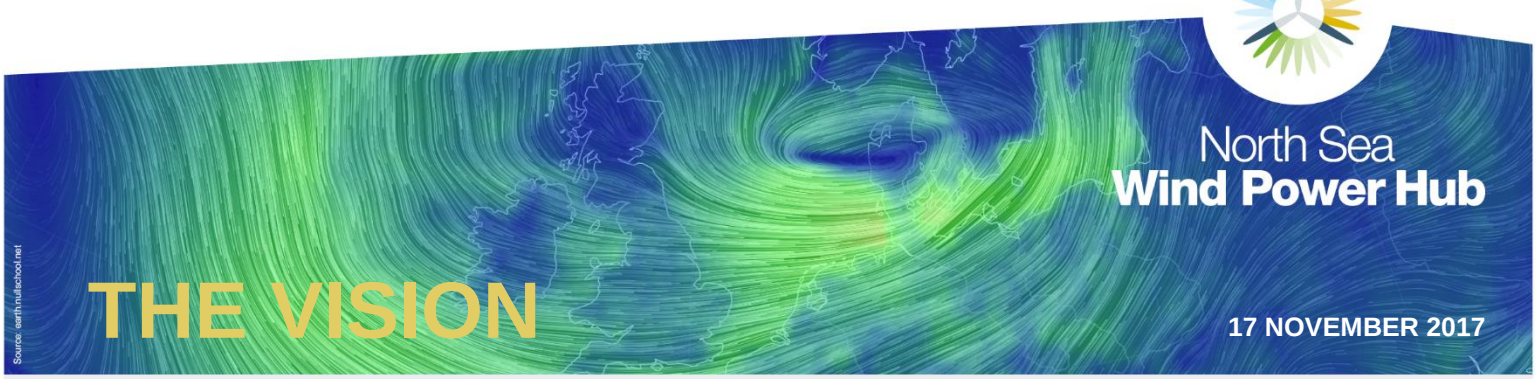


North Sea
Wind Power Hub

THE VISION

17 NOVEMBER 2017

Executive Summary

- To combat climate change and keep global warming well below 2 °C, in line with the Paris Agreement, a full decarbonisation of the power sector is required.
- A significant share of the renewable energy generation capacity needed for the North Seas countries will be provided by offshore wind supported by decreasing cost.
- The installed offshore wind capacity for the North Sea countries is expected to grow significantly to an estimated 70-150 GW by 2040, requiring an offshore wind deployment rate of approximately 2-7 GW/year over the period 2023-2040. The actual ramp-up of the deployment needs to acknowledge that industry and supply chain require time to accomodate the larger volumes.
- Further cost reduction for the development of offshore wind - including the electrical infrastructure - is needed to balance rising cost levels due to increasing distances to shore and onshore grid integration cost.
- Significant cost reductions can be achieved through an internationally coordinated roll-out that maximises the synergies between in-feed of offshore wind electricity and interconnection capacity and minimises onshore grid integration cost.
- In a decarbonised power sector, the strongly reduced levels of dispatchable generation and increased levels of the non-dispatchable generation capacity, imply significantly higher levels of interconnectivity and use of cost-efficient flexibility options such as demand response, small/large-scale storage and power-to-gas to maintain operational security.
- Utilising the available resources across the North Sea efficiently and ensuring minimum impact on the environment requires an international spatial planning strategy and cross-border alignment on development and realisation.
- The consortium's vision starts from a stepwise development with bi-national hybrid connections and builds towards an accelerated roll-out facilitated by large scale (10-30 GW) offshore wind collection hubs feeding and connecting multiple North Sea countries.
- To ensure optimal grid investment trends in the long run from a societal perspective, and with sufficient stability for the entire industry, a collaboration of network operators with a leading role in reliable regional system operations is driving this vision.

Offshore wind is essential to realise 100% decarbonisation of the electricity supply

At the Paris Conference of the Parties (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid climate change by limiting global warming to well below 2 °C, and with an aim to limit the increase to 1.5 °C. The EU formally ratified the Paris Agreement, enabling its entry into force on 4 November 2016. With the political will and mandate to act, the major challenge that Europe now faces is how to implement this agreement. Decarbonising the power sector is generally considered to be a first step and a sector where it is possible to fully decarbonise well before 2050. Key in the decarbonisation of the power sector will be an increased and efficient deployment of renewables, a sufficient roll-out of interconnection, development of flexibility options and a smart design of markets to ensure free flow of energy across price zones based on market signals.

