



Future North Sea
Infrastructure

Enabling the change

Prof. Mart van der Meijden
TenneT / TUDelft

The European energy transition

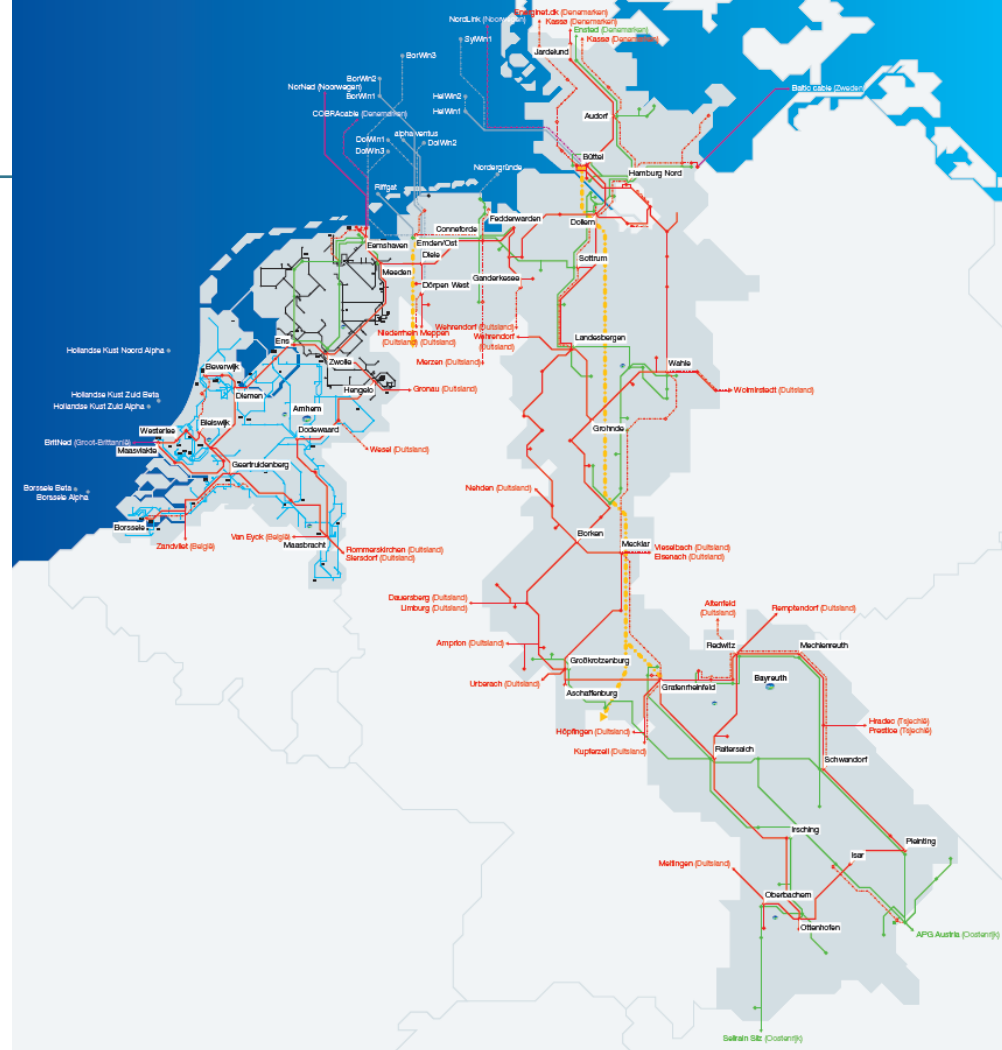


Ambitious goals

- 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

TenneT

- Europe's first cross-border grid operator for electricity
- 22,000 km high-voltage lines
- 41 million end-users, ~3000 employees
- HQ Arnhem (NL), Bayreuth (GER)
- 99,99% security of supply
- EUR 15.4 bn assets
- EUR 22 bn investments: 8-10 bn offshore (NL + GER, 10 years)





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.

