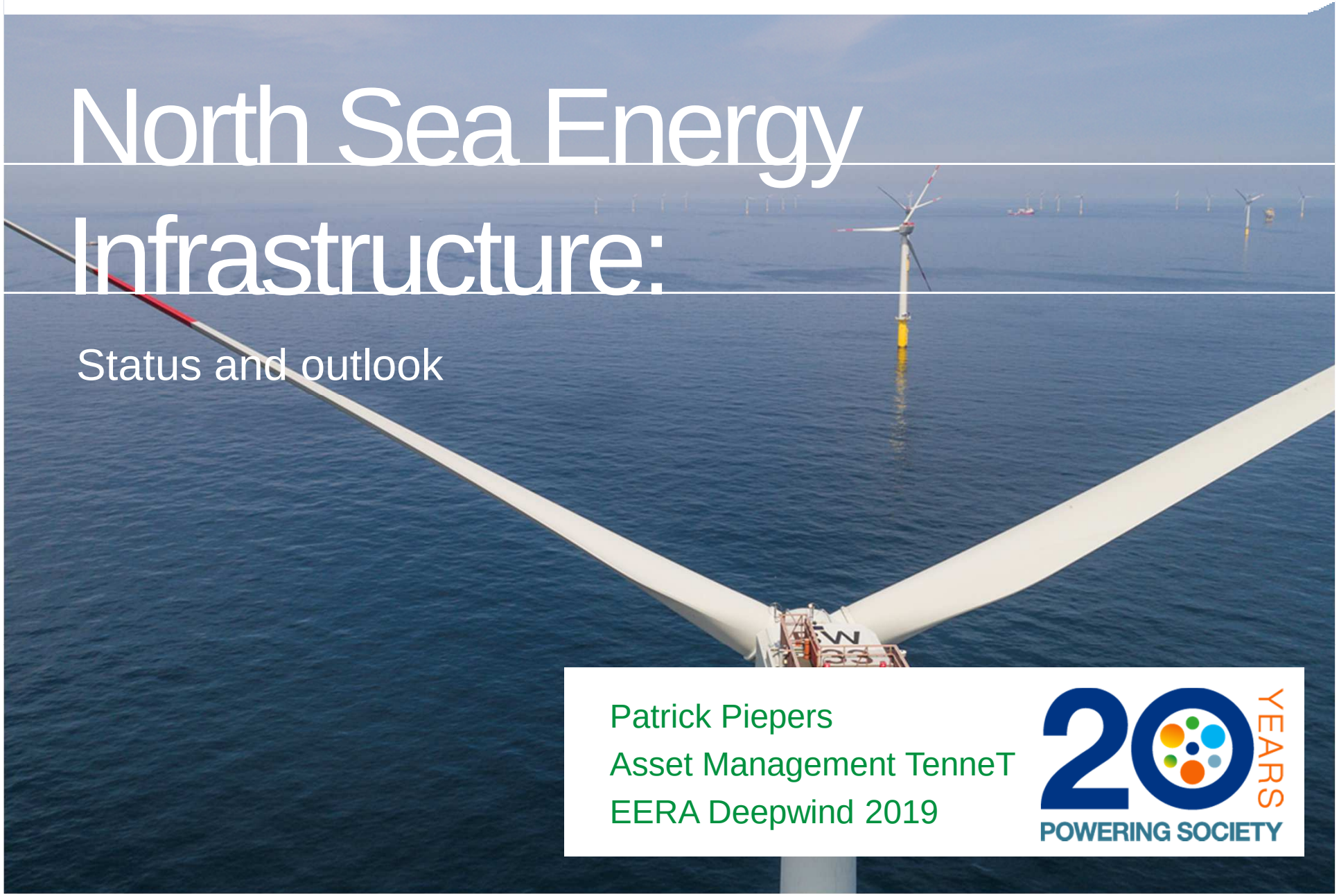
North Sea Energy Infrastructure:

