Future North Sea Infrastructure

Enabling the change, one of the EnergyNL2050 puzzle pieces!

KIVI Engineering Society
Afdeling Elektrotechniek

UTRECHT SUSTAINABILITY INSTITUTE

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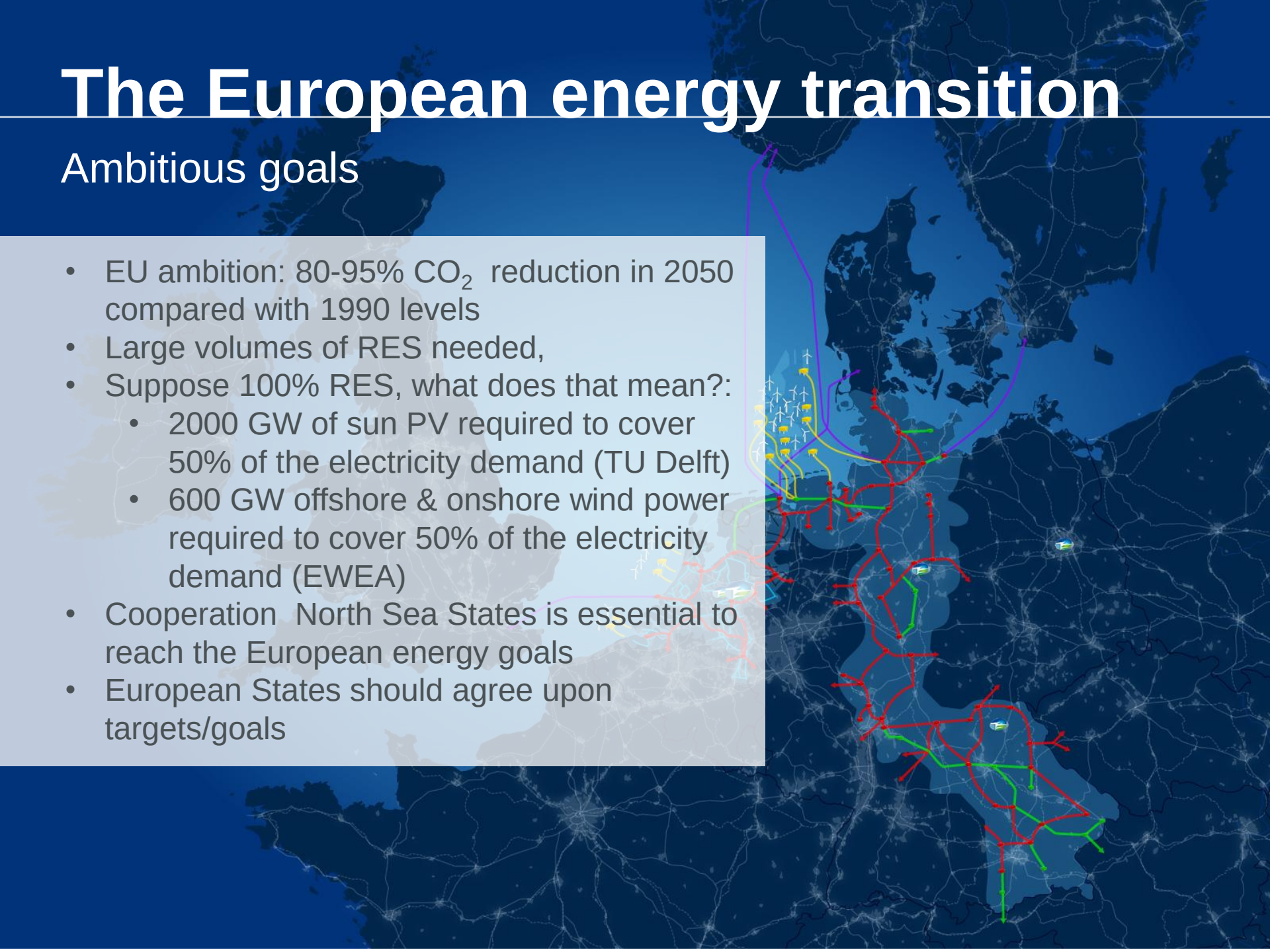
The European energy transition