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

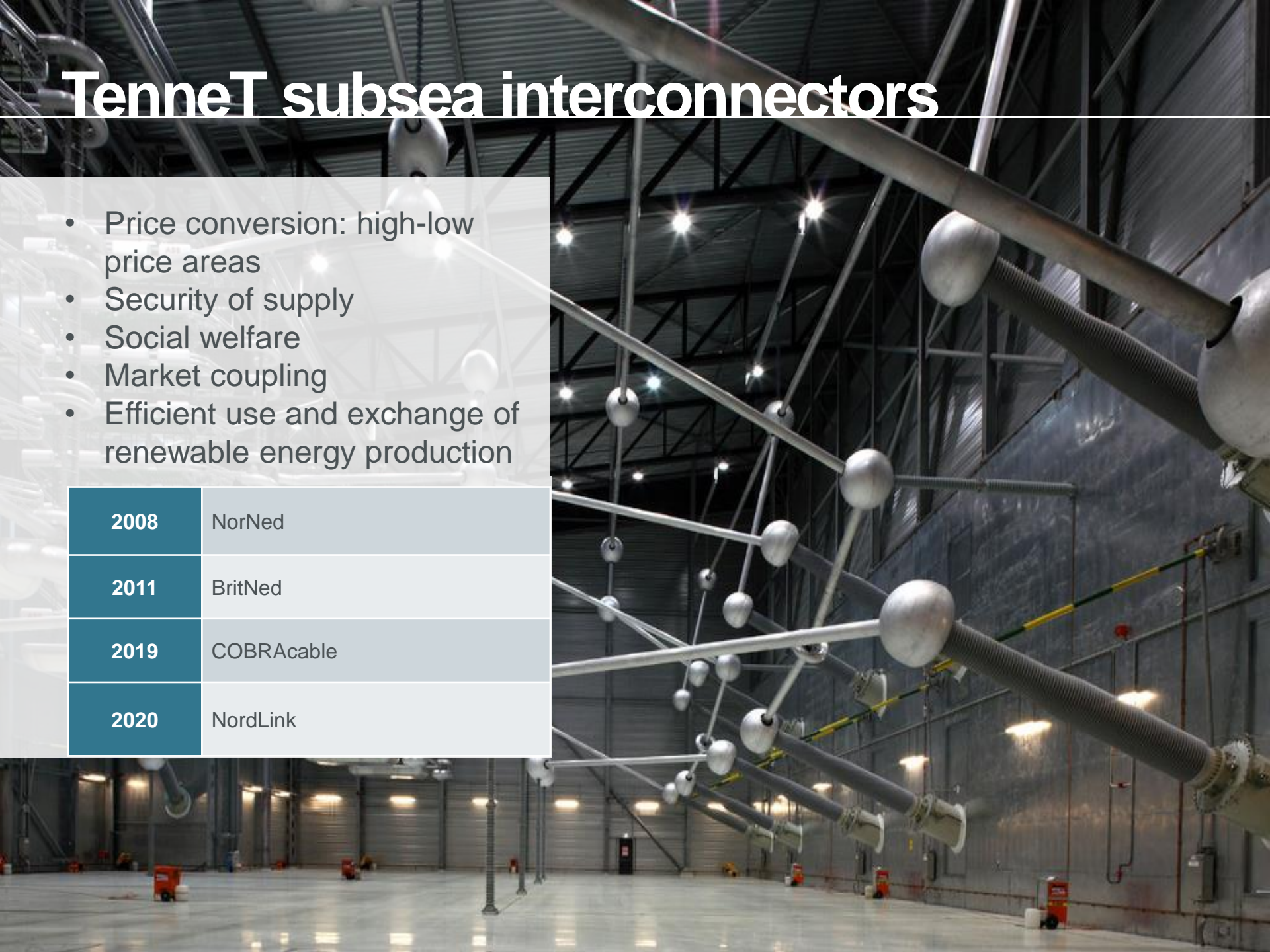
Year	Capacity	Area
2016	700 MW	Borssele
2016	700 MW	Borssele
2017	700 MW	Hollandse Kust (zuid)
2018	700 MW	Hollandse Kust (zuid)
2019	700 MW	Hollandse Kust (noord)



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



Tonstad

NO

NordLink

- TenneT (25%), KfW (25%), Statnett (50%)
- First direct connection between German and Norwegian electricity markets
- 623-km-long HVDC cable link, capacity of 1,400 MW, ready by 2020
- Connecting Norwegian hydropower to German wind and solar energy; natural storage of wind energy

