North Sea
Wind Power Hub

4 THE BENEFITS

The modular Hub-and-Spoke concept has substantial societal benefits and thus the potential to incentivise all involved stakeholders

The Consortium

The North Sea Wind Power Hub consortium has joined forces to realise climate goals. The consortium her work is based on research, stakeholder interaction and experience from earlier projects.

Port of Rotterdam

Biggest port in Europe with a strong ambition to become the most sustainable port in the world

ENERGINET

Danish transmission system operator working for a green, reliable and sustainable energy supply of tomorrow

gasunie

European energy infrastructure company serving the public interest and facilitating the energy transition by providing integrated infrastructure services

TenneT

TenneT is a Dutch-German electricity TSO and is one of Europe's major investors in national and cross-border grid connections on land and at sea in order to enable the energy transition.

Executive Summary

The modular Hub-and-Spoke concept, as a building block in a step-by-step and international coordinated roll-out, has multiple benefits over a national and incremental approach.

Benefits include cost savings and increased societal value, by leveraging synergies of wind integration and regional interconnection capacity, synergies of international coordination in roll-out through efficient system integration, and synergies across energy sectors.

The analyses – with an initial focus on the electricity system – have provided insights into the benefits of the concept; a longer-term vision on offshore wind development, and an integral assessment framework for costs and benefits are required to assess the specific benefits of individual projects and a full roll-out.

Six concept papers, one storyline

The goal of the concept papers is to inform North Sea stakeholders, and the general public, of the results the NSWPH has obtained working on the modular Hub-and-Spoke concept over the last two years. The six concept papers tell one story: from the challenge to meet the Paris Agreement, through the solution building on the modular Hub-and-Spoke concept, to the next steps required to meet the Paris Agreement timely and in a cost-effective manner.

Action is required today from all North Sea stakeholders to initiate and facilitate the required international coordinated roll-out to realise the full potential benefits for society and ensure meeting long term climate goals.

The modular Hub-and-Spoke concept, as a building block in a step-by-step and international coordinated roll-out, has multiple benefits over a national incremental approach

The energy system of the North Sea countries will undergo dramatic changes to meet long term climate goals (Concept Paper 1). Part of the required change to the energy system is the large-scale deployment of offshore wind capacity: likely more than 150 GW in the North Sea alone by 2040. It is a major challenge to connect these large amounts of capacity and integrate them into the wider energy system while maintaining security of supply at all times. The current national oriented approach to offshore wind development and system integration, and its separation from interconnection development is expensive and insufficient to meet the long-term climate goals. Onshore grid integration is already a challenge for the currently planned offshore wind farms.

The consortium has presented its vision to facilitate an accelerated deployment of offshore wind in the North Sea, together with the development of interconnection capacity to provide system flexibility and wider system integration though an internationally coordinated roll-out of the modular Hub-and-Spoke concept (see also Concept Papers 2 and 3). This concept offers multiple benefits for society over a national incremental approach which are further elaborated in the next section. In this context it is important to assess costs and benefits for different offshore wind and energy system integration concepts from a total energy system's perspective. A concept that results in the most cost-efficient design for an individual project (e.g. individual offshore wind farm connection, or separate interconnection development) might result in higher overall costs when assessed from a holistic energy system perspective. Action is required today from all North Sea stakeholders to initiate and facilitate the required international coordinated roll-out to realise the full potential benefits for society and ensure meeting long term climate goals.

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One of the main benefits of the modular Hub-and-Spoke concept in an internationally coordinated approach is the higher likelihood of delivering on the Paris Agreement, through lower costs, higher value for society, lower risk of delay and stranded assets, stable long-term market conditions and minimised environmental impact.

