

view on DC
breakers

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TenneT offshore Germany



Project	Capacity (MW)	Commissioning
Operational		
alpha ventus	62	2009
BorWin1	400	2010
BorWin2	800	2015
DolWin1	800	2015
HelWin1	576	2015
HelWin2	690	2015
Riffgat	113	2014
SylWin1	864	2015
Under construction		
BorWin3	900	2019
DolWin2	916	2016
DolWin3	900	2018
Nordergründe	111	2016
Total	7,132	
Planned		
DolWin6	900	2021
DolWin5	900	2022
BorWin5	900	2023



TenneT offshore Netherlands

- Five wind areas of 700 MW
- Lowest possible LCOE
- Planning of the 'Energy Agreement'
- Future proof
- Minimal habitat disturbance
- Innovative

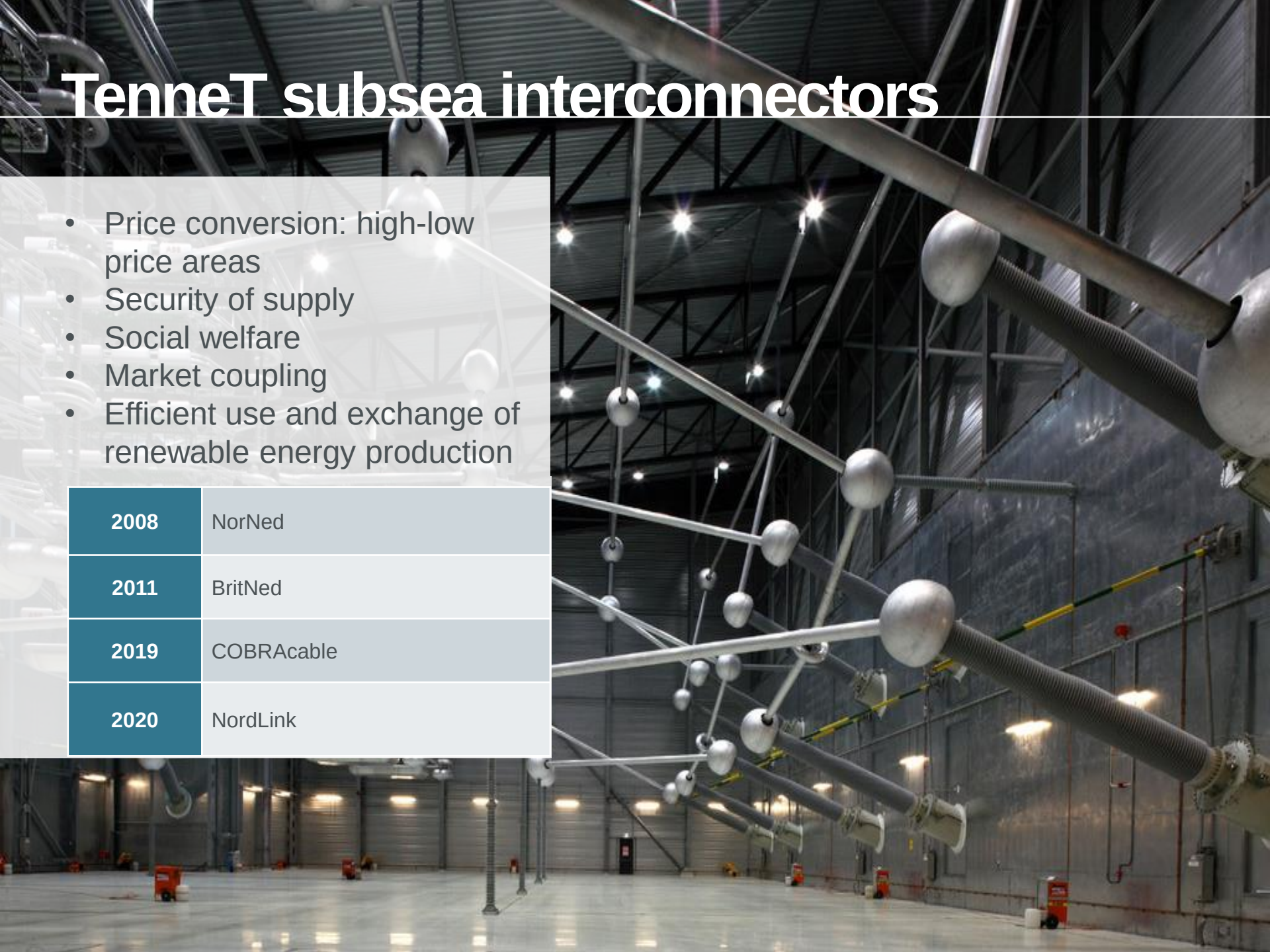
Year	Capacity	Area
2016	700 MW	Borssele
2016	700 MW	Borssele
2017	700 MW	Hollandse Kust (zuid)
2018	700 MW	Hollandse Kust (zuid)
2019	700 MW	Hollandse Kust (noord)