DK

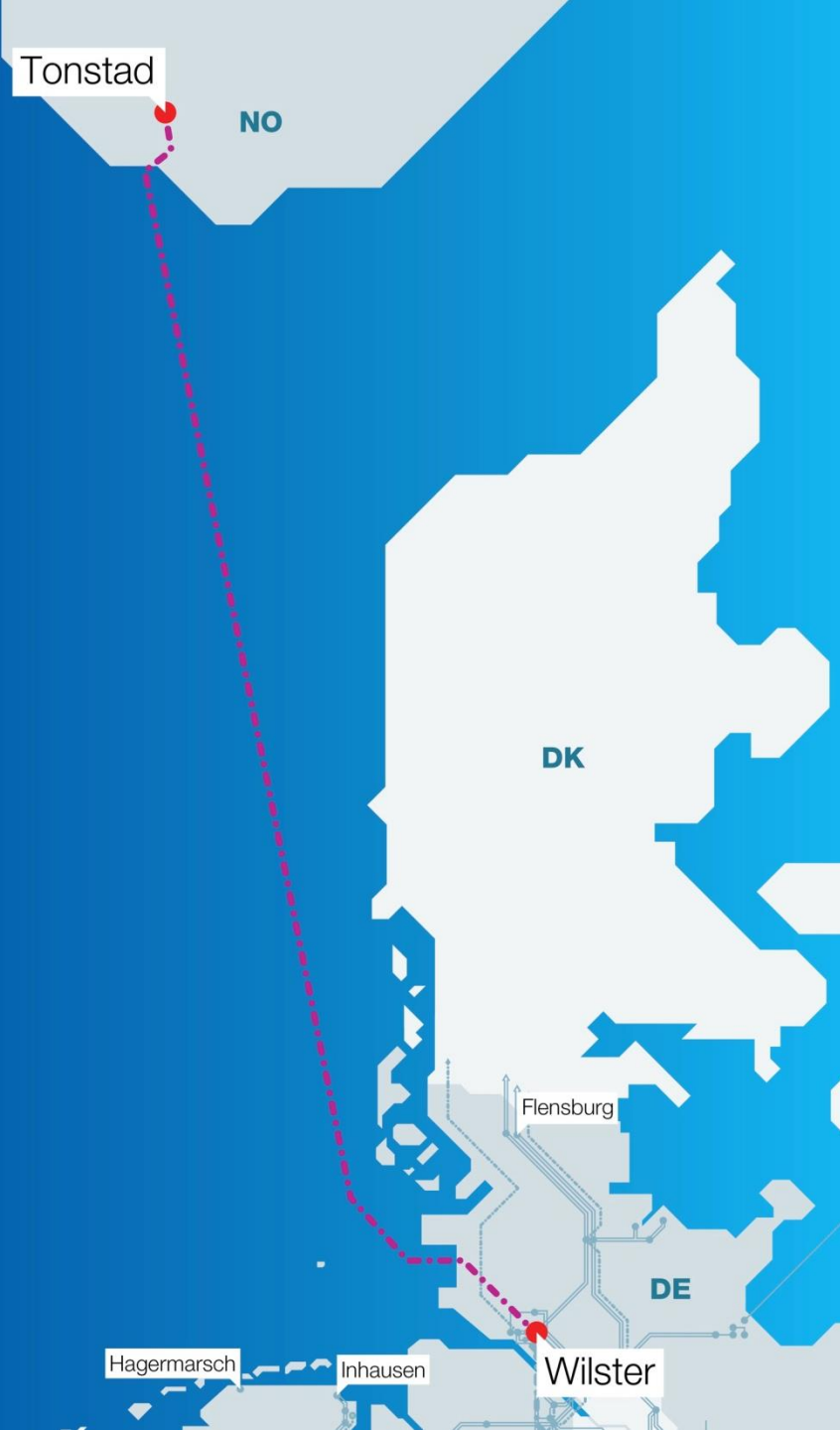
Flensburg

DE

Hagermarsch

Inhausen

Wilster





COBRACable

- TenneT (50%), Energinet.dk (50%)
- First direct connection between the Dutch and Danish electricity markets
- 325-km-long HVDC cable link, capacity of 700 MW, operational ready by 2019
- Multi terminal ready: prepared to connect wind farms
- Connecting Danish wind power to Dutch/European wind and solar energy
- Security of supply

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)