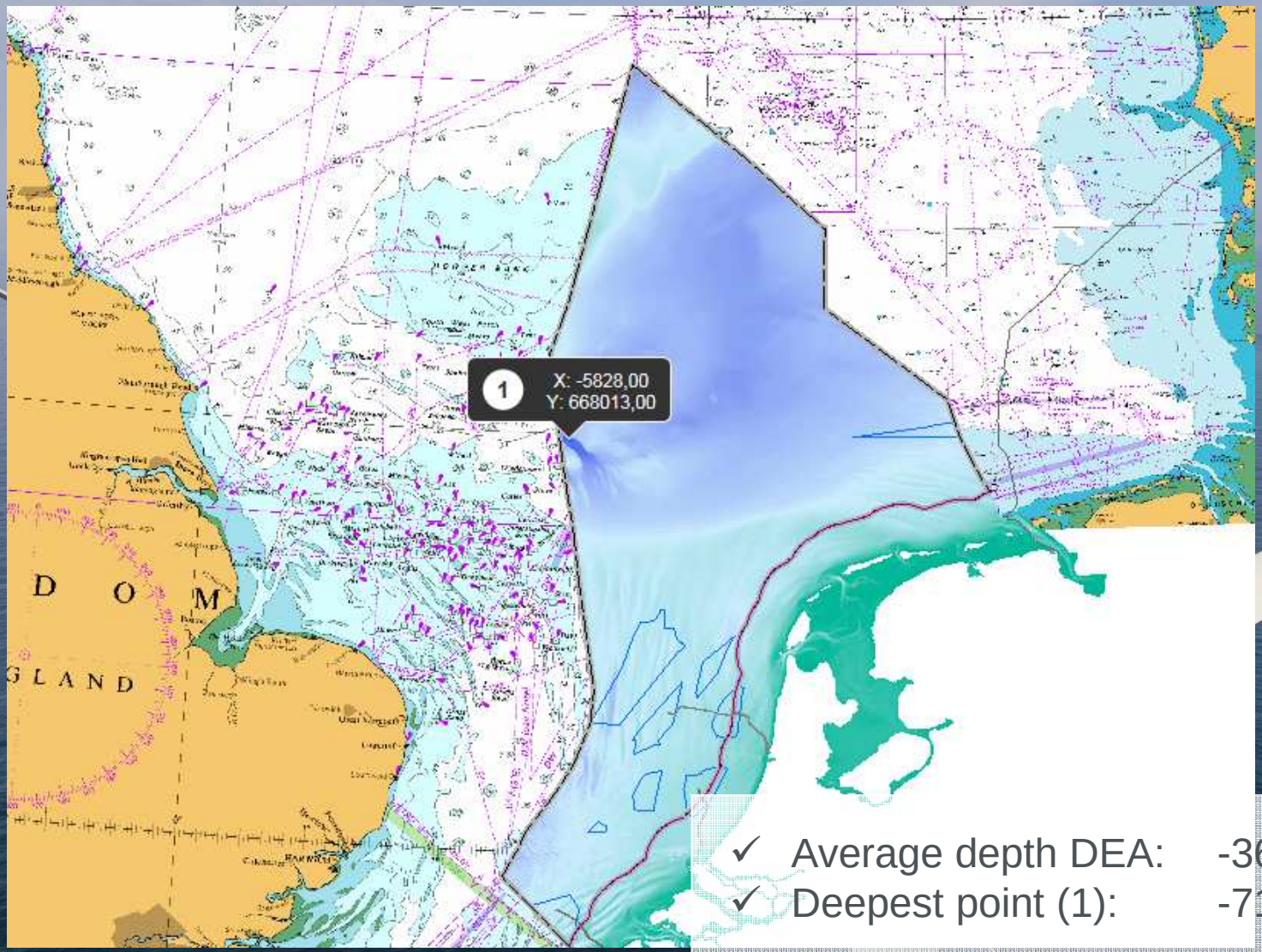
Status and outlook



Patrick Piepers
Asset Management TenneT
EERA Deepwind 2019

20 YEARS POWERING SOCIETY

Deepwind?



- ✓ Average depth DEA: -36,0m LAT
- ✓ Deepest point (1): -71,5m LAT

Strategy 2002: “strenghten and build”

- ✓ One strong, independent transmission grid
- ✓ Expansion cross border connections
- ✓ One cross border high voltage grid
- ✓ Strenghten the Dutch electricity grid

A leading TSO in Europe

	2002	2017	
Asset base (€ bn)	1	**20.4**	X 20
Staff	276	**4,068**	X 15
Connections (km)	2,686	**22,500**	X 8
Offshore connections (km)	0	**4,700**	
Offshore platforms	0	**12**	

Investments (10Y): € 28 bn

Strong development offshore wind

COP21 : radical change in electricity generation mix

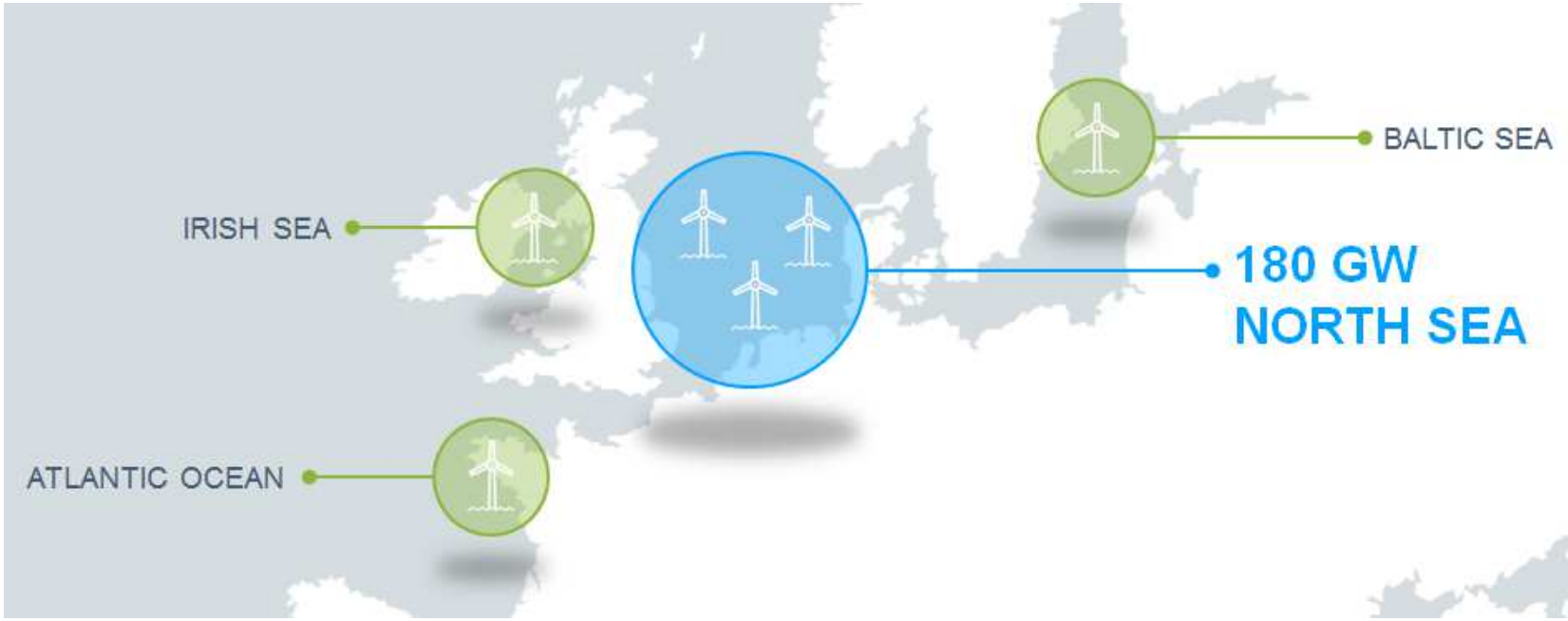
- **230** GW offshore wind capacity, **180** GW to be developed in the North Sea in 2050

