Project Sheet

Project 335 - North Sea Wind Power Hub

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Index

Key Information 3
Description 3
Project Description & Context 6
Project Investments 6
System Needs addressed by the project 8
Interconnection targets 9
Project Assessment 13
Transfer capacity increase (National Trends 2025) 13
CBA results 13
Central scenario: National Trends 13
Scenarios: Distributed Energy & Global Ambition 15
Sensitivity Study: Current Trends 17
Residual impact 18
Project Costs 18

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Key Information

Cross Border Project
Offshore substation
New

PCI number 1.19 (4th list, 31 Oct. 2019)
Under Consideration

Description

TenneT Netherlands, TenneT Germany, Energinet, Gasunie and Port of Rotterdam joined forces to develop a large scale European electricity system for offshore wind in the North Sea. The North Sea Wind Power Hub (NSWPH) consortium partners consider the project to be an im-portant possible alternative path of an internationally coordinated roll-out towards accom-plishing the green energy transition and achieving the Paris Agreement.

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.

This project is a first building block in the hub-and-spoke concept (NSWPH) connecting up to 12 GW future offshore wind parks to the systems of Denmark, the Netherlands and Germany after 2035.

Analysis by Roland Berger (commissioned by the EC) on this innovative project has shown that the hub-and-spoke concept provides significant cost savings (EUR 3.6bn over a 25year span) compared with the current, traditional, point-to-point interconnections and individual connec-tions for offshore windfarms (see Additional Information for source).

An integral part of the NSWPH is to assess the perspectives of coupling large-scale wind power production with the gas system through power-to-gas (PtG) technology. The combination of cost-efficient infrastructure and the flexibility offered by the gas system may very well outweigh conversion losses, increasing the value of wind production and contribute to synergy effects through sector coupling in the transition of the energy system (see additional information).

Several studies examining the benefits of PtG solutions can be found under “Additional Infor-mation”.

As such the NSWPH infrastructure offers benefits by optimising integration costs of offshore

wind, increasing socio-economic welfare by further coupling energy markets, supporting security of supply at wider regional level and providing potential to innovative power-to-gas con-cepts to optimise total energy system costs.

Project promoters

Energinet.dk
TENNET-NL
TenneT DE

Countries

Germany
Denmark
Netherlands

National development plan(s)

The NSWPH is not yet included in the last National Development Plans of Denmark, Germany or the Netherlands and therefore the additional internal required grid reinforcements are not yet analysed. Note that generally these plans have a shorter time horizon than 2035 (expected commissioning year of the project). In the Danish case, a future 'Strategic Investment Plan' will be developed and cover a 20-year period in which the NSWPH will be included. The NSWPH is presently analyzed in various feasibility studies at wider regional level. It builds on long-term system needs also identified in ENTSO-E's Regional Investment Plan North Sea. Due to the strong internationally coordinated drive of this project, the concept is first addressed in ENTSO-E's TYNDP process. In next steps it can be considered for NDP inclusion in a consistent manner.

Additional information on the project

https://northseawindpowerhub.eu/

https://www.youtube.com/watch?v=lBnWEK9IUn4

Roland Berger for the European Commission, DG-ENER; "North Seas Offshore Energy Clusters - North Sea Wind Power Hub"; 2018.

Cost-effective transition of energy through sector coupling:

- THE IMPORTANCE OF THE GAS INFRASTRUCTURE FOR GERMANY'S ENERGY TRANSITION – A model-based analysis, Frontier economics et al. 2018

http://frontier-economics.com/publication/der-wert-der-gasinfrastruktur-fuer-die-energiewende-deutschland/

- The Potential role of Power-to-Gas in the e-Highway2050, European Power to Gas Platform/ DNV-GL 2017

http://europeanpowertogas.com/new-study-released-on-potential-role-of-power-to-gas-in-the-e-highway2050-study/

Increasing the value of wind through the reduction of low electricity prices and curtailment:

- System Perpective 2035 – Long-term perspectives for efficient use of renewable energy in the Danish energy system, Energinet 2018

https://en.energinet.dk/-/media/Energinet/Analyser-og-Forskning-RMS/Dokumenter/Analyser/_Analyser-Engelsk/System-Perspective-2035---Main-Report_English.pdf

Demand for renewable H2 in countries of the Project Promotors

- DE: Role of gaseous energy carriers in decarbonising Germany - Results of a brief meta-study of independent third party studies, Wagner, Elbling & Company 2018