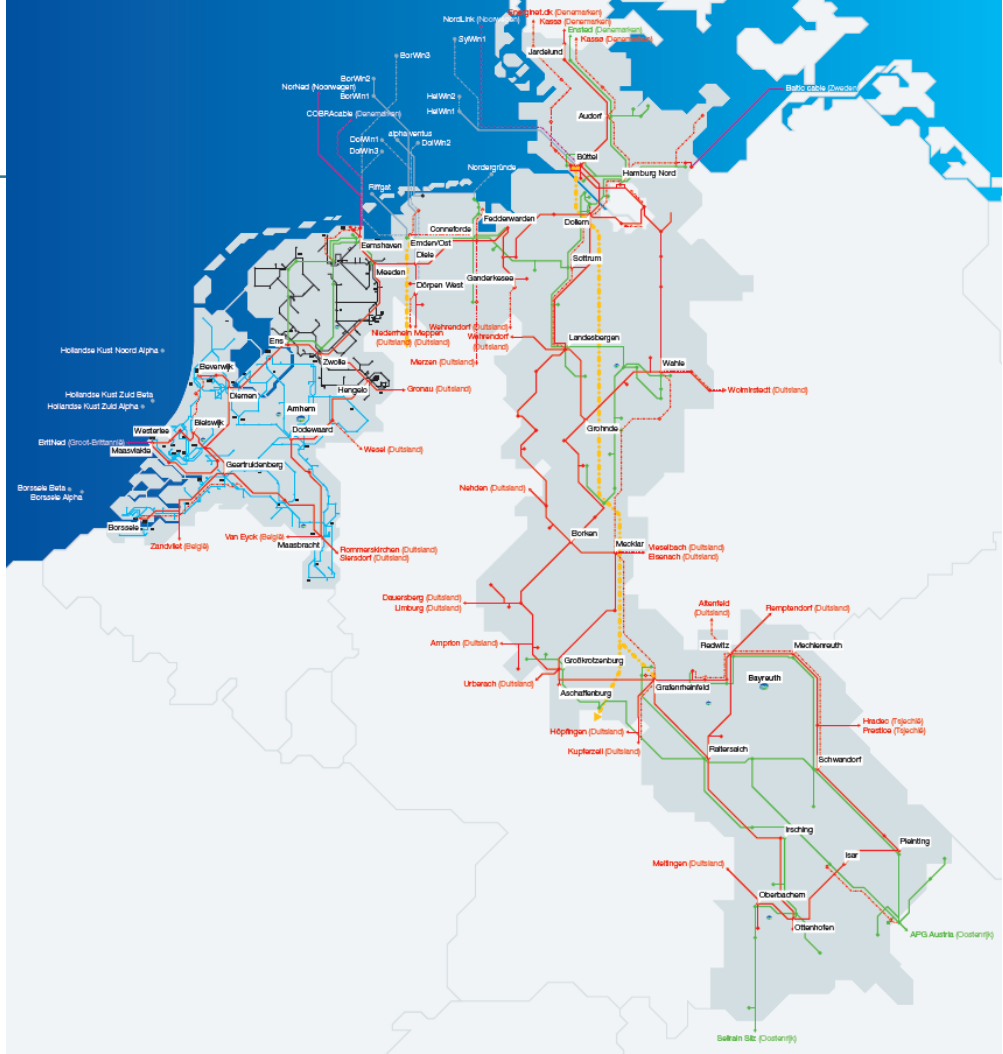
Ambitious goals

- EU ambition: 80-95% CO_2 reduction in 2050 compared with 1990 levels
- Large volumes of RES needed,
- Suppose 100% RES, what does that mean?:
  - 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 North Sea States is essential to reach the European energy goals
- European 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
- 5,000 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.