WindEurope forecast

- **70** GW offshore wind capacity in the North Sea in 2030

PBL forecast

- **60** GW offshore wind capacity in the Dutch part of the North Sea in 2050



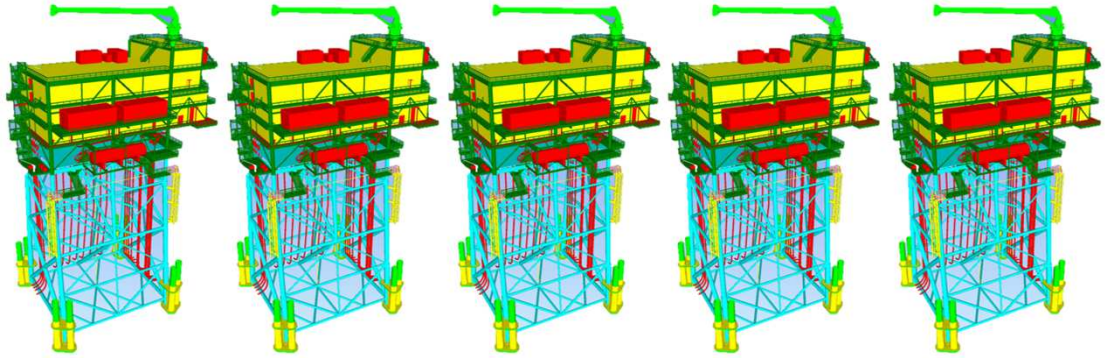
NL: Phase I: 2019 – 2023 (+3.5 GW)

- 3,500 MW: 5 x 700 MW
- Standardized concept
- AC connections

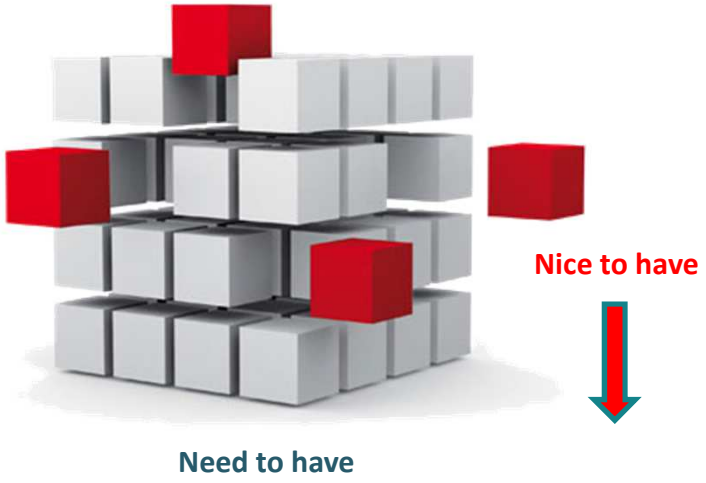
Year	Capacity	Area
2019	700 MW	Borssele
2020	700 MW	Borssele
2021	700 MW	Hollandse Kust (zuid)
2022	700 MW	Hollandse Kust (zuid)
2023	700 MW	Hollandse Kust (noord)

700MW AC Substations, focus

- **Standardization**
  - Layout
  - Functionality
  - Operation
  - However some freedom for contractor (EPC contract)



- **Lean Design**
  - Unmanned
  - No helideck
  - No seawater
  - No diesel generator
  - Simple HVA/C

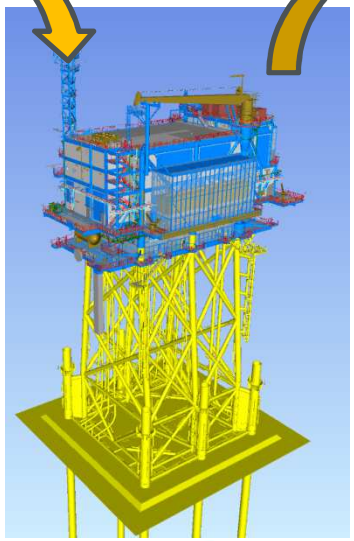


700MW AC Substations, focus

- **Lessons learned**

RAMBØLL

Borssele



Iv-Oil & Gas

HKZ

Petrofac

HKN

Tender started Q3 2018

Significant cost reduction due to standardization

(Engineering, Risk profile, Project management, Efficiency, …).