TenneT subsea interconnectors

- Price conversion: high-low price areas
- Security of supply
- Social welfare
- Market coupling
- Efficient use and exchange of renewable energy production

2008	NorNed
2011	BritNed
2019	COBRACable
2020	NordLink





TenneT offshore by 2023

Germany

- Fifteen grid connections for offshore wind farms
- Twelve DC connections, three AC connections
- 4,300 MW at present
- 9,832 MW by 2023 (7,132 MW by 2019)
- NordLink: 1,400 MW (2020)

Netherlands

- Five grid connections for offshore wind farms
- Only AC connections
- 3,500 MW by 2023
- NorNed (2008): 700 MW
- BritNed (2010): 1,000 MW
- COBRA cable (2019): 700 MW



By 2023 TenneT will have realized 17.1 GW of offshore connection capacity (13.3 GW for offshore wind energy, 3.8 GW for interconnection): 13.000 km cable.



The European energy transition

6 June: Political declaration on energy cooperation between the North Seas Countries (EU)

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Noordzeelanden gaan samenwerken bij bouw windmolens

North Seas countries agree on closer energy cooperation

Noordzeelanden werken samen voor meer en goedkopere windparken

Nieuwsbericht | 06-06-2016 | 09:15

North Seas nations join forces for offshore clean energy voyage