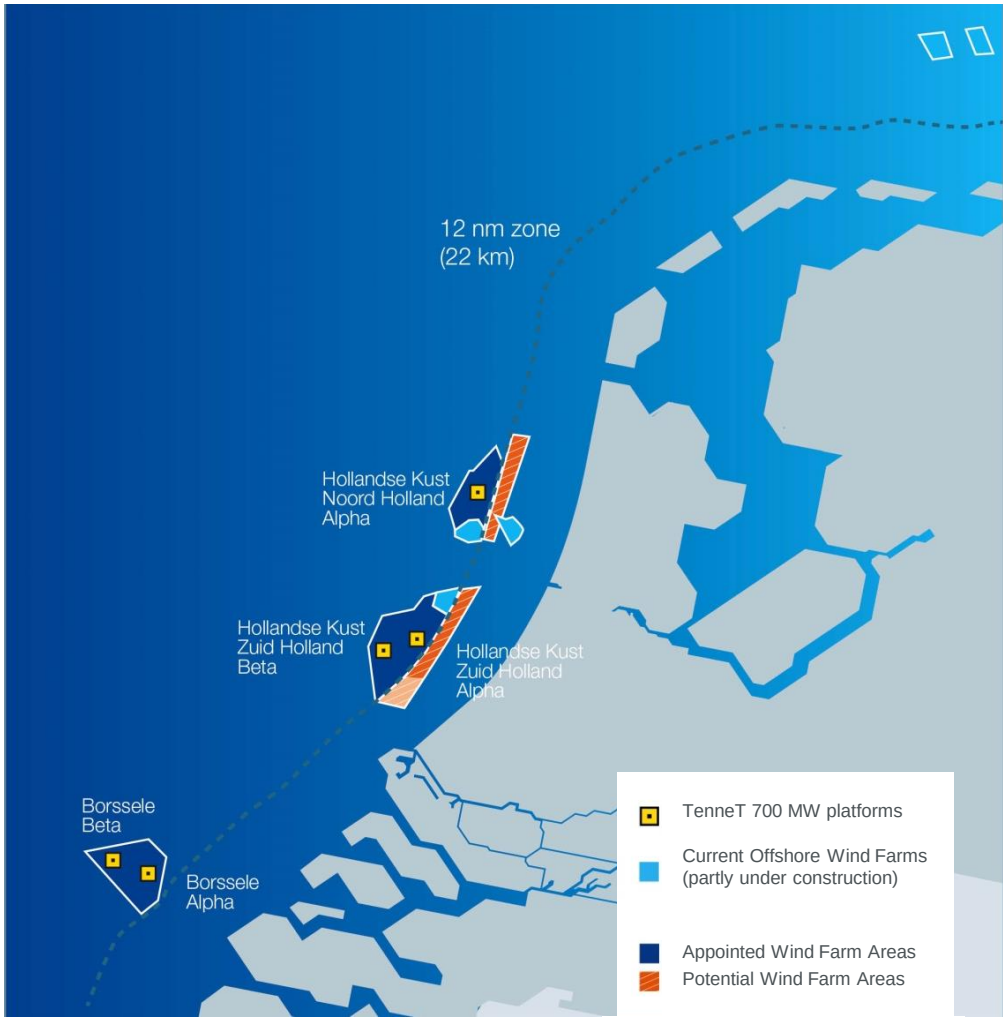
TenneT offshore Germany

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	2023
DolWin5	900	2024
BorWin5	900	2025

TenneT offshore Netherlands

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

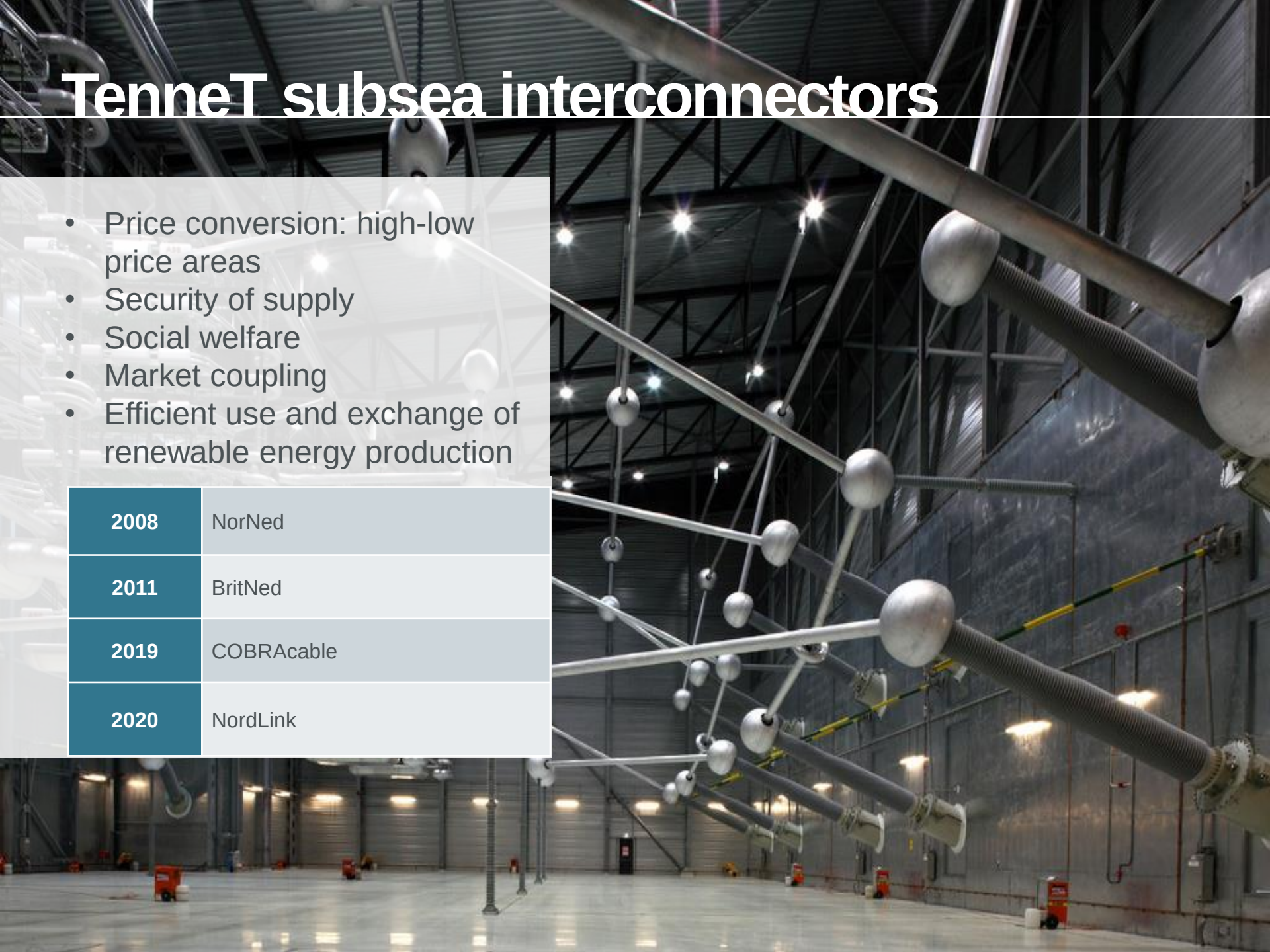
Year	Capacity	Area
2016	700 MW	Borssele
2016	700 MW	Borssele
2017	700 MW	Hollandse Kust (zuid)
2018	700 MW	Hollandse Kust (zuid)
2019	700 MW	Hollandse Kust (noord)