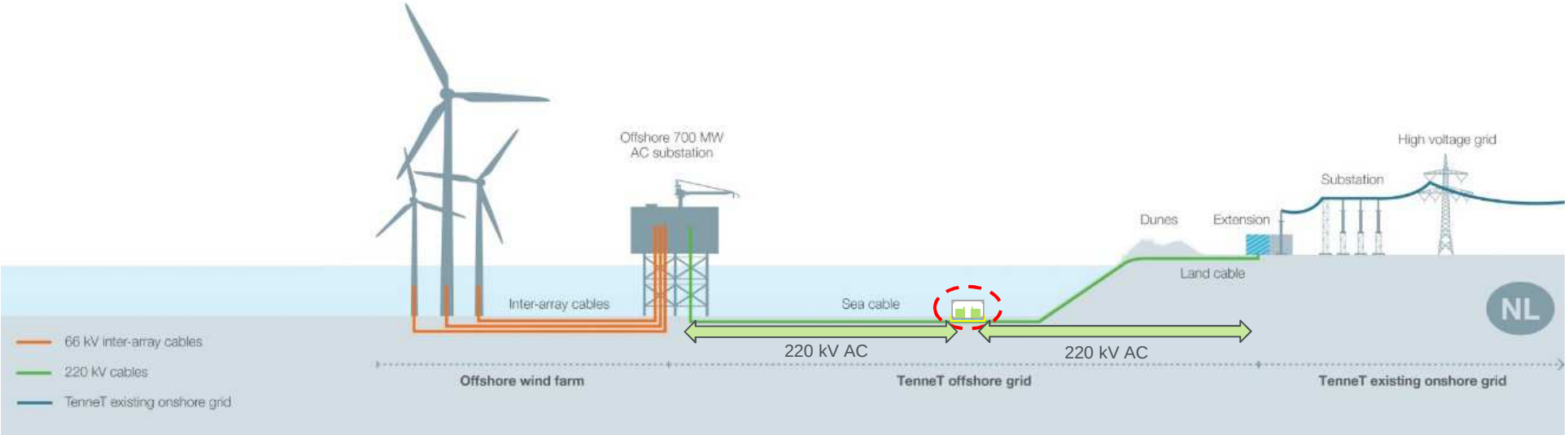
700MW AC Substations, innovation

Subhydro AS

SINTEF Energi

SINTEF Ocean

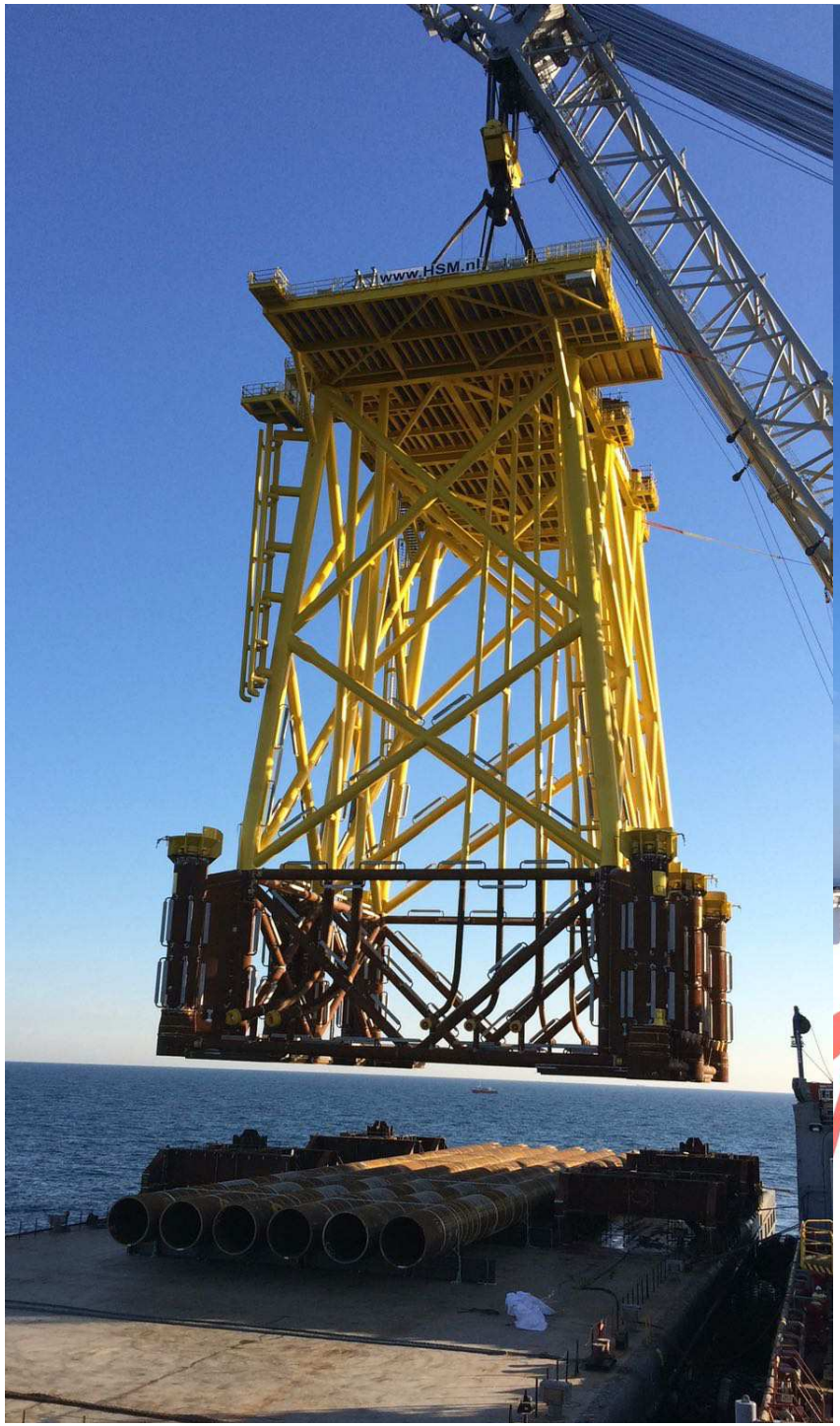