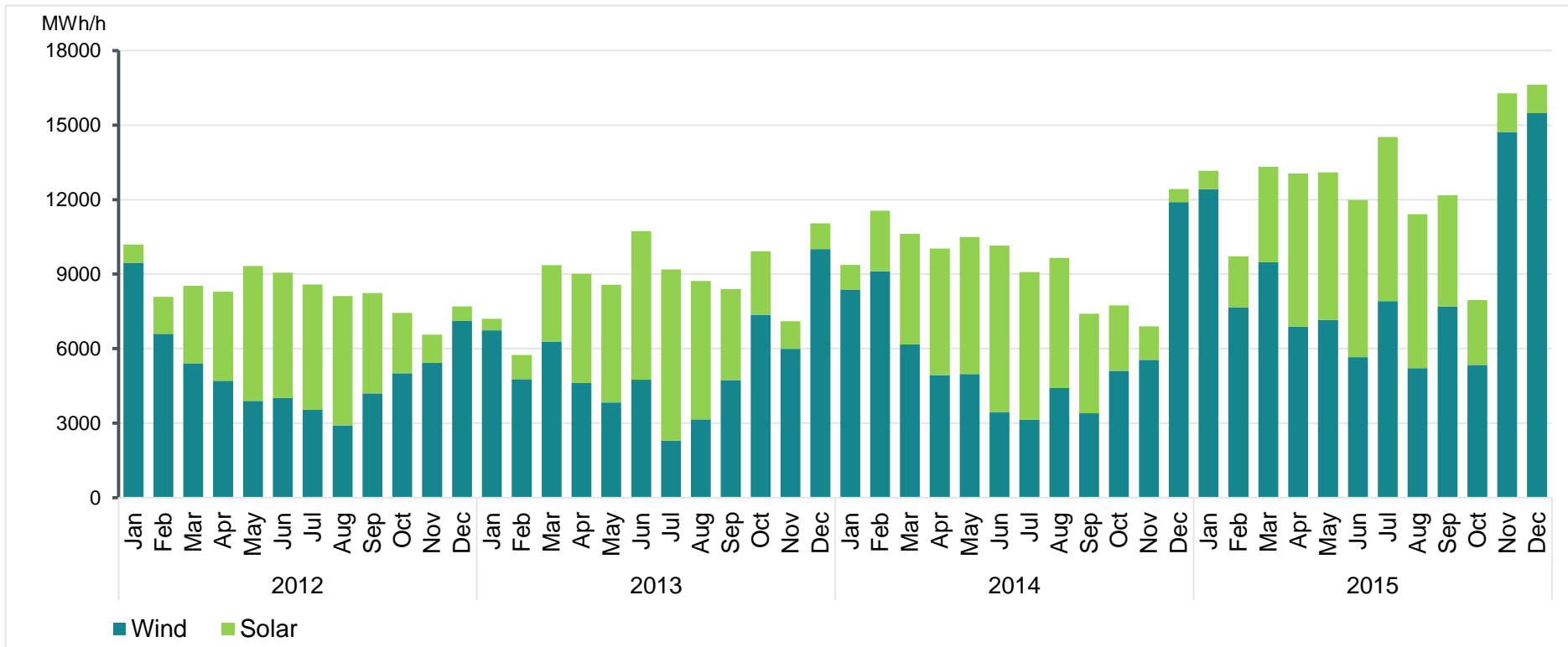
Challenge

- How to get cost level down?
(below Borssele)