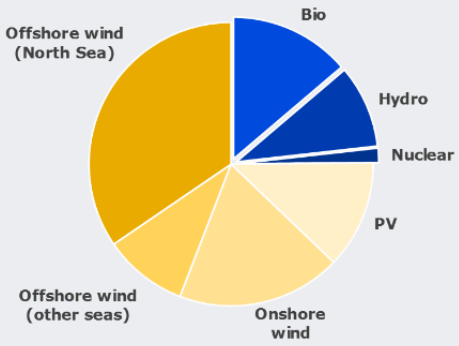


Figure 1 Estimated renewable energy electricity generation mix in 2045 for the North Seas countries.

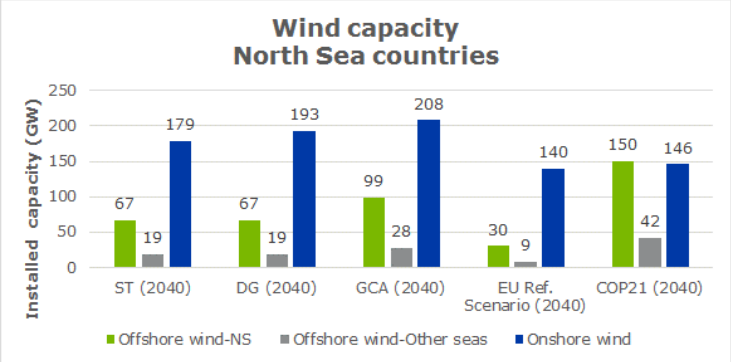


Figure 2 Projected installed wind capacity in the North Sea countries by 2040 for three ENTSO-E scenarios (TYNDP 2018), the EU reference scenario and the COP21 scenario.

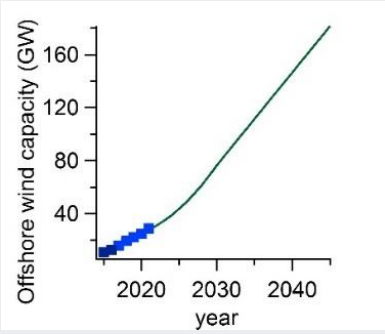
Several long term scenarios (e.g. Fraunhofer, PRIMES, Greenpeace, WindEurope, ENTSO-E, IEA) all point to wind in general - and offshore wind in the North Sea in particular - as a major contributor to renewable energy generation for the North Seas countries. The long term scenarios set out a range of possible future deployments of offshore wind power, as illustrated for selected scenarios in Figure 2. The deployment estimates range from 70 GW to 150 GW of offshore wind in the North Sea in 2040. A specific scenario conducted by the consortium which is based on the COP21 Paris Agreement commitment estimates 180 GW offshore wind capacity by 2045 in the North Sea. While the overall estimated electricity demand is similar for all scenarios, the main differences result from assumptions with respect to (i) the 2040 level of decarbonisation of the power sector (between 60-75% for the TYNDP scenarios and 90% for the COP21 scenario) and (ii) the contribution of fossil fuels to the 2040 electricity generation mix (only limited amount of gas in the COP21 scenario, while coal and gas both contribute in the TYNDP scenarios).

Q: Do you share the vision that offshore wind is one of the important facilitators of the energy transition?

Q: Do you see the need for a strong acceleration and sustained long term development of offshore wind? And how should this be facilitated?

Independent of the specific scenario used, all forecasts indicate a significant increase in offshore wind in the coming decades. This strong increase of offshore wind capacity is further supported by recent developments that have shown sharply decreasing cost for offshore wind.

Currently just over 9 GW of offshore wind capacity is operational in the North Sea, with a pipeline looking forward towards 2023 of approximately 2 GW/year of new installations. As an example, to reach an installed offshore wind capacity between 70-150 GW for the North Sea by 2040, a deployment rate towards 2-7 GW/year over the period 2023-2040 is required.



Q: Which deployment rate for offshore wind in the North Sea do you consider realistically feasible?

Q: What are the essential pre-conditions to realise such a deployment rate?

Figure 3 Notional gradual ramp-up of the offshore wind deployment rate - acknowledging that industry and supply chain need time to accomodate the larger volumes - for the North Sea in the COP21 scenario.

Further cost reduction for the development of offshore wind, including the electrical infrastructure, is needed

With space for offshore wind close to shore increasingly limited because of third party use, nature protection or visual impact, offshore wind will move increasingly further offshore. While this may be offset in part by increased wind resource, the longer distances to shore and generally deeper waters (impacting cable and foundation cost and cost for installation and O&M) will put pressure on cost levels. In addition, with strongly increasing levels of offshore wind fed into the grid, onshore grid integration cost will also increase.