SINTEF Byggforsk

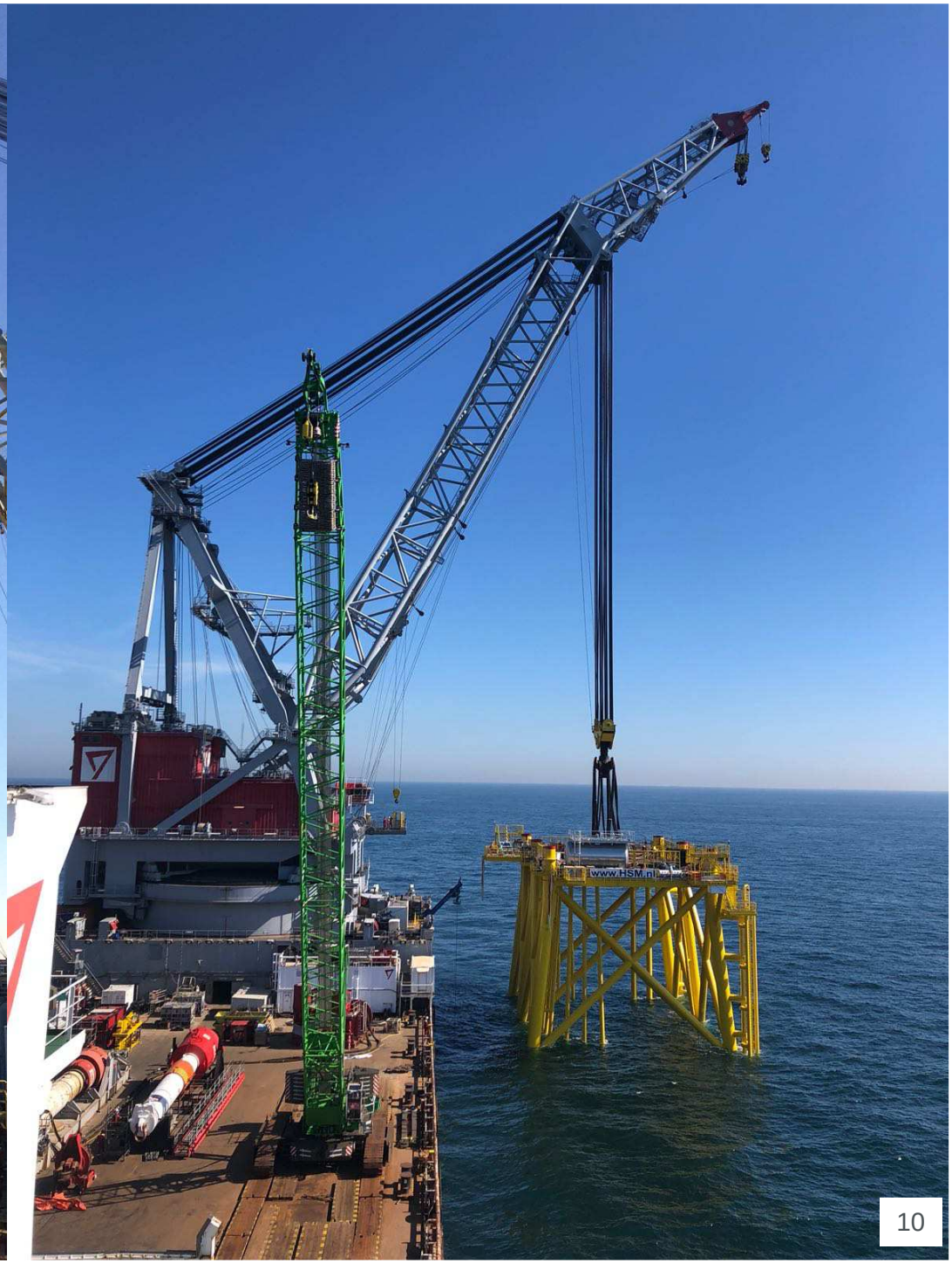


AC technology limited due to increasing reactive power in longer cables.