Complementary cycles



Sun PV and wind energy are complementary during the year



Two main functions

1. Connection of countries: price convergence
2. Transmission of offshore wind energy

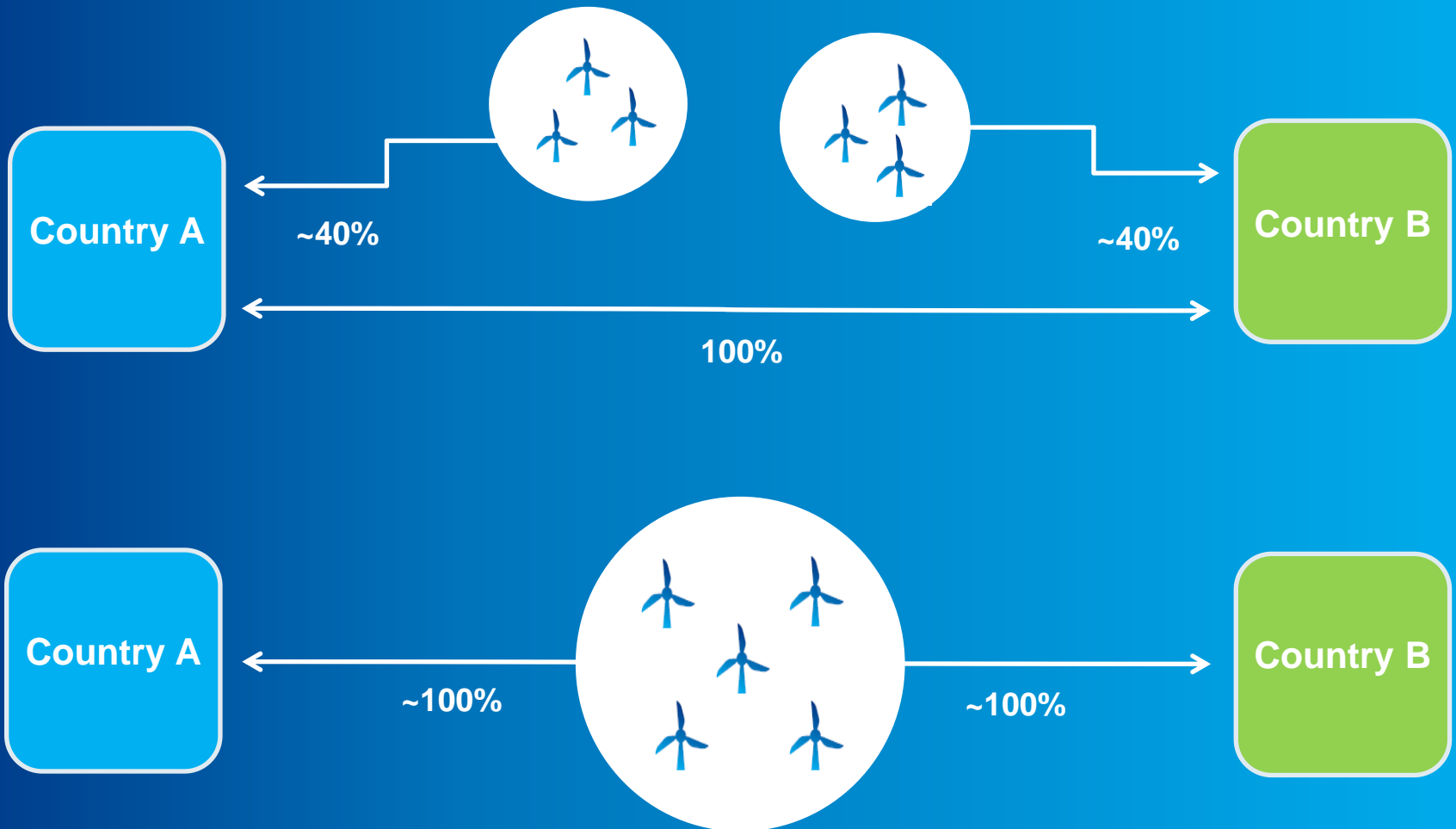
No consumption at sea

Impact of failures differs

- Cost of onshore failure 200 x cost of electricity not delivered
- Cost of offshore failure 1 x cost of electricity not delivered

Solution: the Wind Connector

The *'wind-connector'*: wind infrastructure and interconnector combined in one function





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

Shallow waters

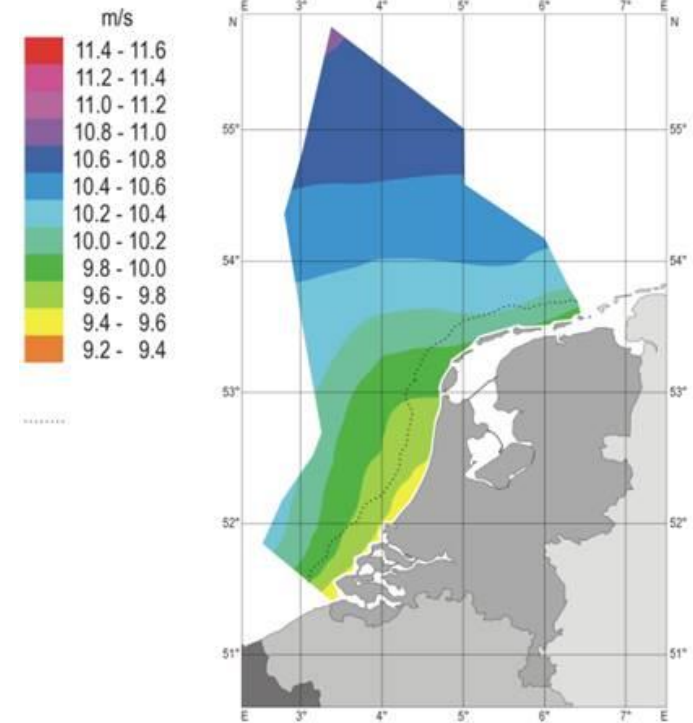
Water depth has a significant impact on the development for offshore wind. A development in shallow waters contributes significantly to cost reduction.

Wind conditions

Wind conditions get better further at sea, which partially compensates the increase in cost for distance.