Rijksoverheid

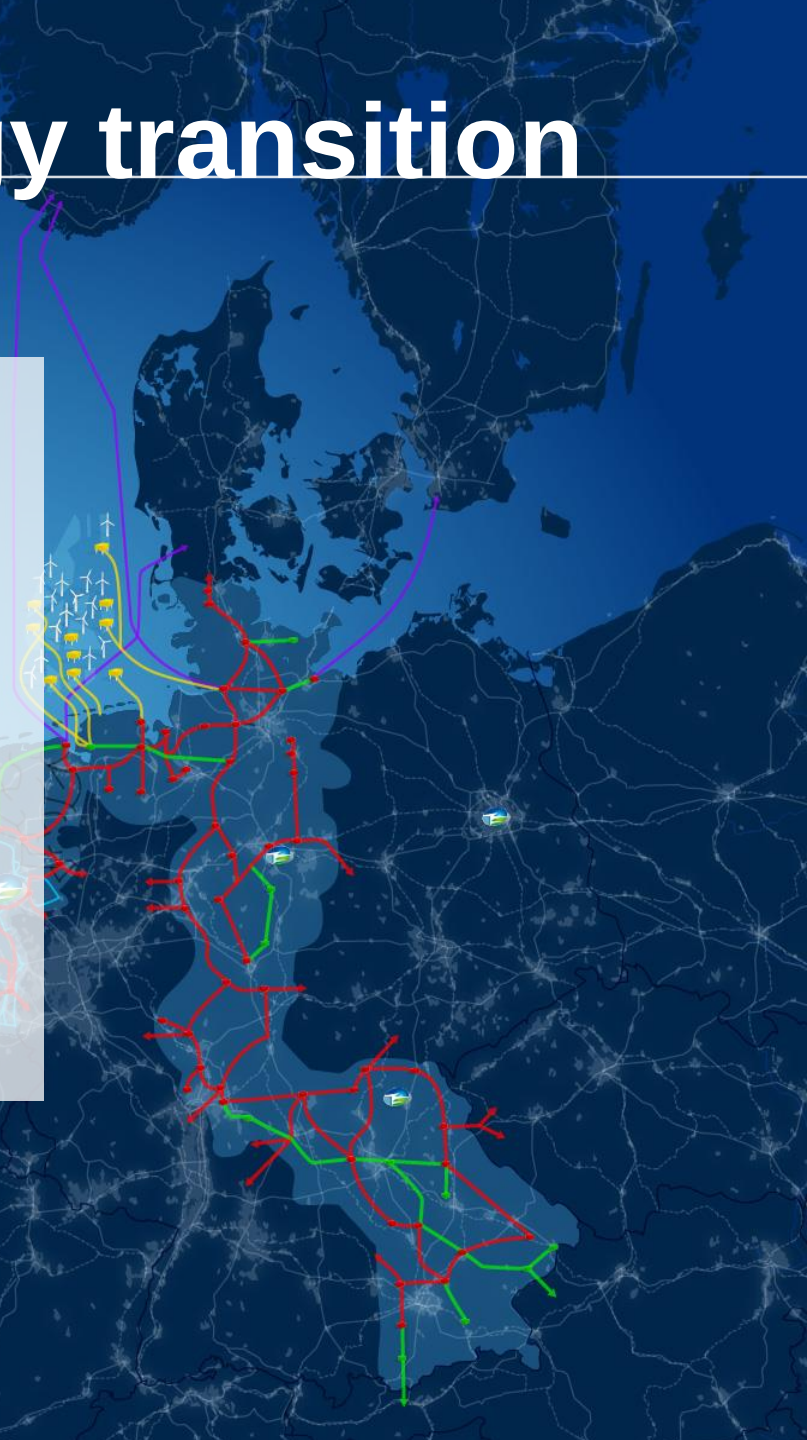


Assumptions EU: regional cooperation, cost reduction offshore wind, take away barriers

The European energy transition

Ambitious goals

- EU ambition: 80-95% CO₂ reduction in 2050 compared with 1990 levels
- Large volumes of RES needed:
 - 2000 GW of sun PV required to cover 50% of the electricity demand (TU Delft)
 - 600 GW offshore & onshore wind power required to cover 50% of the electricity demand (EWEA)
- Cooperation Member States is essential to reach the European energy goals
- Member states should agree upon targets/goals



The challenge

- Sun will be the winner
- But, also wind needed
- Wind energy on land
- Wind energy near shore
- Wind energy far shore
 - Construction (expensive)
 - Maintenance (expensive)
 - Infrastructure (expensive)

Challenges

- How to get cost level down





Solution: hub and spoke concept

Hub and spoke delivers

Scale

A large scale European roll-out for offshore wind delivers a significant contribution to cost reduction.

Location

When far shore becomes necessary, shallow waters with great wind conditions contribute to cost reduction.

Wind connector

The wind connector combines large scale wind farms with powerful interconnectors for higher system efficiency.