Intermediate compensation feasible but costly

Possible cost reduction due to subsea intermediate compensation

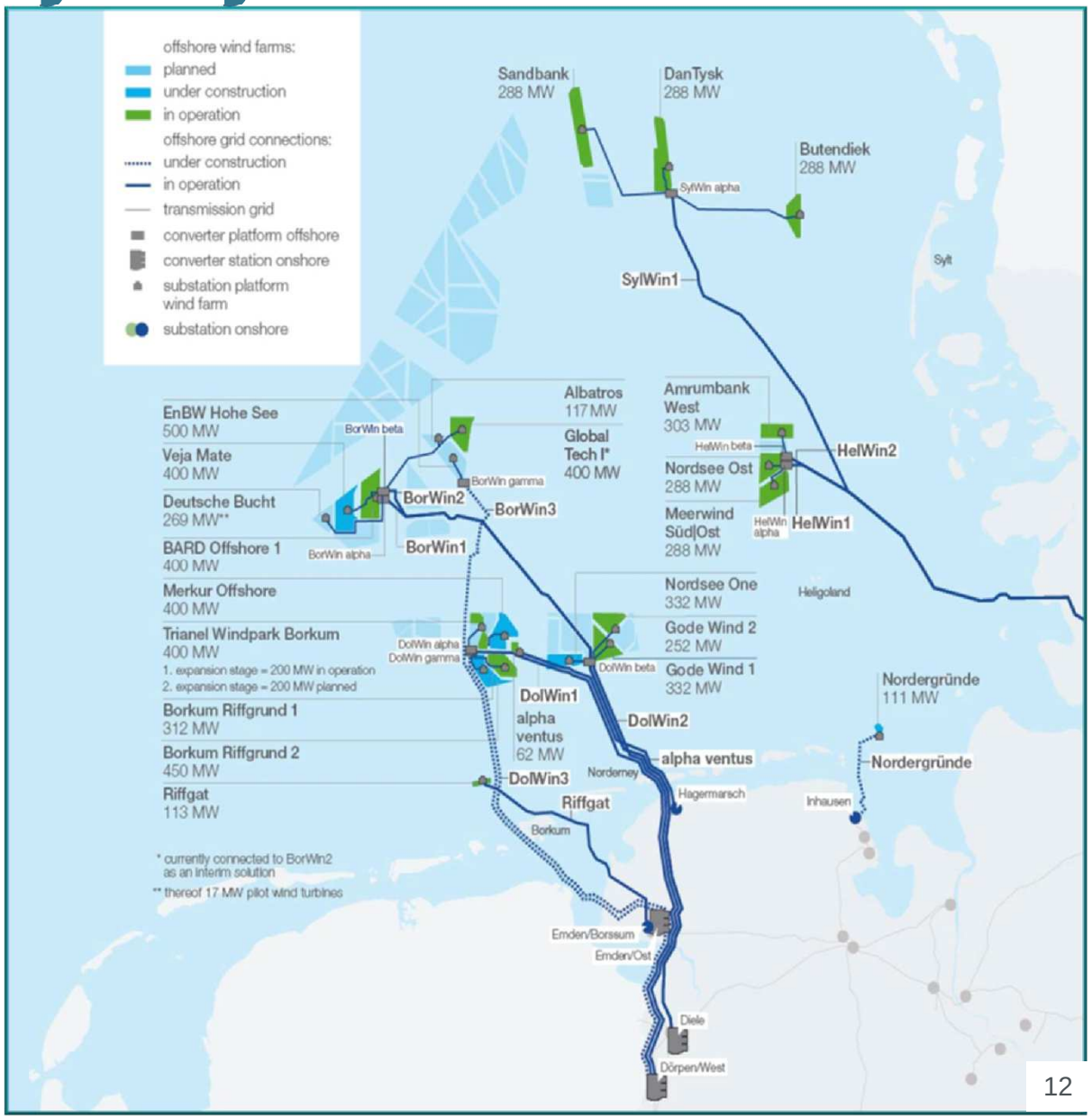

www.HSM.nl


www.HSM.nl


www.HSM.nl

GE: Untill 2025 yearly 900MW HVDC

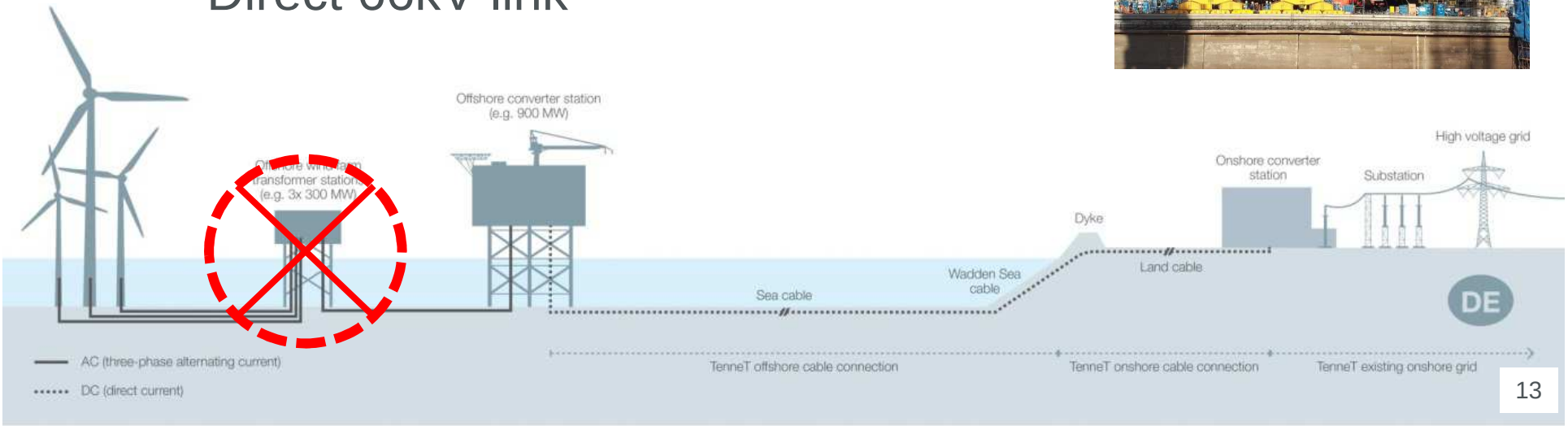
Year	Capacity	Project
Operational		
2009	62	alpha ventus
2010	400	BorWin1
2015	800	BorWin2
2015	800	DolWin1
2016	916	DolWin2
2015	576	HelWin1
2015	690	HelWin2
2014	113	Riffgat
2015	864	SylWin1
2017	111	Nordergründe
Under construction		
2019	900	BorWin3
2018	900	DolWin3
2023	900	DolWin6
To be built		
2023	900	DolWin5
2024	900	BorWin5
2025	?	BorWin6



900MW HVDC, focus

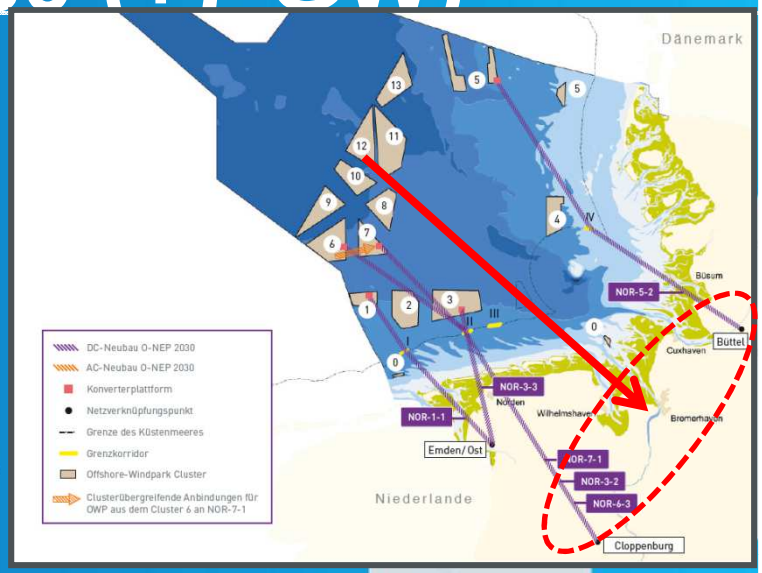
- **Existing Platforms ➔ OPEX reduction**
  - Long term unmanned
  - New logistic concepts

- **New Platforms ➔ CAPEX reduction**
  - Lean design
  - Standardization
  - Direct 66kV link