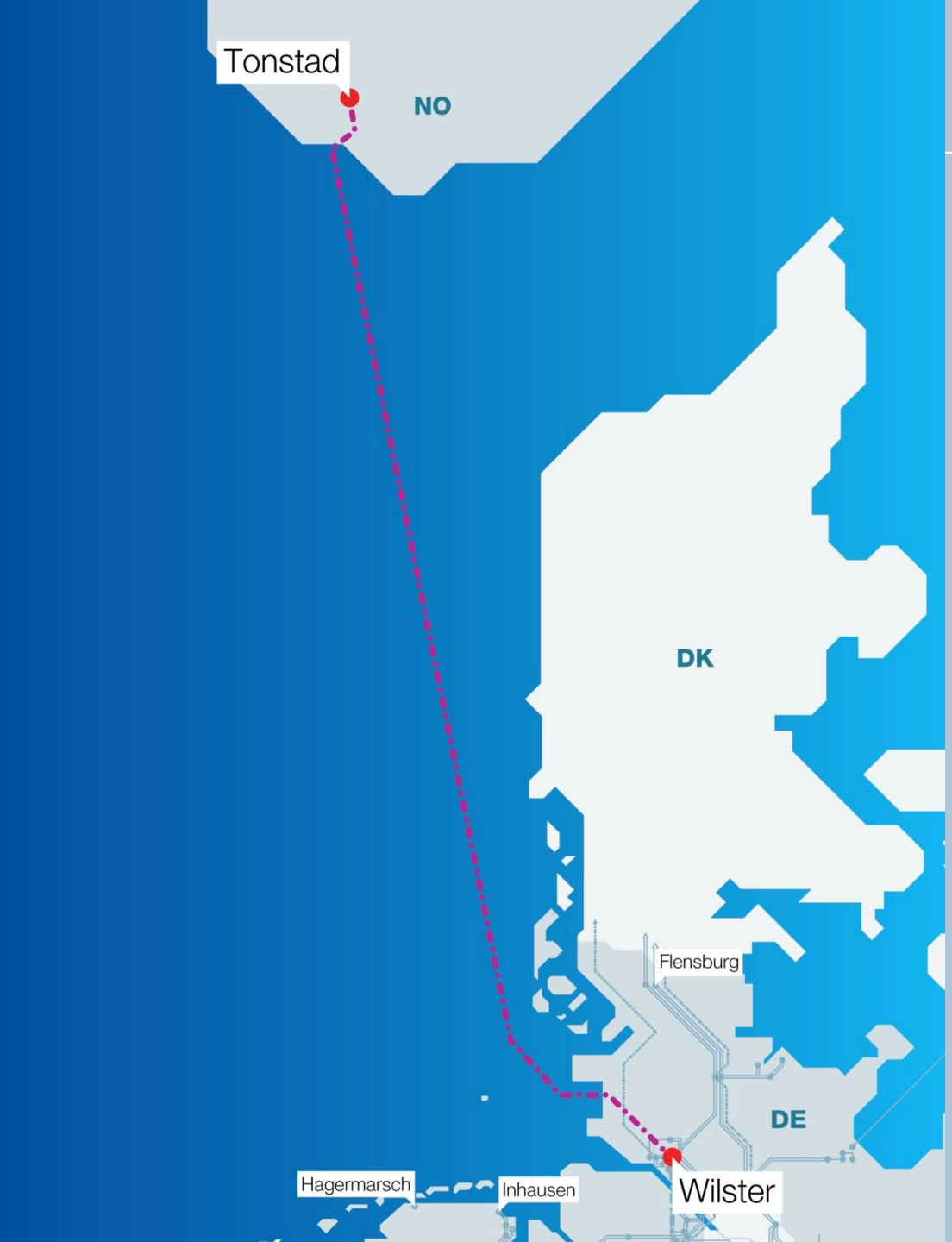


TenneT subsea interconnectors

- 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





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

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

Our view

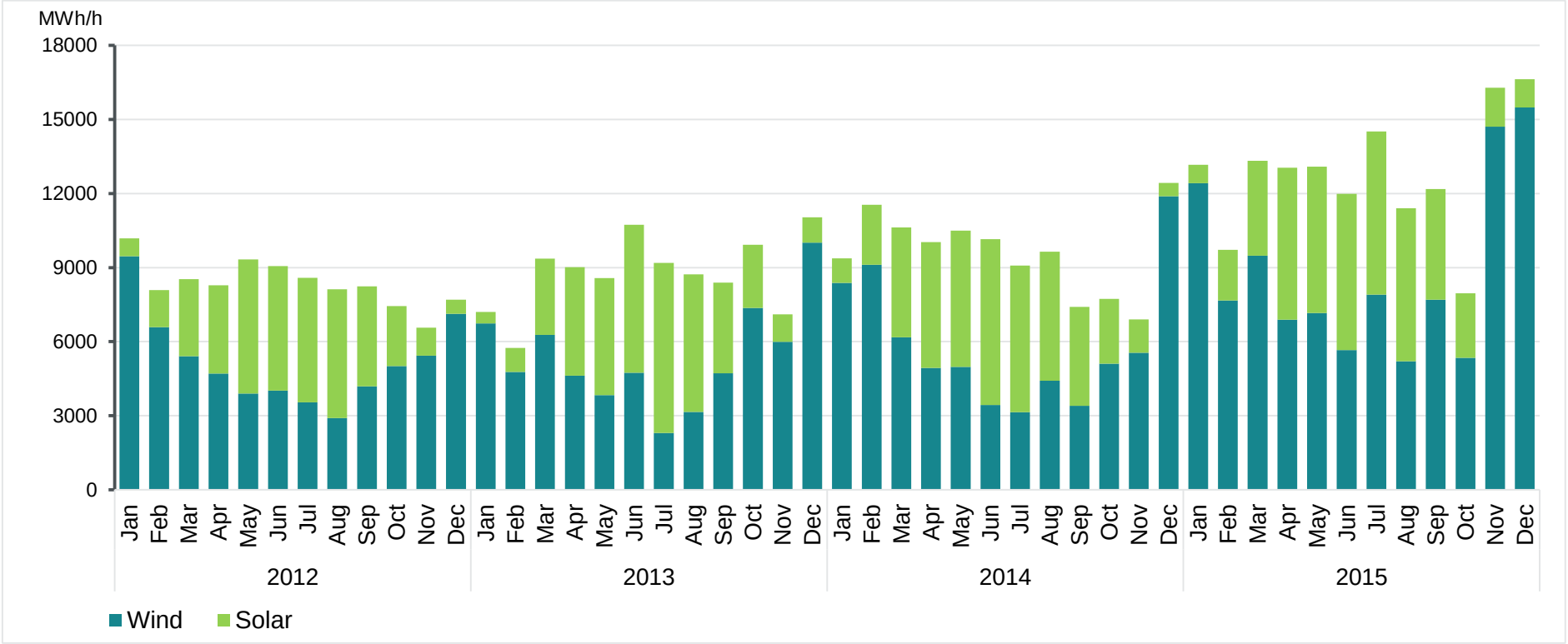
- Sun will be the winner
- But, also wind needed
  - Wind energy on land
  - Wind energy near shore
  - Wind energy far shore
    - Construction (expensive)
    - Maintenance (expensive)
    - Infrastructure (expensive)

Challenge

- How to get cost level down?

Why is offshore wind needed?

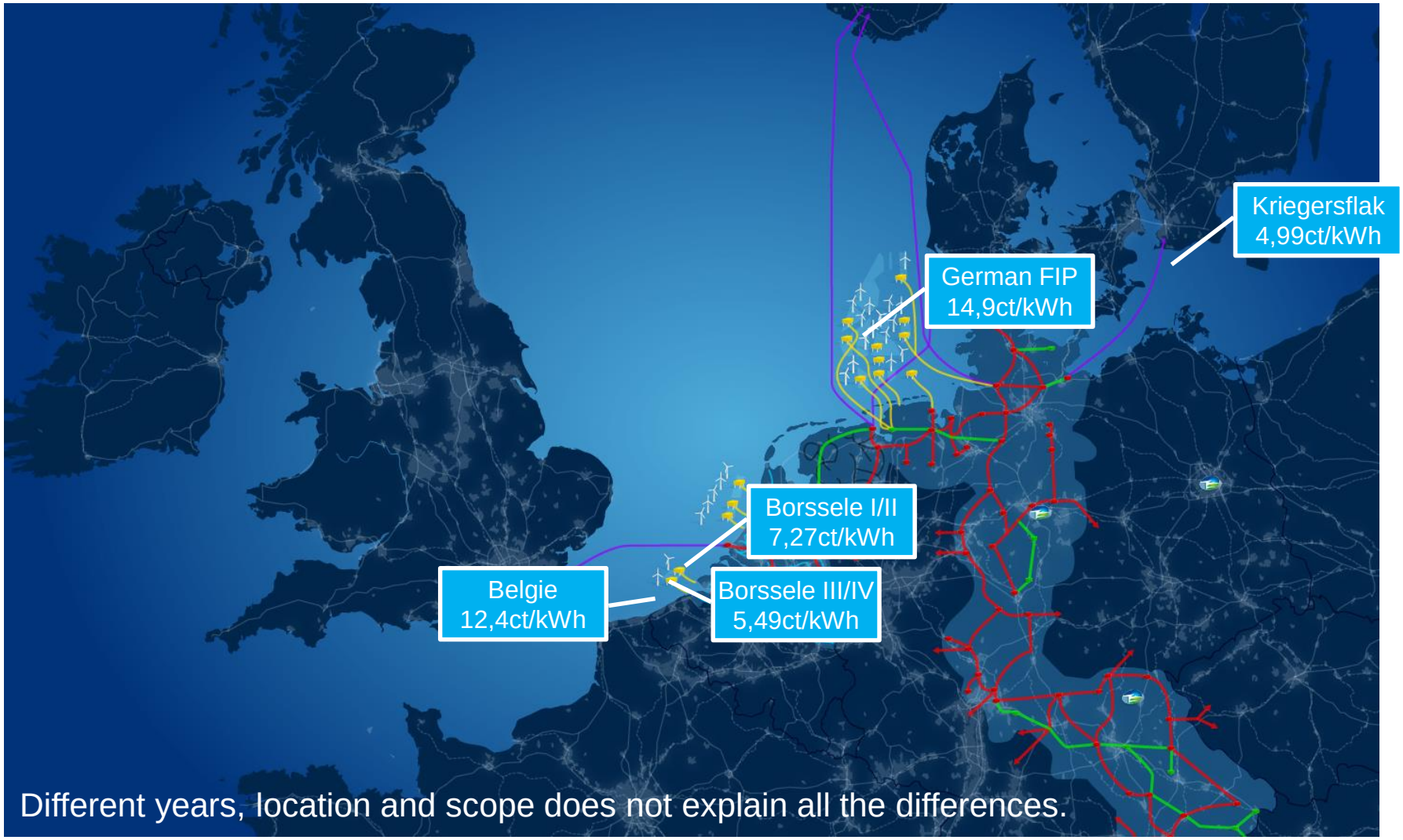
Complementary cycles reduce seasonal storage