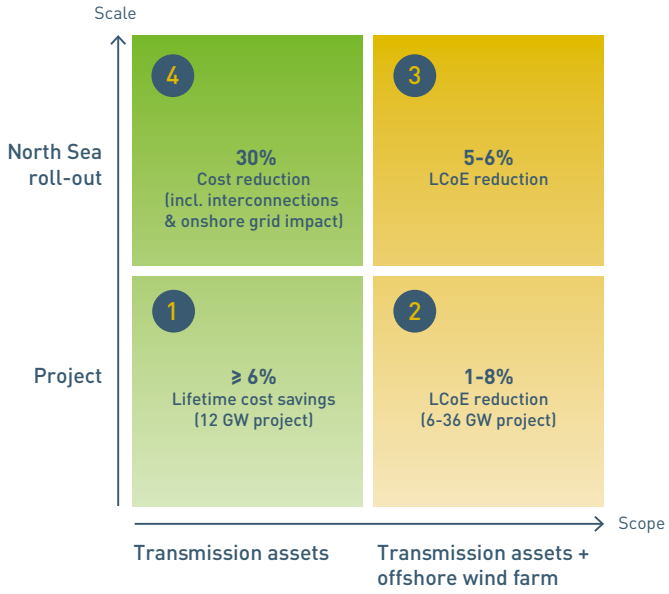
Characteristics Hub-and-Spoke	Benefits	Compared to Business as usual
The modular Hub-and-Spoke concept ensures cost-effective and timely ramp-up of offshore wind energy	Timely ramp up of offshore wind energy to meet long term climate goals	The current approach will not allow for timely ramp-up and integration of offshore wind this concept increases the chances of doing so
	Cost effective ramp-up of offshore wind	More cost effective due to lower cost by combining wind farm connections and interconnectors, international coordination ensures minimizing the need for onshore grid reinforcements
The modular Hub-and-Spoke concept provides flexibility to adapt each project to location specific needs	Modularity allows for adaptability each project to location specific needs	Scale and design can be adapted to location specific needs – wide range of design options available across scale, foundation type, and configuration, optimisation to leverage synergies with end-use sectors
Interconnections and sector coupling maximise offshore wind integration and synergies across energy sectors	Interconnections and sector coupling ensure maintaining security of supply, and synergies across energy sectors	Concept offers flexibility to integrate increasing shares of renewables by (i) Increasing interconnection levels (ii) Sector coupling and re-using existing gas infrastructure (iii) Reduced electricity pricing (iv) Synergies between offshore wind and renewable gas & fuel production

Cost reductions

The Hub-and-Spoke concept taps into infrastructure synergies by merging offshore wind farm transmission assets and interconnector assets. Independent wind farm connections are usually only utilised up to a capacity factor of approximately 50% due to the capacity factor of offshore wind farms[i]. Interconnectors can be utilised to a larger degree, such as the BritNed connection between the Netherlands and the UK which was utilised over 80% in 2017 and 2018[ii]. By combining these asset types, the utilisation of individual connections could increase significantly to at least >65%[1] . In addition, a hub-based wind farm transmission concept can reduce costs compared to radial platform connections due to benefits of scale by using e.g. island-based foundations and reduced operational expenses.

[1] *Based on initial CBA analysis by the consortium based on non-optimised configurations.*