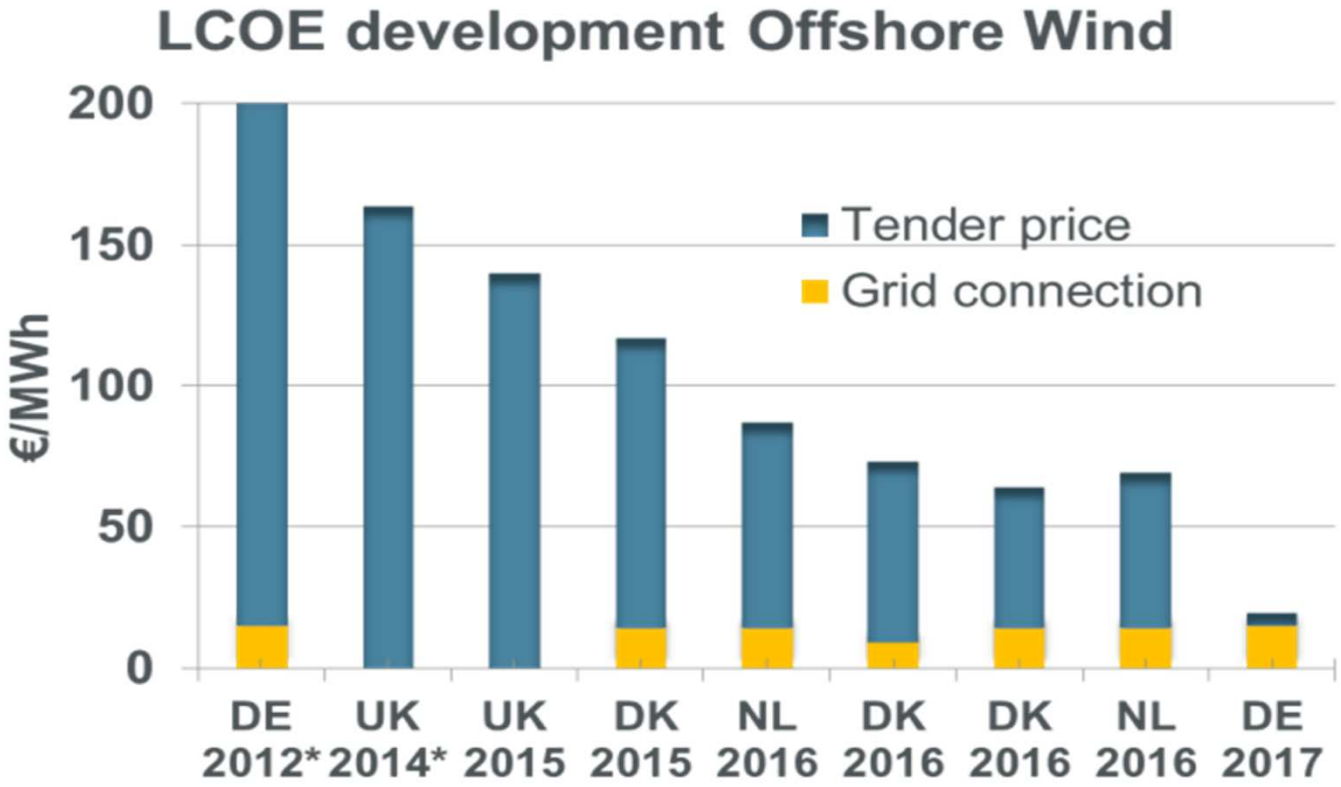


NL: Phase II: 2024 – 2030 (+7 GW)

Year	Wind Area	Power
2024	HKWest Alpha	700 MW HVAC
2025	HKWest Beta	700 MW HVAC
2026	Ten Noorden van de Waddeneilanden	700 MW HVAC
2027-2030	IJmuiden Ver	4000 MW HVDC
2027-2030	?	900 MW



Challenge: Cost



- **Limited cost reduction in grid connections.**
- **Longer offshore connections lead to increase in cost**

Large HVDC connections (1,2-2GW)

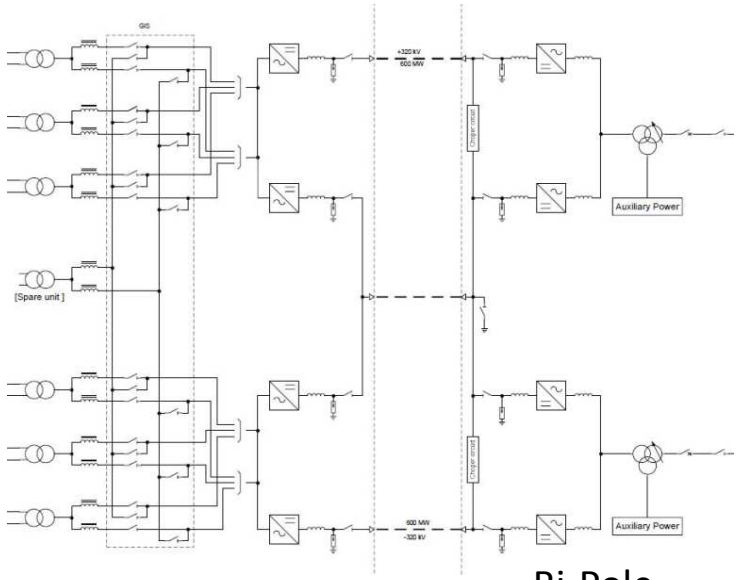
- Grid quality (HVAC cables result in deteriorating grid quality)
- More cost effective then HVAC
- Less cables (Ecology & Stakeholder)

Netherlands aim ➔ 2GW (525kV)

Requires market adaptations to ensure system reserve

Germany ➔ limited by 2K criteria (Cable temperature)