Preliminary analyses by the consortium suggests that cost reductions can be achieved through an internationally coordinated roll-out that minimises the total societal cost - including onshore grid integration - and combines in-feed of offshore wind electricity with interconnection capacity. This cost reduction is relative to a business-as-usual scenario, assuming a national approach with more and more radial (individual) connections for offshore wind and incrementally improved grid connection technology changes. Fundamental to this internationally coordinated roll-out is that (i) there is some form of an integrated North Sea infrastructure planning realising - in parallel - offshore wind connection and interconnector capacity; (ii) this integrated planning also coordinates location and timing of wind park sites at a North Sea regional level to provide investor certainty for the industry and allow grid developers to work towards a regional strategic infrastructure; and (iii) total system costs (wind farm connection, interconnection and onshore grid reinforcement) are minimised on a North Sea regional level.

Q: What do you believe is required to realise cost reduction and security of supply simultaneously for the future roll-out of offshore wind?

Q: Do you think an integral (societal) cost optimisation – including the development of offshore wind, the electrical infrastructure and grid integration – is required to ensure security of supply at the lowest cost for society?

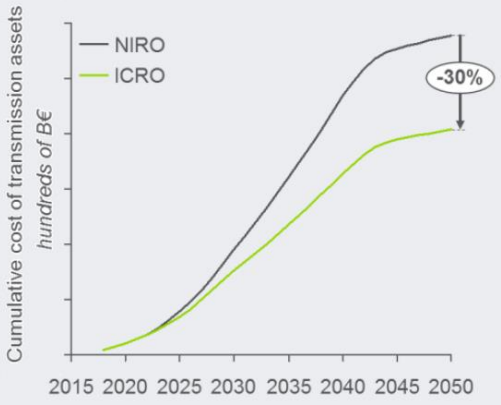


Figure 4 Potential cumulative cost reduction for the electrical infrastructure of an internationally coordinated roll-out (ICRO) scenario for offshore wind towards 2045, relative to a national incremental roll-out (NIRO) scenario.

A total cost saving potential on the electrical infrastructure of approximately 30% results from international coordination and optimisation of grid connection concepts, including interconnection build-out, where the realisation of this benefit for society depends critically on early adoption of this approach.

Higher levels of renewable energy sources require increased interconnectivity

A higher share of variable sources in the power system, with strongly reduced levels of dispatchable generation and increased levels of non-dispatchable generation capacity, requires increased use of flexibility options. Thus the estimated strong increase in offshore capacity in the North Sea implies higher level of interconnectivity across the North Sea (and onshore) for flexibility options and markets to function. Sufficient interconnection capacity is essential to maintain operational security. In addition, given this radical change in the electricity generation mix, increased use of cost efficient flexibility options, such as demand response, small/large-scale storage and power-to-gas, will become essential in the 2040 scenario.

Cost efficient realisation of offshore wind capacity requires cross border cooperation and a strategic approach to overall spatial planning of offshore wind in the North Sea

The North Sea is an important nature area, with intense use by a wide variety of economic sectors, where cost of offshore wind varies across the region depending on wind resource, depth, distance to shore/port, grid connection concept, inter-array wakes, etc. Utilising the available resources across the North Sea efficiently requires a regional view on resource use, deployment and operation based on a common sustainability commitment and an integrated market.

Q: What do you see as the most critical elements for international cooperation in terms of spatial planning strategy to reach the overall target?

The foreseen internationally coordinated roll-out of offshore wind builds from a stepwise development, starting from bi-national hybrid connections towards large scale (10-30 GW) offshore wind collection hubs feeding and connecting multiple North Sea counties. To ensure optimal grid investment trends in the long run from a societal perspective, and with sufficient stability for the entire industry, a collaboration of network operators with a leading role in reliable regional system operations is driving this vision.

ABOUT THE NORTH SEA WIND POWER HUB

TenneT Netherlands, TenneT Germany, Energinet and Gasunie joined forces to develop a large scale European electricity system for offshore wind in the North Sea. The NSWPH consortium partners consider the project to be an important possible alternative path of an internationally coordinated roll-out towards accomplishing the green energy transition and achieving the Paris Agreement. By developing the North Sea Wind Power Hub project, the consortium endevours to make the energy transition both feasible and affordable. Central to the vision is the construction of one or more hubs at a suitable location in the North Sea with interconnectors to bordering North Sea countries. The whole system may function as a hub for transport of wind energy, an interconnection hub to the connected countries, a working hub for offshore wind developers and a location for possible Power to Gas solutions.

CONTACT DETAILS

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