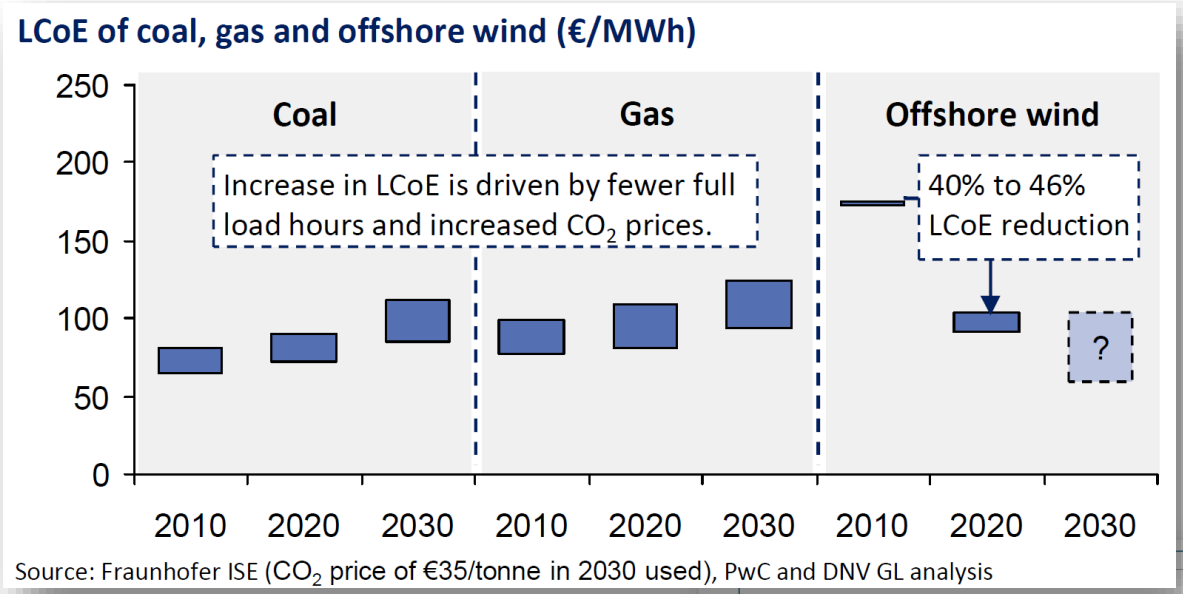
Sun PV and wind energy are complementary during the year

mix 1kWh sun
with 2kWh wind

Tender results OWF

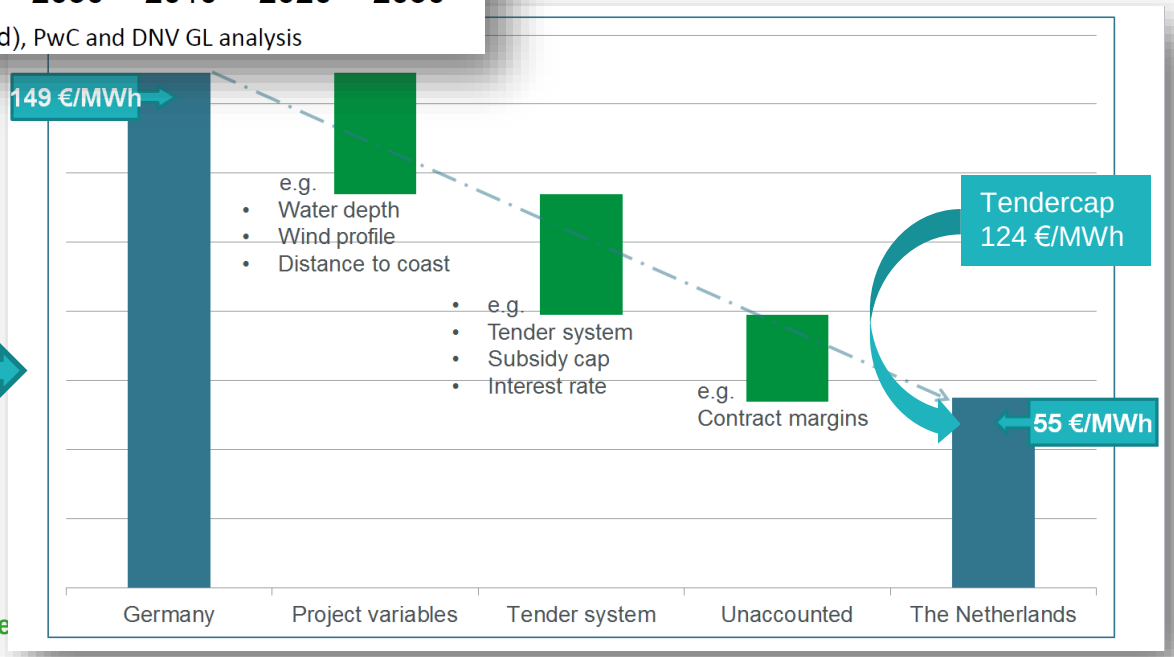


Realism or optimism in cost reduction



TKI Wind op Zee analyse uit Okt-15

Ecofys analyse ’17 obv TenneT aansluitingen in GE en NL



North Sea infrastructure

Three main functions

- Connection of countries: price convergence
- Transmission of offshore wind energy
- Enhance system security and stability by allowing the exchange of power