- DK: System Perspective 2035 – Long-term perspectives for efficient use of renewable energy in the Danish energy system, Energinet 2018 (Danish Version)

https://energinet.dk/-/media/4DDC27A7159245E985CEC07A92FB70AF.pdf

- NL: Chemistry for Climate – Roadmap for the Dutch Chemical Industry towards 2050, Ecofys 2018

https://www.ecofys.com/files/files/vnci_routekaart-2050.pdf

Project sheet backlog

6 Nov. 2020 - Publication as part of the draft TYNDP 2020 package for consultation

Project Description & Context

Project Investments

Main investment(s): Artificial island central in the North Sea (best location for the first hub is under investigation) with a 'copper plate' type electrical installation suitable to connect 12GW of HVDC systems to shore and up to 12GW of nearby offshore wind. The artificial island is large enough to host all equipment HVDC converters and O&M facilities. Reduction of the total system cost is essential to facilitate large scale offshore wind and interconnection capacity deployment and all options in design, installation and operation should be considered to further reduce cost, including the use of a power hub as an island. Realising a power hub as an island located centrally in the North Sea has been assessed to be technically feasible, based on - amongst others - bathymetry, extreme wind speed and hydraulic conditions (wave heights, surge levels, etc.) and geotechnical data.

Type of element	Total route length (km)	From substation 1	To substation 2	Present status	Commissioning year	Progress of the investment	Explanation in case of delay or reclustering
Offshore substation		0	0	Under Consideration	2035	New Investment	

Other investments

Description	Type of element	Total route length (km)	From substation 1	To substation 2	Present status	Commissioning year	Progress of the investment	Explanation in case of delay or reclustering
HVDC connector including substations interfacing the Power Link Island and the Western Danish power system.	Offshore DC transmission cable	328	"Endrup, DKw"	Power Link Island DKw	Under Consideration	2035	New Investment	
One of two HVDC connectors	Offshore DC transmi	360	Maasvlakte 380 kV	Power Link Island	Under Consideration	2035	New Investment	

Description	Type of element	Total route length (km)	From substation 1	To substation 2	Present status	Commissioning year	Progress of the investment	Explanation in case of delay or reclustering
including substations interfacing the Power Link Island and the Dutch power system.	ssion cable			NL1				
One of two HVDC connectors including substations interfacing the Power Link Island and the Dutch power system.	Offshore DC transmission cable	290	Eemshaven 380 kV	Power Link Island NL2	Under Consideration	2035	New Investment	
One of three HVDC connectors including substations interfacing the Power Link Island and the German power system.	Offshore DC transmission cable	390	German substation located in the area of Brunsbüttel (north of the Elbe)	Power Link Island DE1	Under Consideration	2035	New Investment	
One of three HVDC connectors including substations interfacing the Power Link Island and the German power system.	Offshore DC transmission cable	400	German substation located in the area of Oldenburg	Power Link Island DE2	Under Consideration	2035	New Investment	
One of three HVDC connectors including substations	Offshore DC transmission cable	490	German substation located	Power Link Island DE3	Under Consideration	2035	New Investment	

Description	Type of element	Total route length (km)	From substation 1	To substation 2	Present status	Commissioning year	Progress of the investment	Explanation in case of delay or reclustering
interfacing the Power Link Island and the German power system.			in the area of Krümmel					

Reason for investment clustering

The North Sea Wind Power Hub investment items need to be clustered and thereby realized together to meet its full benefit. The investment items are mutually dependent on each other. Realizing one investment contributes to the realization of the full potential of another investment item.
Without the Power Link Island, the concept cannot reach the same level of scale and would depend on multiple smaller configurations with higher costs. Without the wind farm connections, the configuration would merely provide interconnection while the RES integration would still require additional (radial) connections to shore. And without the interconnection links, the concept would be a single hub to shore, while missing the opportunities of market integration and sharing of reserves.
Presently all investments in the NSWPH project are 'under consideration', with a provisional commissioning for 2035.

Is the project in the reference grid?

No

System Needs addressed by the project

Project promoter(s) selected up to 4 system needs that are addressed by their project in a predefined list. Available needs ranged from reduction of price differentials between countries, improvement of system flexibility and stability, enabling cost-efficient connection of high volumes of RES, improvement of voltage stability...
As part of the TYNDP 2020, ENTSO-E released a study investigating cross-border system needs in the 2030 and 2040 horizons.

