion.net

ELIA TRANSMISSION BELGIUM N.V.

Boulevard de l'Empereur 20	+32 (0)2 546 70 11
1000 Brussels	info@elia.be
Belgium	www.elia.be

ENERGINET

Tonne Kjærsvej 65	+45 (0)70 10 22 44
7000 Fredericia	Info@energinet.dk
Denmark	www.energinet.dk

N.V. NEDERLANDSE GASUNIE

Concourslaan 17	+31 (0)50 521 91 11
9727 KC Groningen	info@gasunie.nl
The Netherlands	www.gasunie.nl

TENNET TSO GMBH

Bernecker Straße 70	+49 (0)921 50740-0
95448 Bayreuth	info@tennet.eu
Germany	www.tennet.eu

TENNET TSO B.V.

Utrechtseweg 310	+31 (0)26 373 11 11
6812 AR Arnhem	servicecenter@tennet.eu
The Netherlands	www.tennet.eu