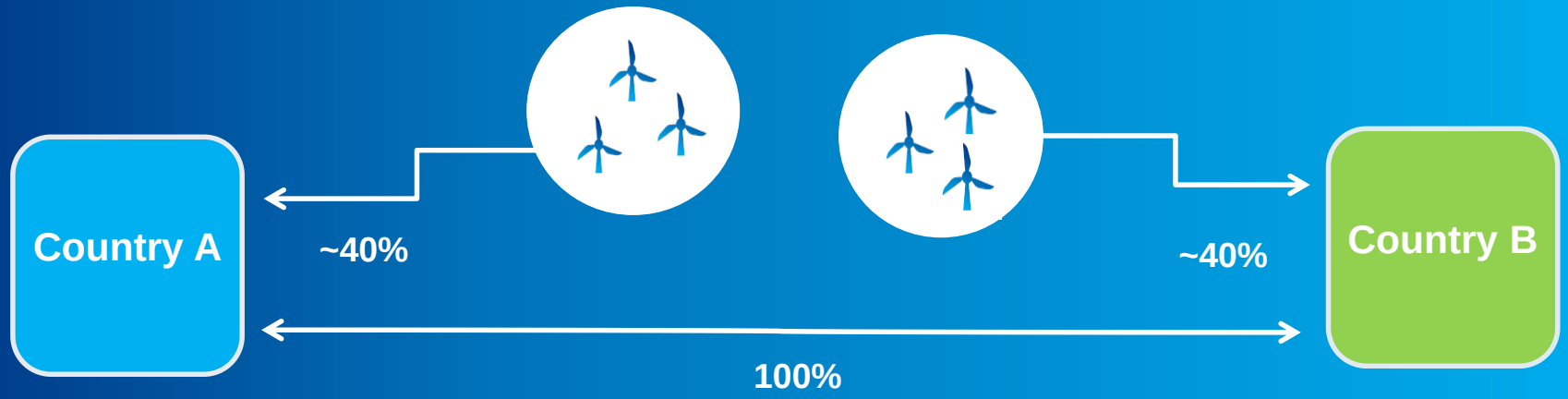
No consumption at sea

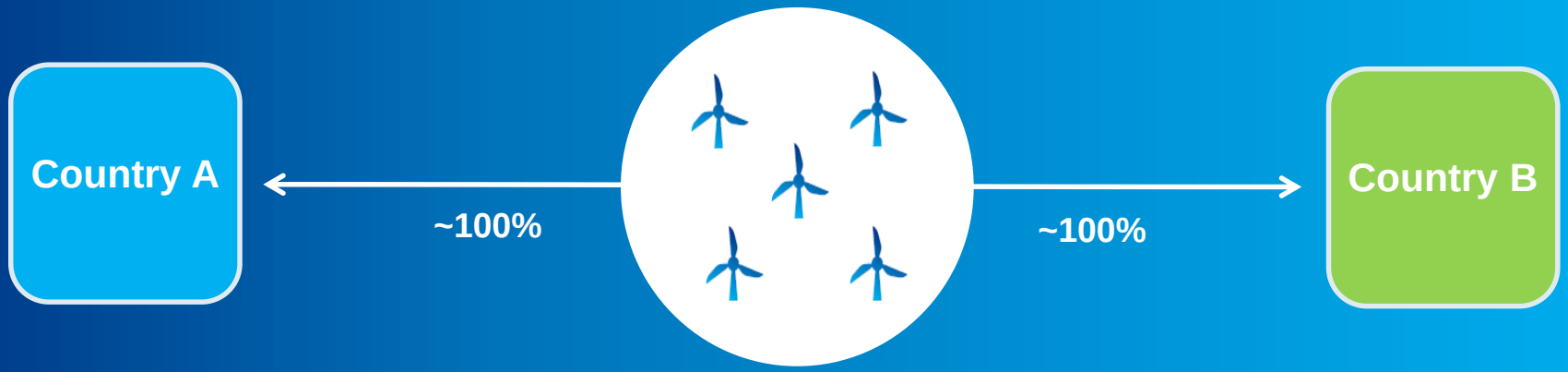
Impact of failures differs

- 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 interconectors 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

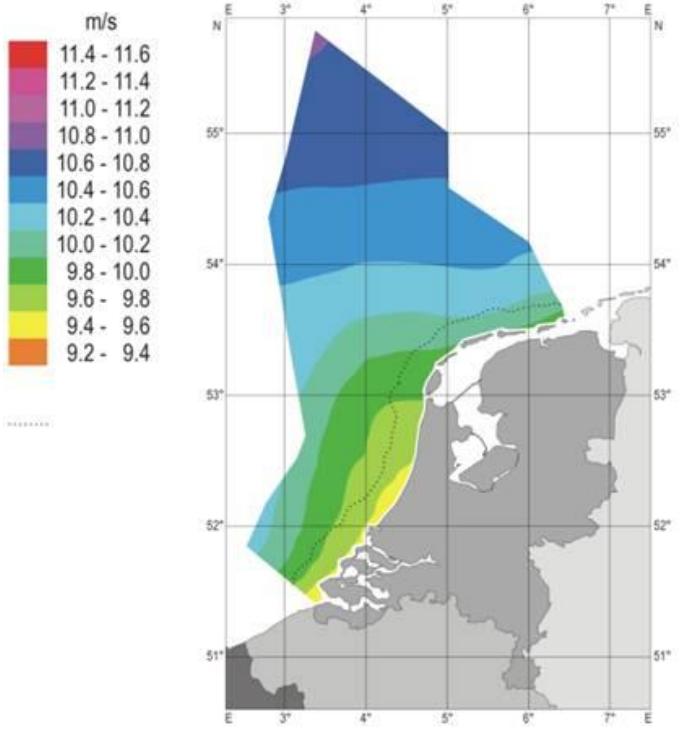
Water depth has a significant impact on the development for offshore wind. A development in shallow waters contributes significantly to cost reduction.

Wind conditions

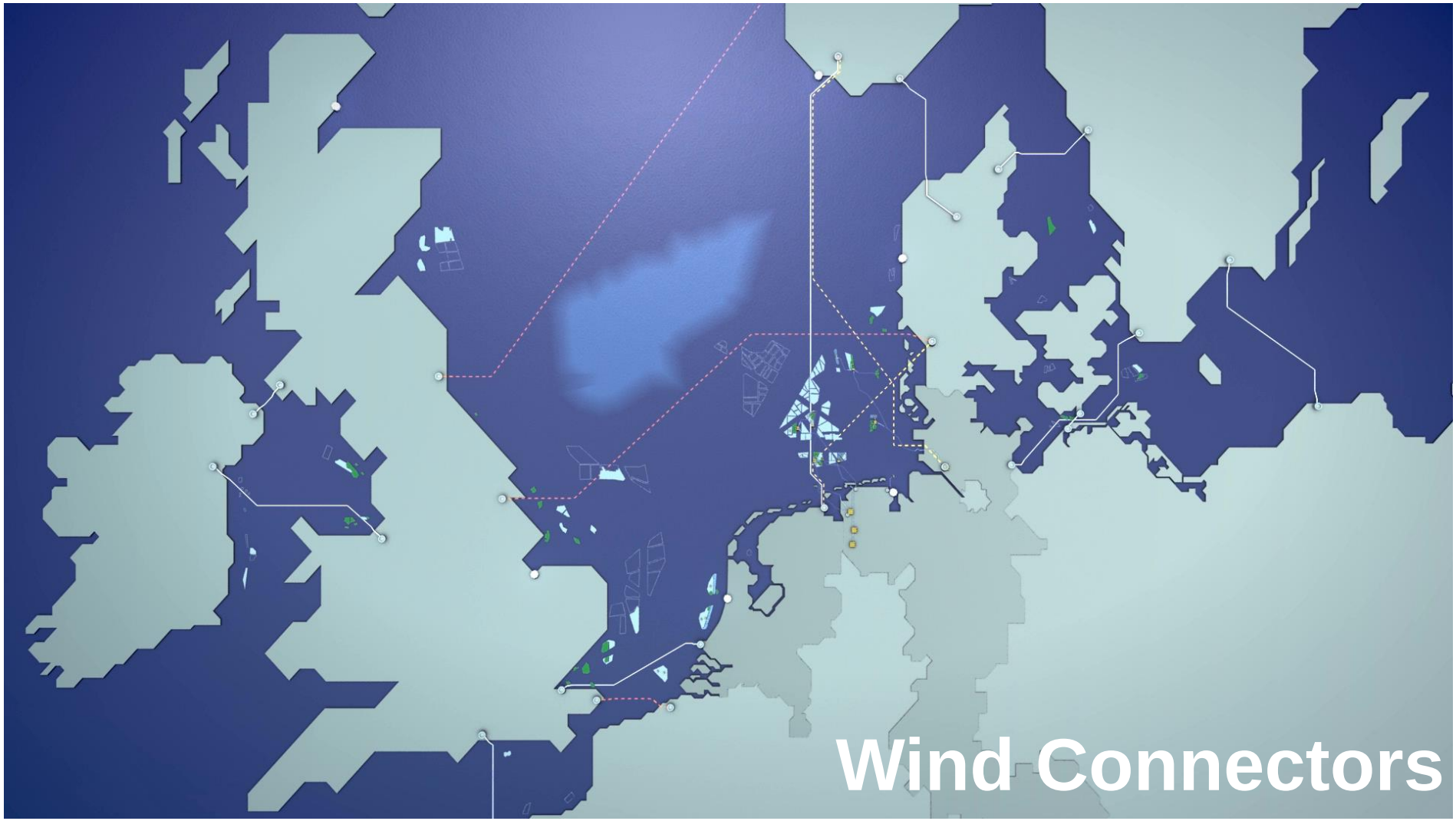
Wind conditions get better further at sea, which partially compensates the increase in cost for distance.