Need		How the project addresses each need (explanation provided by the project promoter(s))
	Infrastructure to reduce price differentials between EU and/ or non-EU countries	The NSWPH entails deployment of new offshore wind capacity, which will be connected to European countries (NL, DK, DE). In addition, the new interconnection capacity via the hub will support the reduction of price differentials between EU countries.
	Infrastructure to facilitate and accommodate future scenarios, cross-border flows or loop flows.	The infrastructure in relation to the NSWPH can accomodate future scenarios and cross-border flows, reducing the congestions in the onshore transmission system.

Need		How the project addresses each need (explanation provided by the project promoter(s))
	Infrastructure designed to enable cost-efficient grid connection of high volumes of RES and/or reduce RES curtailment	The infrastructure in relation to the NSWPH, including combined grid connection and interconnection (and possibly large scale sector coupling) optimise large scale cost efficient integration of offshore wind.

Interconnection targets

In 2017, the Interconnection Target Expert Group proposed alternative indicators to the 15% interconnection criteria for every country and electrified island with a new methodology developed collaboratively between the European Commission, ENTSO-E, ENTSOG, industry, universities and other experts. The methodology is based on three indicators:
1. Price differential between EU countries, with an objective to reduce it below 2 EUR/MWh
2. Ratio between nominal transmission capacity and installed RES capacity, with a target of past 30%
3. Ratio between nominal transmission capacity and peak load, with a target of past 30%

The following maps show the ITEG methodology applied to the TYNDP 2030 scenarios, with the 2020 grid.

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Project Assessment

Transfer capacity increase (National Trends 2025)

	Border	A B	B A
Transfer capacity increase (in MW)	Germany - Denmark/Netherlands	-	-

CBA results

ENTSO-E has assessed the benefits delivered by each project in 2025 (scenario National Trends 2025) and in 2030 (three scenarios: National Trends, Distributed Energy and Global Ambition). Indicators B1 to B6 were computed by ENTSO-E, while promoters had the possibility to compute and submit so-called project-level benefits (B7 to B10). The benefits must be understood as benefits for Europe as a whole, not for the promoters of the project.
Results are presented per scenario.

Because its planned commissioning date is in 2035 or later, this project has only been assessed in the 2030 scenarios and based on a subset of CBA indicators.

Central scenario: National Trends

National Trends is the central policy scenario of the TYNDP2020, designed to reflect EU member state's National Energy and Climate Plans (NECP), in line with the requirement to meet current European 2030 energy strategy targets.

			Comparison of the COP21 scenarios with NT2030 average result		
	NT2025	**NT2030**	**DE2030 is < or > than NT2030**	**GA2030 is < or > than NT2030**	

Increase in socio-economic welfare

B1 Annual Socio-Economic Welfare (SEW) increase (M € / year)	max average min	2166 2166 2166	1231 1231 1231	>	>	ENTSO-E assessment
B1_CO2 Annual Socio-Economic Welfare increase resulting from CO2 emissions reduction	max average min	493 493 493	384 381 379	>	>	ENTSO-E assessment

B1_RES Annual Socio-Economic Welfare increase resulting from RES integration	max average min	2462 2462 2462	1546 1505 1463	>	>	ENTSO-E assessment

Reduction of CO2 and GHG emissions

B4 Non-CO2 emissions (kg/year)

B4a Nitrogen oxides	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B4b Ammonia	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B4c Sulfur dioxide	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B4d Particular matter 5	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B4e Particulate matter 10	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B4f Non-methane volatile organic compounds	average	N/A	N/A	n/a	n/a	ENTSO-E assessment

B2a Annual CO2 variation from market simulation (ktonnes / year)		max average min	-21440 -21440 -21440	-13543 -13622 -13700	<	<	ENTSO-E assessment
B2a_€ Annual Societal cost variation resulting from CO2 variation from market simulation monetised (M € / year)	CO2 price	60€/ ton 100€/ ton 189€/ ton	793 1651 3559	436 981 2193	< < <	< > >	ENTSO-E assessment
B2b Annual CO2 variation due to network losses (ktonnes / year)		average	0	0	n/a	n/a	ENTSO-E assessment
B2b_€ Annual Societal cost	CO2 price	60€/ ton	0 0	0 0	n/a	n/a	ENTSO-E assessment

variation resulting from CO2 variation from network simulation monetised (M € / year)	100€/ ton 189€/ ton	0	0			

Integration of renewable energy sources

B3 Annual avoided curtailment (RES integration) (GWh / year)	max average min	48931 48931 48931	40199 39795 39391	>	>	ENTSO-E assessment
B3a Connected RES (MW)	-			n/a	n/a	ENTSO-E assessment