The modular Hub-and-Spoke concept offers cost reductions across scope and scale

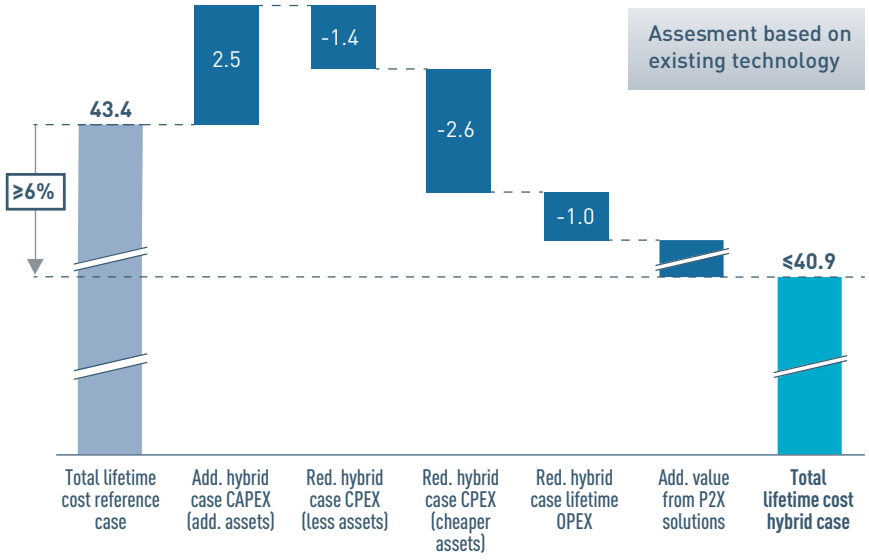


The figure above gives an overview of the cost reduction potential for the Hub-and-Spoke concept as found in different assessments, which are further elaborated in a description below.

1. A study on behalf of the European Commission by Roland Berger[iii] confirmed significant lifetime savings for a 12 GW Hub-and-Spoke project connecting to Denmark (2 GW), Germany (6 GW) and the Netherlands (4 GW) compared to a radial approach. The lifetime savings consist of CAPEX savings (€1.5 billion), and OPEX savings (€1.0 billion) mainly driven by the omission of additional point to point interconnection capacity between the countries, as indicated in the figure below[iv]. Adding P2X functionality could realise lifetime cost savings of more than 6%.

2. A levelised cost of energy (LCoE) analysis by the consortium investigated the LCoE reduction potential for Hub-and-Spoke projects compared to a national radial approach (excluding interconnections) where multiple 2 GW steel HVDC platforms offer connection capacity. Different hub capacities between 6 and 36 GW were investigated. It showed that the LCoE reduction for the Hub-and-Spoke configuration is rather limited for larger capacity hubs (24-36 GW), while the LCoE reduction potential for smaller hub sizes (6-12 GW) can increase to 8% (for a 6 GW hub). The differences are mainly a result of reduced OPEX levels for hubs compared to steel-based platforms (approximately 50% OPEX reduction). The CAPEX cost reduction potential from caisson or sand filled islands, compared to steel platforms, is offset (especially for larger hub sizes: >12 GW, depending on wind farm density) due to the need for additional collector platforms and 380 kV cabling, the increased length of 66 kV array cables for larger hubs, and the longer construction times.

Deep-dive learning 2: Significant lifetime benefits (€ bn)



1) Results are subject to barriers; currently no deal-breakers (8% discount factor) assumed. Source: Reproduction of lifetime cost reduction water-fall chart by Roland Berger, in IV, p6

Increased offshore wind levels between North Sea countries result in reduced electricity prices and emissions through improved system integration of renewables.

3. In another analysis on behalf of the consortium[v], the impact of the Hub-and-Spoke concept was investigated for a full North Sea offshore wind roll-out 2030-2050, with a focus on societal levelised cost of energy (including both the cost for developers and TSO, but without considering additional interconnectors or onshore grid extensions). The result of this study was a reduction of approximately 5-6%[vi] on societal levelised cost of energy (LCoE) due to the aforementioned synergies and benefits of international coordination.

4. A cost assessment initiated by the consortium[vii] found that – for an all-electric hub - transmission asset lifecycle costs could be reduced by 30%[viii] over a full 180 GW offshore wind roll-out in the North Sea towards 2050. Approximately 17% of this cost reduction would be due to cost reductions in wind farm transmission assets and 5% due to reduced interconnector requirements. In addition, an international approach towards the onshore connection of offshore wind farms, e.g. by connecting German offshore wind farms in the Netherlands where capacity would be available, was found to reduce the offshore wind roll-out and grid connection costs by approximately 8%.