Central location

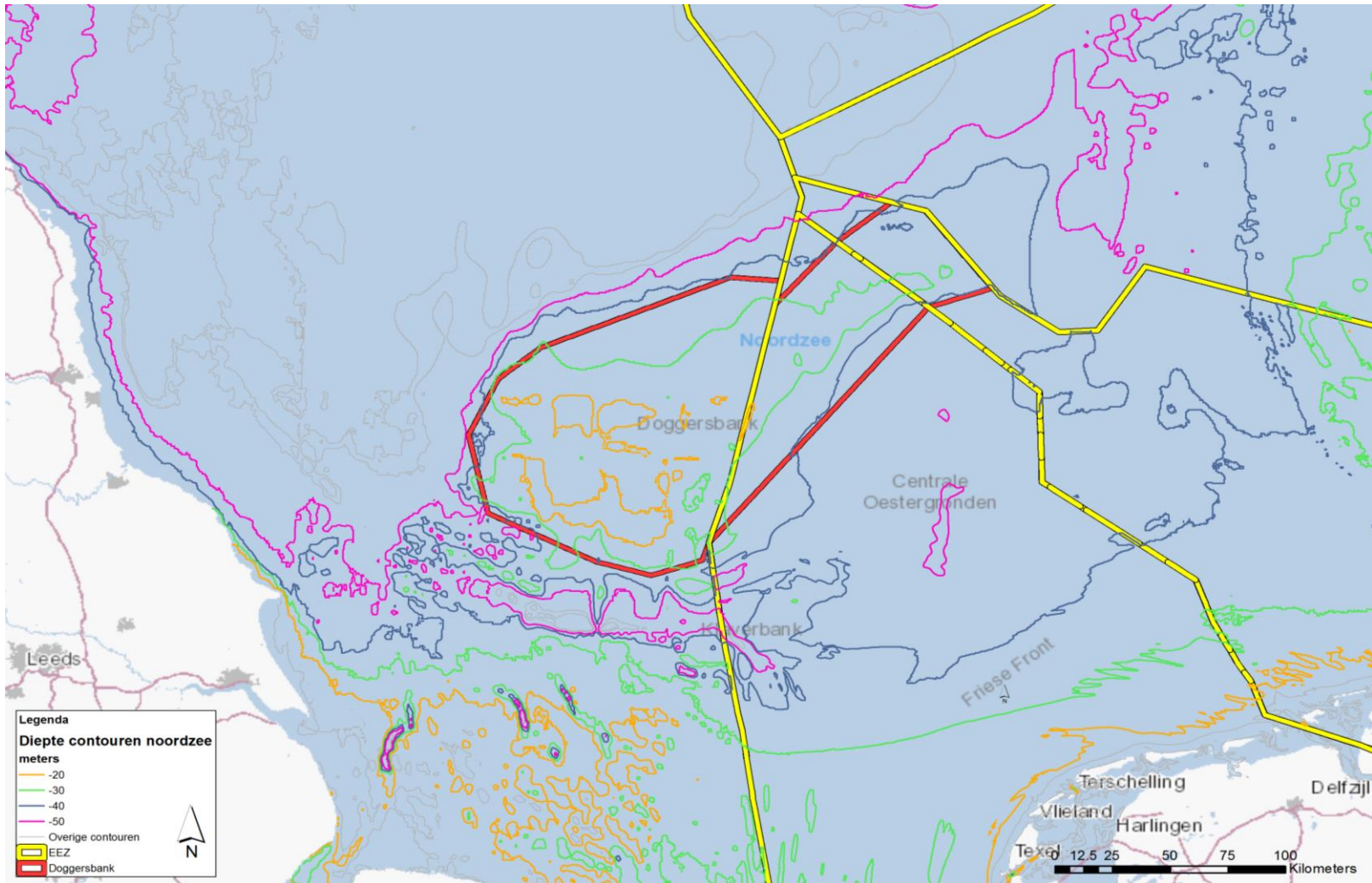
For a European coordinated roll-out, a central location is important.