Impact on grid losses

B5 Variation of network losses (GWh / year)	average	N/A	N/A	n/a	n/a	ENTSO-E assessment
B5_€ Variation of network losses monetised (M€ / year)	average	N/A	N/A	n/a	n/a	ENTSO-E assessment

Security of supply

B6 Annual reduction in Energy Not Served (MWh / year)	max average min		N/A	n/a	n/a	ENTSO-E assessment
B6_€ Annual Socio-Economic Welfare increase resulting from reduction in Energy Not Served monetised (M€ / year)	average	n/a	N/A	>	n/a	ENTSO-E assessment

Scenarios: Distributed Energy & Global Ambition

DE and GA are two scenarios created in line with the COP21 targets to understand the impact on

infrastructure needs agains different pathways reducing EU-28 emissions to net-zero by 2050. For these two scenarios, projects were assessed with a subset of CBA parameters.

		DE2030	GA2030	
Increase in socio-economic welfare				
B1 Annual Socio-Economic Welfare (SEW) increase (M€ / year)	average	2316	1623	ENTSO-E assessment
B1_CO2 Annual Socio-Economic Welfare increase resulting from CO2 emissions reduction	average	845	568	ENTSO-E assessment
B1_RES Annual Socio-Economic Welfare increase resulting from RES integration	average	2601	1909	ENTSO-E assessment
Reduction of CO2 and GHG emissions				
B2a Annual CO2 variation from market simulation (ktonnes / year)	average	-15942	-16238	ENTSO-E assessment
B2a_€ Annual Societal cost variation resulting from CO2 variation from market simulation monetised (M€ / year)	CO2 price 60€/ ton 100€/ ton 189€/ ton	112 749 2168	406 1055 2501	ENTSO-E assessment
Integration of renewable energy sources				
B3 Annual avoided curtailment (RES integration) (GWh / year)	average	45179	42397	ENTSO-E assessment
B3a Connected RES (MW)	-			ENTSO-E assessment

Sensitivity Study: Current Trends

'Current Trends' describes a future where the energy transition is slower than planned.

	CT2030	

Increase in socio-economic welfare

B1 Annual Socio-Economic Welfare (SEW) increase (M€ / year)	average	2357	ENTSO-E assessment
B1_CO2 Annual Socio-Economic Welfare increase resulting from CO2 emissions reduction	average	528	ENTSO-E assessment
B1_RES Annual Socio-Economic Welfare increase resulting from RES integration	average	2705	ENTSO-E assessment

Reduction of CO2 and GHG emissions

B2a Annual CO2 variation from market simulation (ktonnes / year)	average	-18874	ENTSO-E assessment
B2a_€ Annual Societal cost variation resulting from CO2 variation from market simulation monetised (M€ / year)	CO2 price 60€/ ton 100€/ ton 189€/ ton	604 1359 3039	ENTSO-E assessment

Integration of renewable energy sources

B3 Annual avoided curtailment (RES integration) (GWh / year)	average	48141	ENTSO-E assessment
B3a Connected RES (MW)	-		ENTSO-E assessment

Residual impact

Information on the residual impact of the project was provided by the project promoter(s).

Project Costs

The project costs were provided by the project promoter(s).

	CAPEX (Meuro)	Uncertainty range (%)	OPEX
1504. Power Link Island	2222	The Capex uncertainty range for this asset is -20% to +30%. This can be explained by the different costs which are registered for currently realized projects to connect offshore windfarms. This range can be explained by the project specific differences. Since there is no clarity on the project specifics in this phase of the project, the uncertainty range thereby reflects this.	11
1505. Interconnection DKw to Power Link Island	1310	The Capex uncertainty range for this 525kV link covers -20% to +30%. This can be explained by the different costs which are registered for currently realized projects to connect offshore windfarms. This range can be explained by the project specific differences. Since there is no clarity on the project specifics in this phase of the project, the uncertainty range thereby reflects this.	4.3
1506. Interconnection NL Maasvlakte to Power Link Island	1375	The Capex uncertainty range for this 525kV link is -20% to +30%. This can be explained by the different costs which are registered for currently realized projects to connect offshore windfarms. This range can be explained by the project specific differences. Since there is no clarity on the project specifics in this phase of the project, the uncertainty range thereby reflects this.	4.4
1507. Interconnection NL Eemshaven to Power Link Island	1233	The Capex uncertainty range for this 525kV link is -20% to +30%. This can be explained by the different costs which are registered for currently realized projects to connect offshore windfarms. This range can be explained by the project specific differences. Since there is no clarity on the project specifics in this phase of the project, the uncertainty range thereby reflects this.	4.2
1508. Interconnection DE (area of Brunsbüttel) to Power Link Island	1639	The Capex for the 640kVHVDC links are extrapolated from 525kV HVDC links and therefore are subject to the same uncertainty range. Furthermore, additional needed internal reinforcements that can have a fundamental impact on the costs have not yet been analysed.	5.3
1509.	1661	The Capex for the 640kVHVDC links are extrapolated	5.3