Benefits

In addition to cost reductions, the Hub-and-Spoke concept offers multiple benefits for society. Increased offshore wind deployment and interconnection levels between North Sea countries result in reduced electricity prices and emissions through improved system integration of renewables. A cost benefit analysis conducted by the consortium found that connecting 12-24 GW of offshore wind capacity in the North Sea, through an all-electric Hub-and-Spoke concept, would increase social welfare by approximately €1.0-1.7 billion per year[2] for the whole of Europe by the year 2040, compared to radially connecting these offshore wind farms (without interconnections). In addition, the increased interconnection levels reduce the amount of required dispatchable (fossil) power, resulting in a reduction of CO2 emissions of approximately 4% for the power sector the whole of Europe by 2040, for a 24 GW hub.

An independent CBA analysis was conducted by ENTSO-E for the NSWPH TYNDP submission. This analysis also indicated positive societal benefits derived by the NSWPH and the additional offshore wind capacity supported by the infrastructure. Although the results from the TYNDP and the consortium's own analysis are not directly comparable due to the assessment approach, it provides additional robustness in concluding that the NSWPH offers society significant benefits[ix].

A high-level comparison combining these benefits with the costs directly related to the infrastructure found that the value for the Hub-and-Spoke project ranged between €15-€20 billion[3], compared to a no hub reference. In a situation where the onshore grid would be restricted after 2030 (e.g. due to delays in grid reinforcements onshore), the annual benefits could increase by approximately 25% for a 24 GW hub compared to a reference where the onshore grid continues to develop. It should be noted that current cost benefit frameworks have their limitations as they are only project focussed and are unable to capture

[2] Note that these results are given for the whole Europe, while local benefits may differ.

[3] High level socio-economic NPV at 4% discount rate, excludes taxation, depreciation or any other (corporate) financing. Cases evaluated were with 12 to 24 GW hubs with an onshore grid capacity as per the ENTSO-E GCA2040 scenario.

the full value of hybrid (wind farm connection and interconnector), and/or heavily sector coupled projects. Reconsideration of these frameworks is key to support the development of these types of projects; this is further discussed in Concept Paper 5.

When moving away from dispatchable (and load following) power sources it is key to ensure security of supply in the energy system. The Hub-and-Spoke concept ensures that security of supply is maintained cost-effectively through integrated electricity and gas infrastructure (through P2X[4] conversion) which can produce e.g. hydrogen or other synthetic fuels when (local) electricity excesses occur. The existing gas infrastructure (gas storages, pipelines and compressors) can be used to store and transmit hydrogen, and support decarbonisation in end-use sectors such as industry and transport. Hydrogen can be converted back to power (in other locations) when shortage situations occur. An additional benefit of P2X conversion is that it has the potential to reduce the energy import dependency of the EU, as P2X can provide (decarbonised) synthetic fuels and feedstock for industry.

In exploring the need for flexibility and the potential role of hydrogen as a flexibility provider, the consortium is currently undertaking various exploratory studies.

- To evaluate the potential role of hydrogen as flexibility provider for the electricity system in 2040 and 2050 for the NSCC countries, the flexibility needs have been identified from supply and demand data mapped on a 2030 electrical grid topology (as a worst case pragmatic test case). The data is aligned with ENTSO-E TYNDP 2018 Global Climate Action scenario (2040, and extrapolated to cover 2050 as well). The identified needs were then matched with flexibility options that show how flexibility options balance supply and demand, with an increasing share of variable renewable generation towards 2050. Complementary to short term flexibility options such as demand response and battery storage, the study found that hydrogen power plants (both OCGT and CCGT) can play a valuable role for supplying long term and seasonal flexibility. Gas fired power plants with CCS were identified as an important main competitor in case of higher full load hours requirements for the respective flexibility option. The potential of sourcing hydrogen from surplus electricity generation is found to depend on the need for flexibility to manage variable renewable energy surplus, in addition to demand side response and short-term storage, as well as on its relative market position compared to other (hydrogen) resources.
- Other work by the consortium has shown that based on long term (2050) energy scenarios the transition from a largely fossil based to a predominantly renewable energy electricity generation mix requires significant (approximately 100 – 140 TWh) seasonal storage for the North Sea countries. And that the large scale expansion of North Sea offshore wind, and phase out of fossil based generation capacity, implies a need to transport approximately 25% of the generated offshore wind energy to inland location beyond the coastal regions. Using power-to-gas conversion in coastal regions connected to transmission to demand centres located deep inland may relieve congestions in the electricity transmission grid. Therefore, it can reduce curtailment due to transmission bottlenecks of variable renewable energy and support system adequacy. Also, developing synergies between offshore wind and Renewable Energy-fuel production at large scale coastal industrial facilities, could support system integration of large-scale offshore wind, reducing congestion in the electricity transmission grid through a flexible switch between electricity generation and consumption operation modes. Further analysis is required and will be undertaken by the consortium to quantify the costs and benefits associated with further sector coupling between the electricity and the gas (Hydrogen) grid in relation to the integration of large scale North Sea offshore wind.