Central location

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



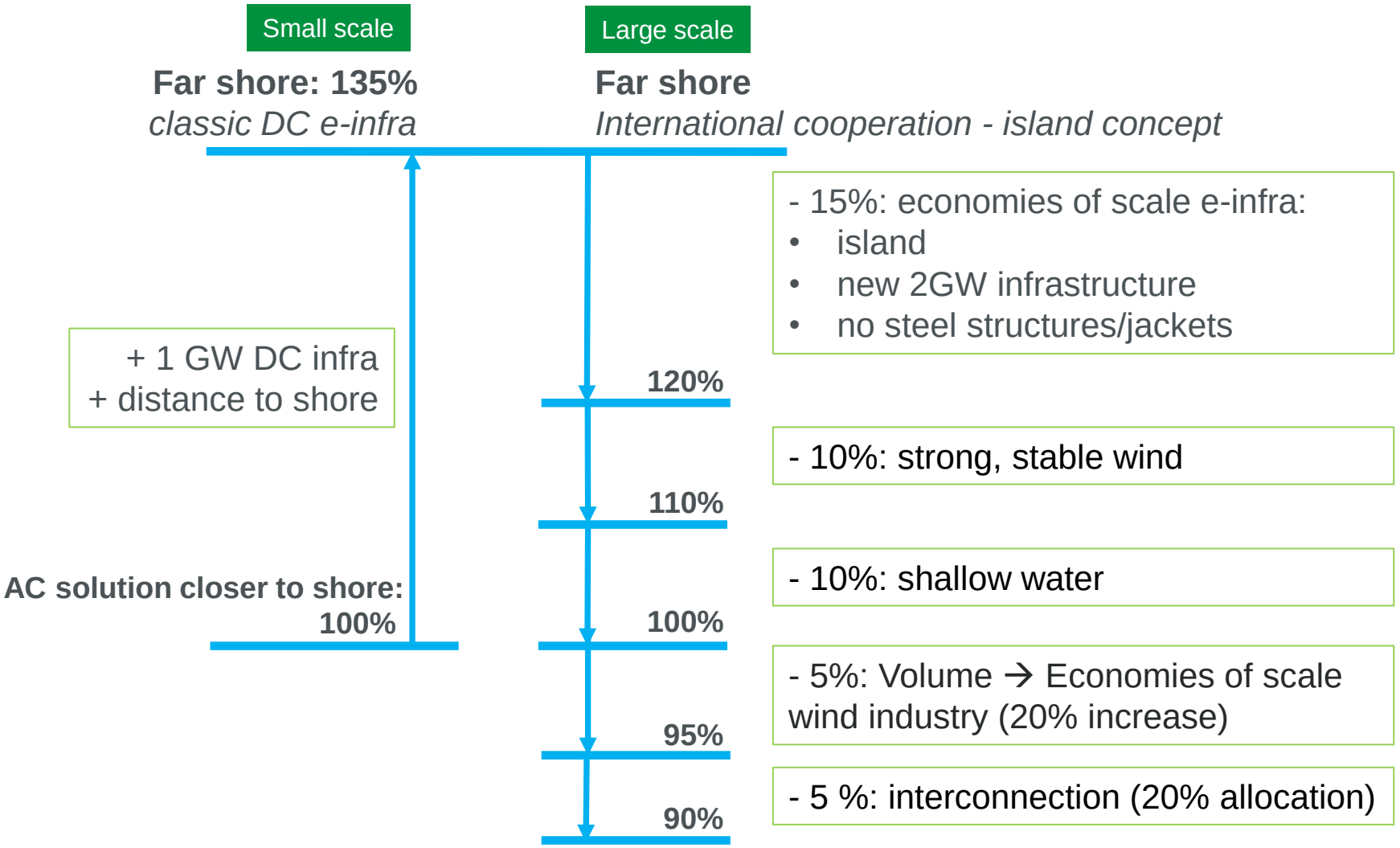
Combining wind with interconnectors



The modular island: facts & figures

- Possibly three islands: 6 km^2 each, 200 mln m^3 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 km^2
- Hard substrate: 4.4 km^2 (0.02% of total Dogger Bank surface)