	CAPEX (Meuro)	Uncertainty range (%)	OPEX
Interconnection DE (area of Oldenburg) to Power Link Island		from 525kV HVDC links and therefore are subject to the same uncertainty range. Furthermore, additional needed internal reinforcements that can have a fundamental impact on the costs have not yet been analysed.	
1511. Interconnection DE (area of Krümmel) to Power Link Island	1860	The Capex for the 640kVHVDC links are extrapolated from 525kV HVDC links and therefore are subject to the same uncertainty range. Furthermore, additional needed internal reinforcements that can have a fundamental impact on the costs have not yet been analysed.	5.6
Total	11300		40.1

Explanation provided by the project promoter on the CAPEX uncertainty range:

1504	For this asset type, no data is available in ACER's documents.
1505	On a first note: it is difficult to explain the differences based on figures that do not show specific characteristics for the data sample. Therefore, a valid comparison of the different estimates is difficult to provide. In general, the explanatory factors for the differences are: 1) deviating installation costs due to an offshore environment for the converters on the island 2) 2k criterion in Germany, impacting the power rating of the HVDC links 3) Isolation material assumptions for the cable 4) Voltage range for cables is not covering the assumed voltage level of the cable 5) Voltage level of the cable is not taken into account for cable costs 6) Cable handling differences due to insulation requirements 7) Rating of the cable is not taken into account for cable costs.
1506	On a first note: it is difficult to explain the differences based on figures that do not show specific characteristics for the data sample. Therefore, a valid comparison of the different estimates is difficult to provide. In general, the explanatory factors for the differences are: 1) deviating installation costs due to an offshore environment for the converters on the island 2) 2k criterion in Germany, impacting the power rating of the HVDC links 3) Isolation material assumptions for the cable 4) Voltage range for cables is not covering the assumed voltage level of the cable 5) Voltage level of the cable is not taken into account for cable costs 6) Cable handling differences due to insulation requirements 7) Rating of the cable is not taken into account for cable costs.
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1508	On a first note: it is difficult to explain the differences based on figures that do not show specific characteristics for the data sample. Therefore, a valid comparison of the different estimates is difficult to provide. In general, the explanatory factors for the

	differences are: 1) deviating installation costs due to an offshore environment for the converters on the island 2) 2k criterion in Germany, impacting the power rating of the HVDC links 3) Isolation material assumptions for the cable 4) Voltage range for cables is not covering the assumed voltage level of the cable 5) Voltage level of the cable is not taken into account for cable costs 6) Cable handling differences due to insulation requirements 7) Rating of the cable is not taken into account for cable costs.
1509	On a first note: it is difficult to explain the differences based on figures that do not show specific characteristics for the data sample. Therefore, a valid comparison of the different estimates is difficult to provide. In general, the explanatory factors for the differences are: 1) deviating installation costs due to an offshore environment for the converters on the island 2) 2k criterion in Germany, impacting the power rating of the HVDC links 3) Isolation material assumptions for the cable 4) Voltage range for cables is not covering the assumed voltage level of the cable 5) Voltage level of the cable is not taken into account for cable costs 6) Cable handling differences due to insulation requirements 7) Rating of the cable is not taken into account for cable costs.
1511	On a first note: it is difficult to explain the differences based on figures that do not show specific characteristics for the data sample. Therefore, a valid comparison of the different estimates is difficult to provide. In general, the explanatory factors for the differences are: 1) deviating installation costs due to an offshore environment for the converters on the island 2) 2k criterion in Germany, impacting the power rating of the HVDC links 3) Isolation material assumptions for the cable 4) Voltage range for cables is not covering the assumed voltage level of the cable 5) Voltage level of the cable is not taken into account for cable costs 6) Cable handling differences due to insulation requirements 7) Rating of the cable is not taken into account for cable costs.