[4] *P2X includes power-to-gas (mainly H2 as well as methane) and other options (such as fuels, feedstock, food, oxygen, residual heat, etc.)*

An international coordinated approach offers the opportunity to join forces with international NGOs to develop the best possible solution for a modular Hub-and-Spoke concept

Other impacts

The consortium realises that the large roll-out of offshore wind in the North Sea, as implied by the Paris Agreement, will have an impact on the environment. It is key to minimise negative environmental impacts as much as possible, or even create benefits, while ensuring realising the climate goals at the same time. An international coordinated approach offers the opportunity to join forces with international NGOs to develop the best possible solution for a modular Hub-and-Spoke concept to realise large scale offshore wind in the North Sea while minimising environmental impacts.

The analysis has provided insights into the benefits of the concept, a longer-term vision is required to assess the specific benefits of individual projects

The assessment by the consortium has demonstrated technical feasibility and economic plausibility of the Hub-and-Spoke concept. To assess the specific value drivers of individual projects it is required to have more clarity on longer term renewable goals, spatial planning and grid planning by policy makers. Given these boundary conditions, a robust and integral assessment framework should be developed and used to asses for each project how the benefits for society can be optimised. In addition, it is essential to drive the debate forward on practical issues including cost/benefit/risk allocation of offshore wind and transmission infrastructure development, and ownership models for specific components of the Hub-and-Spoke concept. The consortium continues to test their study assumptions with stakeholders to ensure that conclusions on techno-economic feasibility are still valid.

Sources

[i] *Energy Numbers, 2019. UK offshore wind capacity factors. http://energynumbers.info/uk-offshore-wind-capacity-factors. Capacity factors also align with consortium studies.*

[ii] *ENTSOE, 2019. Transparency Platform. https://transparency.entsoe.eu/dashboard/show*

[iii] *Roland Berger for the European Commission, 2019. Cost efficient offshore development through hybrid projects. https://publications.europa.eu/en/publication-detail/-/publication/59165f6d-802e-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-98244663 p133*

[iv] *Roland Berger, 2018. NSWPH in the context of the North Seas Offshore Energy Clusters study. https://northseawindpowerhub.eu/wp-content/uploads/2018/11/Presentation-Roland-Berger.pdf, p6*

[v] *Witteveen + Bos & ECN/TNO, 2018. Cost Evaluation of North Sea Offshore Wind Post 2030. https://northseawindpowerhub.eu/wp-content/uploads/2019/02/112522-19-001.830-rapd-report-Cost-Evaluation-of-North-Sea-Offshore-Wind....pdf*

[vi] *p79 of Roland Berger, 2018. NSWPH in the context of the North Seas Offshore Energy Clusters study.*

[vii] *NSWPH, 2017. Modular Hub-and-Spoke. https://northseawindpowerhub.eu/wp-content/uploads/2017/11/Concept-Paper-2-Modular-Hub-Spoke.pdf*

[viii] *p5 of Roland Berger, 2018. NSWPH in the context of the North Seas Offshore Energy Clusters study*

[ix] *ENTSO-E, 2019. Project 335 - North Sea Wind Power Hub. https://tyndp.entsoe.eu/tyndp2018/projects/projects/335*

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