Solution: scale



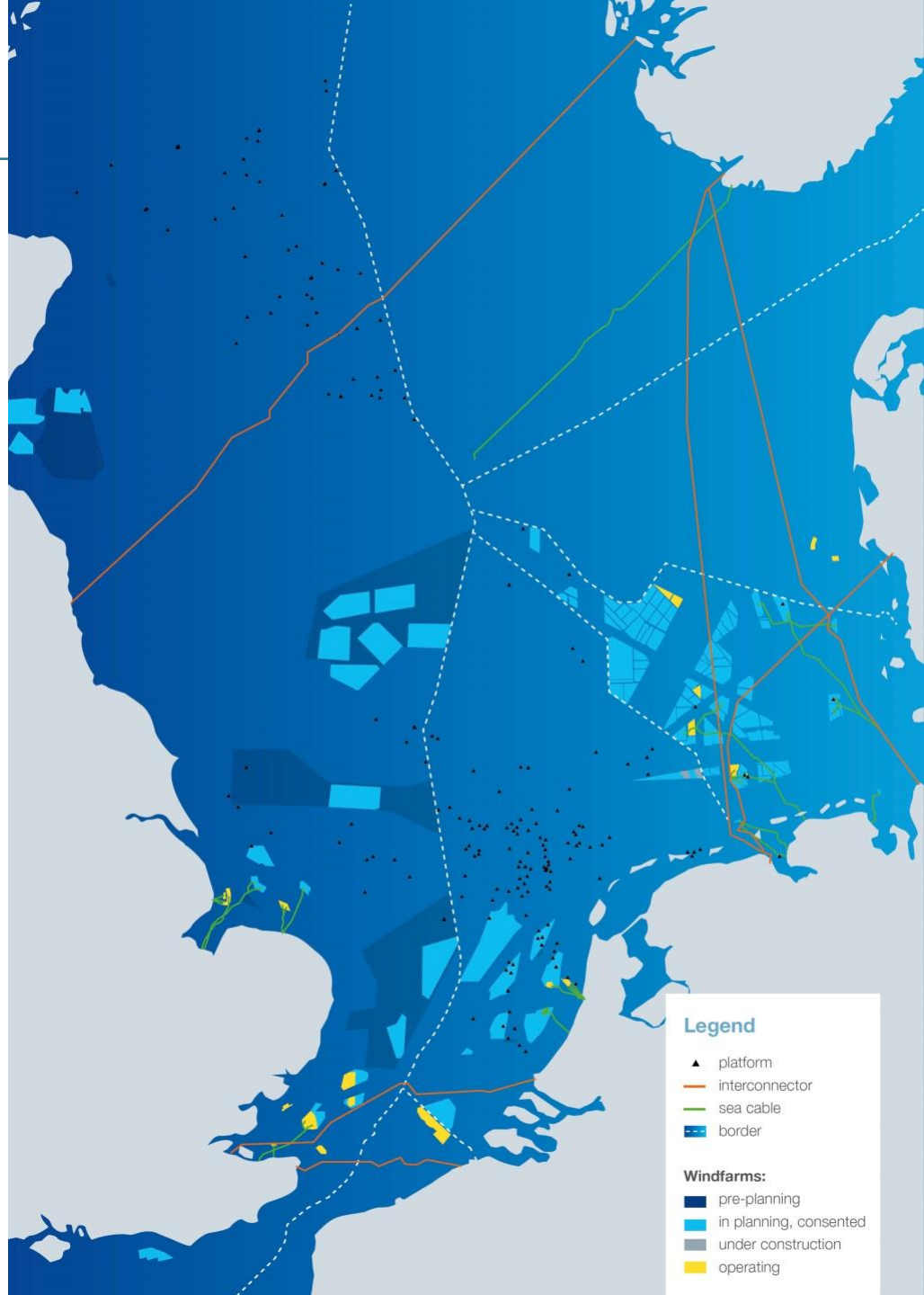
The modular island

Feasibility given a step wise approach & stakeholder views

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



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

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.



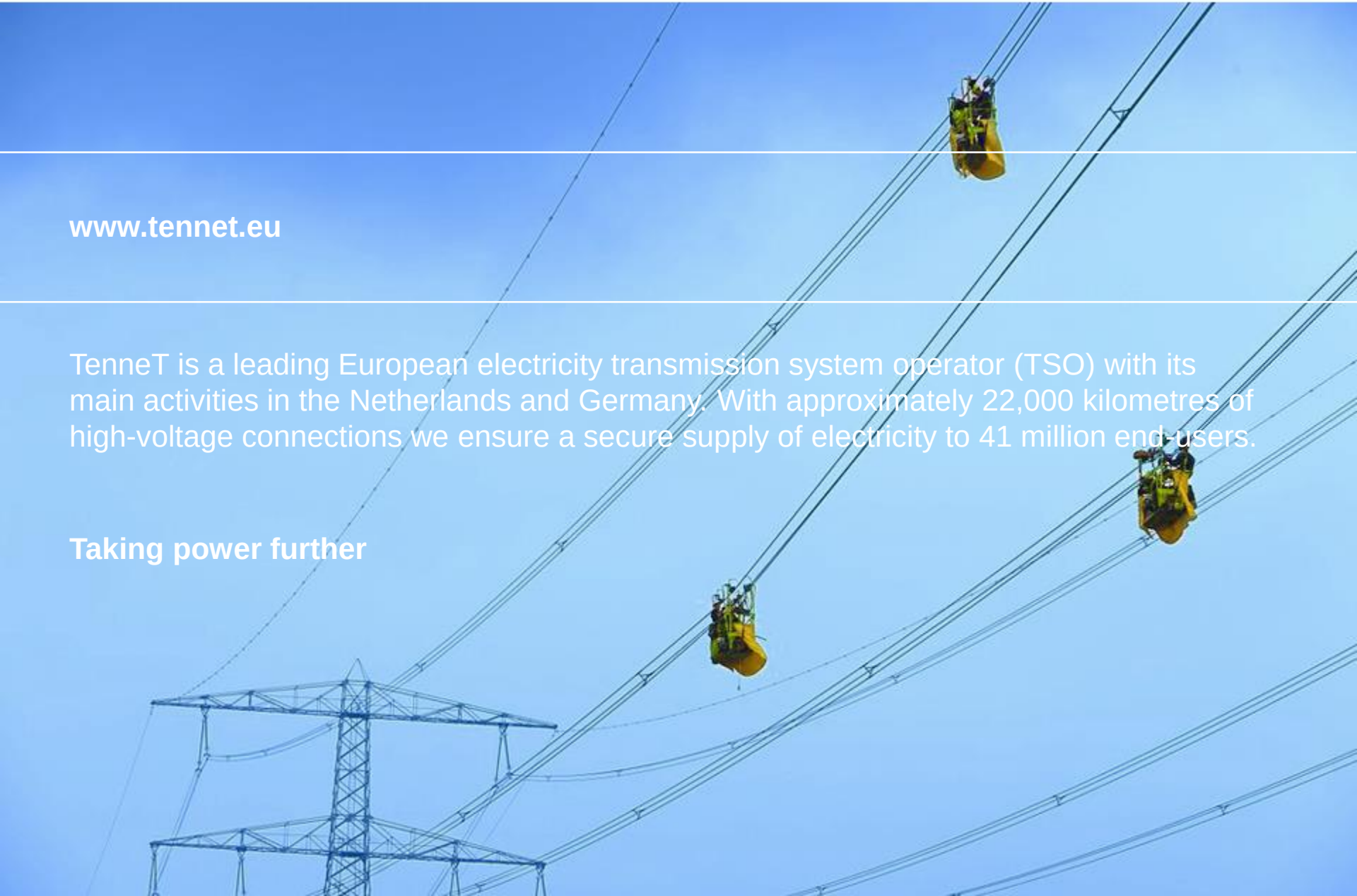

What's next?

- 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
- Invite research community and industry to come with novel ideas

Future North Sea Infrasructure

Thank you for your attention

Alan Croes
TenneT



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