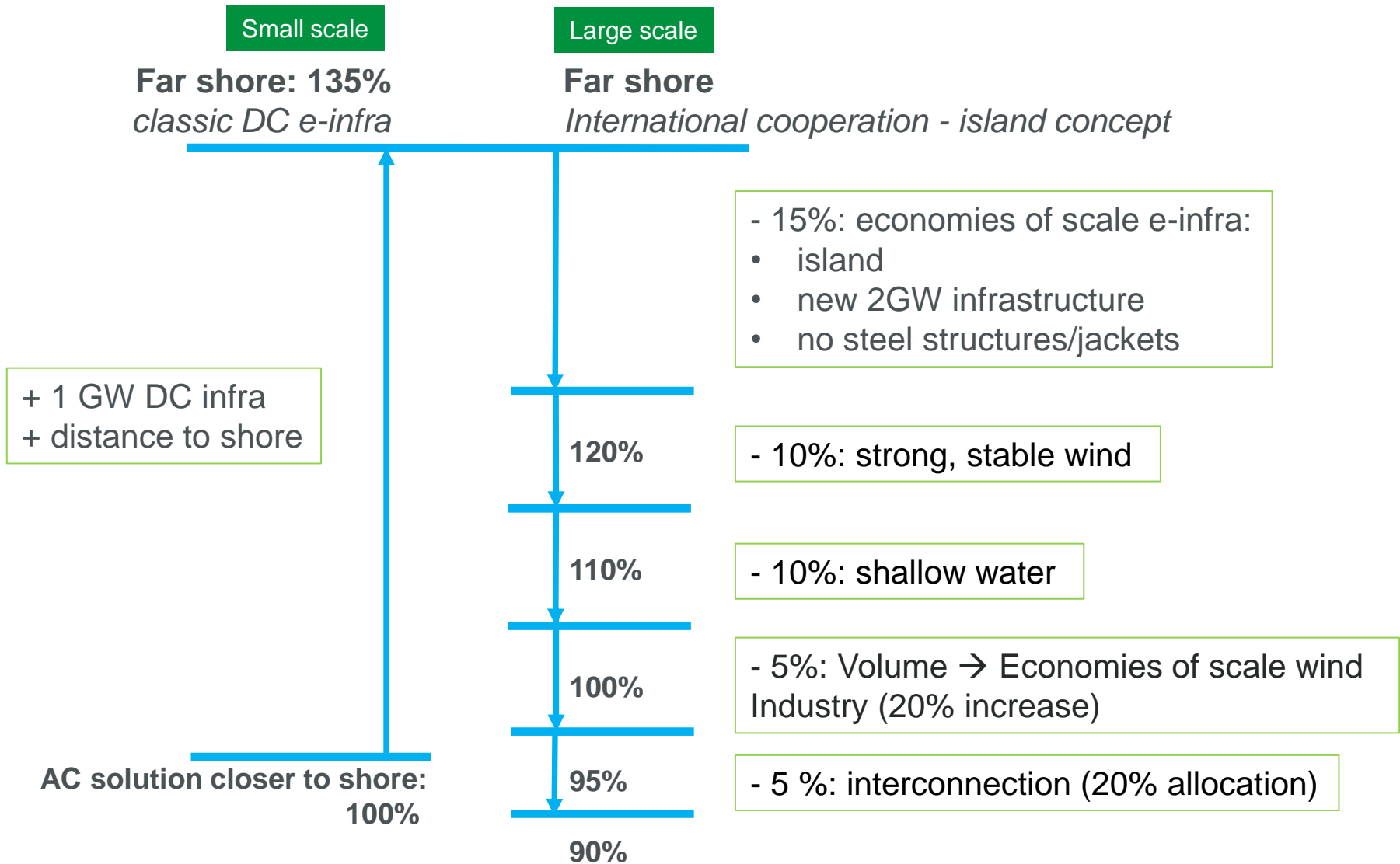
Solution: location

When far shore becomes necessary to realize the required scale





Solution: scale



Combining wind with interconnectors



Wind Connectors



The modular island: facts & figures

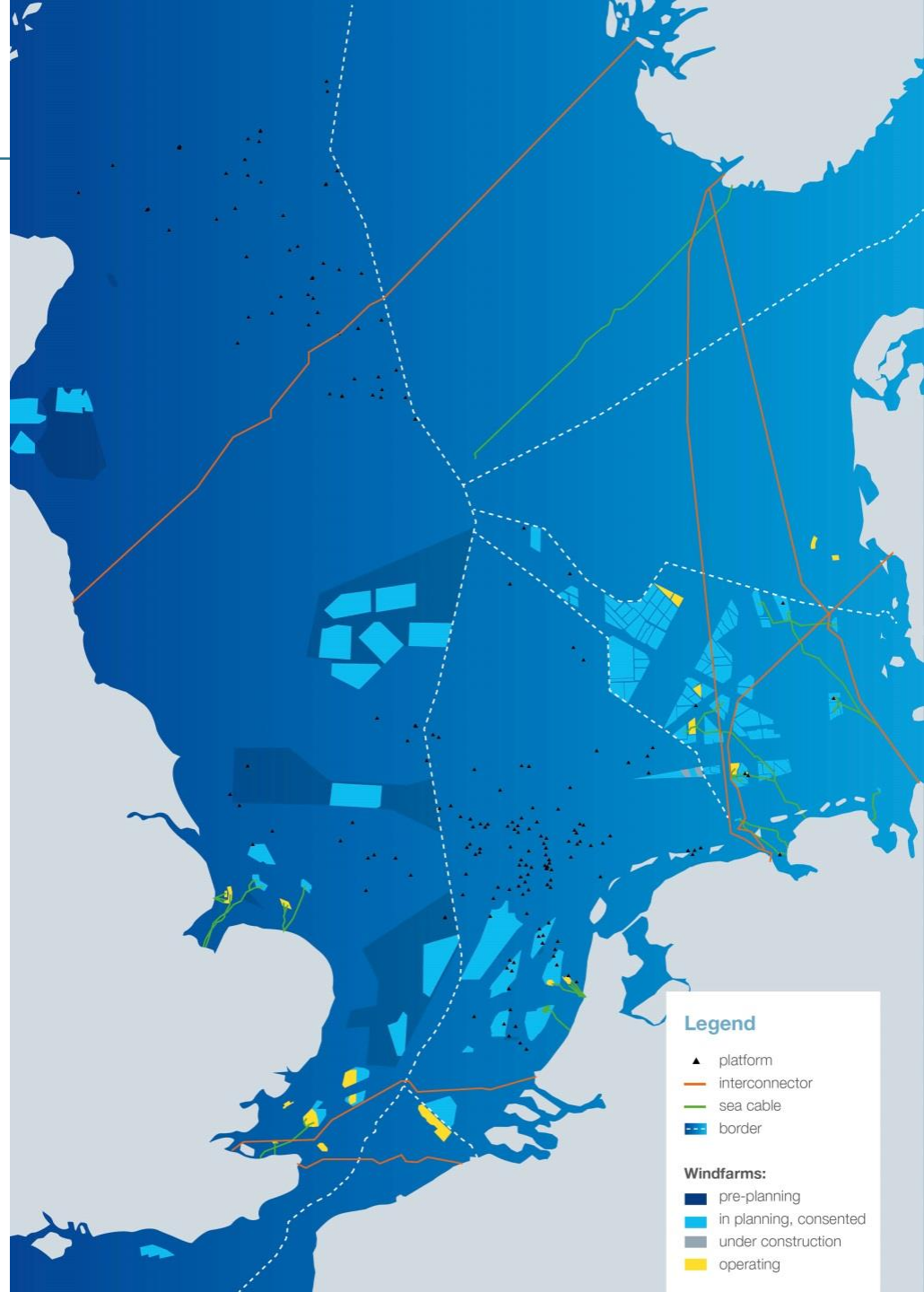
- Possibly three islands: 6 km² each, 200 mln m³ sand
- €1.5 bn (rock and sand only, no infra/facilities)
- Possible connections to existing pipeline infrastructure
- Facilitates approx. 30 GW of wind farms per island
- 15 Converter stations (2 GW each) on the island
- Total: 70 GW, 7,000 turbines (10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