Hub function/ island

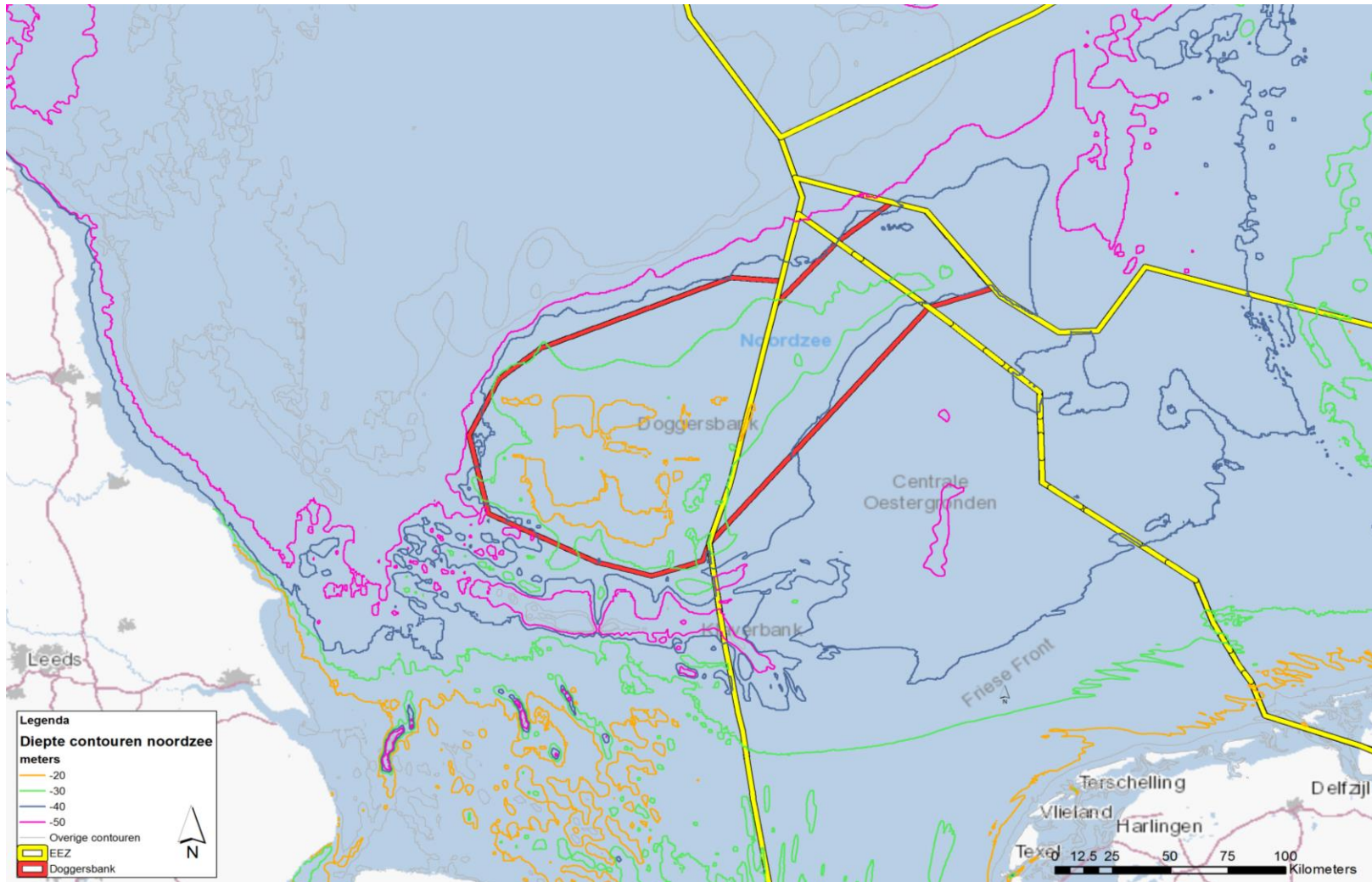
By connecting the interconnectors on the island, a hub can be build that facilitates optimal energy transmission and a further European Market integration.





Solution: location

When far shore becomes necessary to realize the required scale





The modular island: facts & figures

- Possibly three islands: 6 km² each, 200 mln m³ sand
- €1.5 bn (rock and sand only, no infra/facilities)
- Possible connections to existing pipeline infrastructure
- Facilitates approx. 30 GW of wind farms per island
- 15 Converter stations (2 GW each) on the island
- Total: 70 GW, 7,000 turbines (10 MW)
- On the Dogger Bank: 11,400 km²
- Hard substrate: 4.4 km² (0.02% of total Dogger Bank surface)



The modular island

The big step: hub and spoke model



Dc breakers?

- Not essential in the solution
- Based on p-to-p connections
- Breakers required in
 - Meshed DC grids
 - P-P connections with AC bundling

Challenges

- Voltage level
- AC/DC grid topology
- Will connecting on the DC side (to develop meshed solutions) improve performance?
- Only then more accurate requirements can be formulated





www.tennet.eu

TenneT is a leading European electricity transmission system operator (TSO) with its main activities in the Netherlands and Germany. With approximately 22,000 kilometres of high-voltage connections we ensure a secure supply of electricity to 41 million end-users.

Taking power further