Step 1

Explore & develop 'near shore' wind

- Individual projects by North Sea countries
- Relatively short term goals
- NL: 3.500 MW (additional) in 2023
- TenneT offshore grid developer & operator
- Separate interconnectors
- Onshore wind



Legend

- ▲ platform
- interconnector
- sea cable
- - - border

Windfarms:

- pre-planning
- in planning, consented
- under construction
- operating

Step 2

IJmuiden Ver

- Develop grid concept for IJmuiden Ver
- Development of currently appointed areas (Boven de Wadden and Hollandse Kust) possible with standardized TenneT 700 MW concept
- First tender 2020
- In operation from approx. 2024



Step 3

Connect to infra UK

- Connect IJmuiden Ver to UK energy area (e.g. East Anglia)
- Investigate island solutions
- Cooperation with UK
- Connect to existing oil and gas infrastructure
- Approx. 2025 – 2030
- Timing possibly simultaneously to step 2



Step 4

Large scale, far shore

- Facilitates required economies of scale
- Optimal wind conditions
- Shallow waters
- Central position North Sea countries
- Interconnection hub: Wind Connectors
- Development up to 2050



The modular island

The big step: hub and spoke model





Ecological quick scan flora & fauna

In close consultation with environmental organisations

- Dogger Bank = Natura2000 area
- Additionally: the impact on other species using the Dogger Bank area
- First exploratory study of environmental impacts show:
 - Bio diversity: introduction of hard substrate marks a change to the area, however a limited change increasing biodiversity and biomass
 - Fish and sea mammals: mitigation measures or innovations limiting under water noise during construction are necessary, during operation mainly positive impact of offshore wind expected
 - Birds: impact depends on the way birds use the area, more research is needed for several bird species.



What's next?

- Current autonomous offshore developments by the North Sea countries are important to meet national targets and reach necessary cost reduction
 - Invite the North Sea countries to discuss and further develop this vision to work towards a coordinated approach
 - Explore possibilities IJmuiden Ver (interconnection, small island, conversion, combination with existing infrastructure)
 - Explore possibilities East Anglia with British TSO
 - Start talks with 'Brussels' to explore possibilities to make this a European project
 - Invite research community and industry to come with novel ideas
- 
- A photograph of an offshore wind farm in the North Sea. The image shows several white wind turbines with three blades each, mounted on dark blue or black steel towers. The turbines are spaced out across a vast expanse of blue water under a clear, bright sky. The water's surface is slightly rippled, and the overall scene is clean and modern, representing renewable energy infrastructure.



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



The island





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



North Sea Infrastructure

Properties

Cooperation	EU coordination versus individual
Economies of scale	large volumes reduce marginal costs
Location	strong winds, shallow waters
Efficiency	combining wind farms with interconnector-hub
Technics	island facilitates AC connection technology
Logistics	optimization by means of island
Storage/conversion	power 2 gas plus existing infrastructure or water bassins
Modularity	guaranteed continuity and stable pipeline for market, lowering financial risks