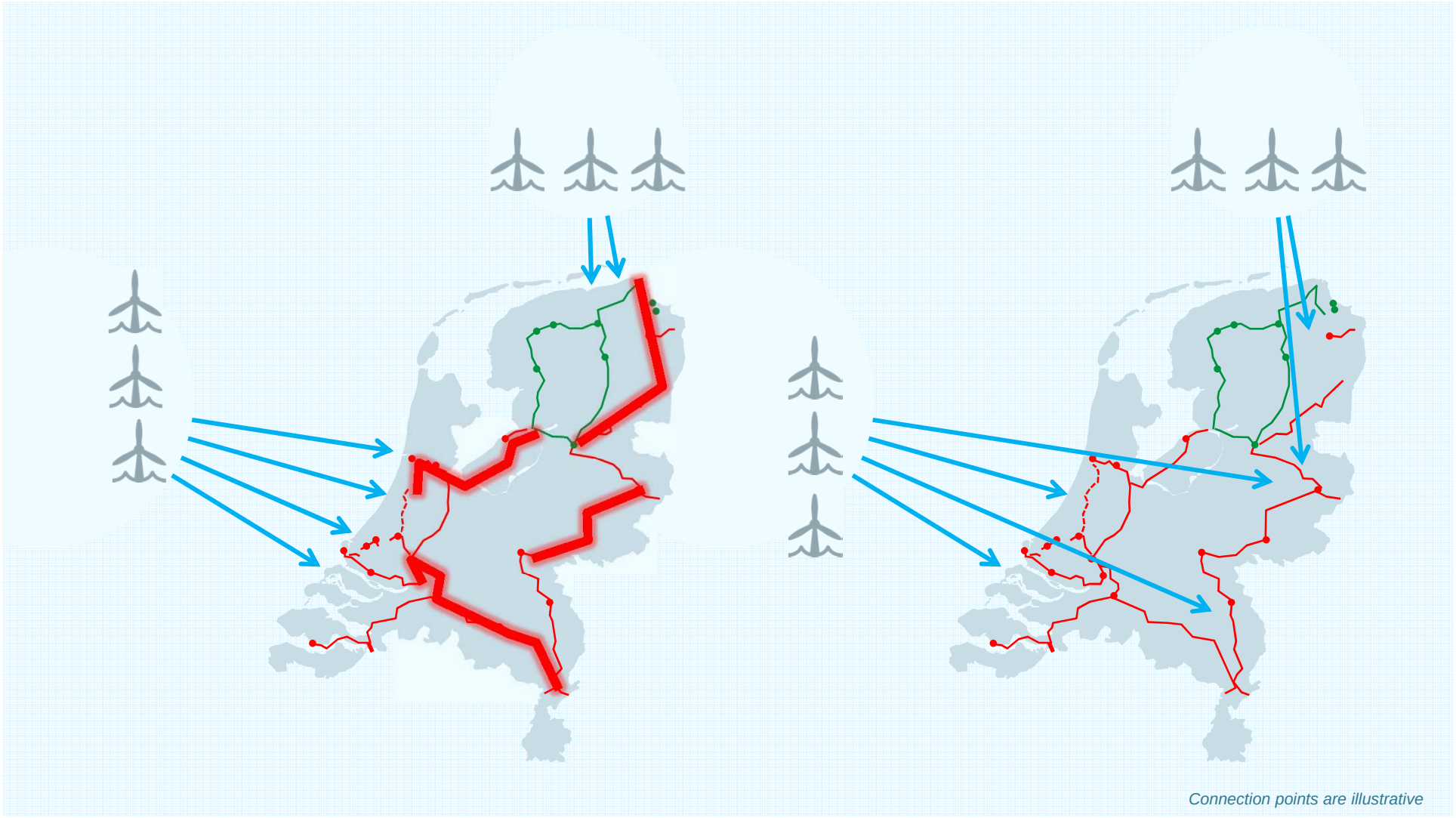
Large HVDC connections (1.2-2GW)



Bi-Pole

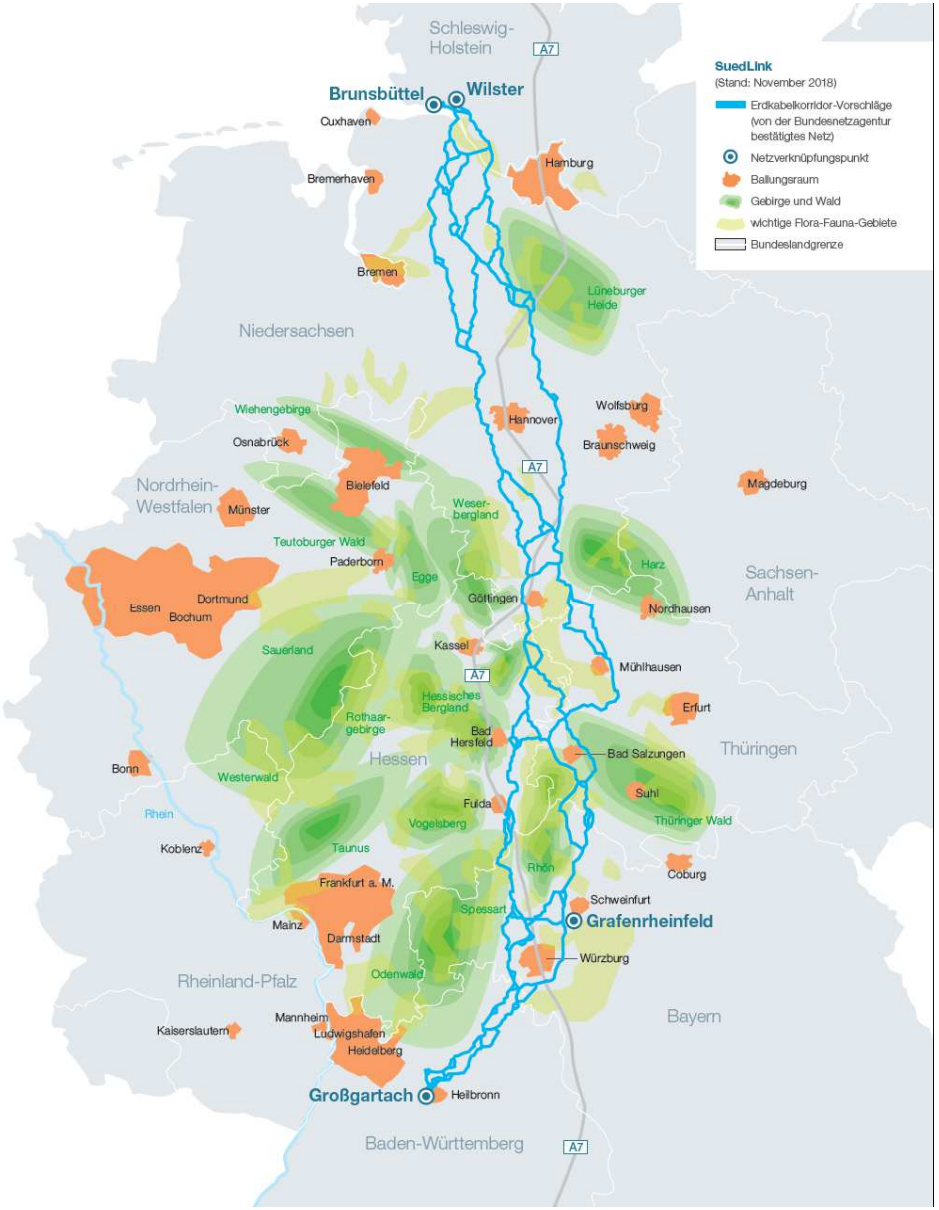
- 2GW
- 525kV
- Bi-Pole
- Double converter rooms
- ≥6 transformers

NL challenge: Onshore connections

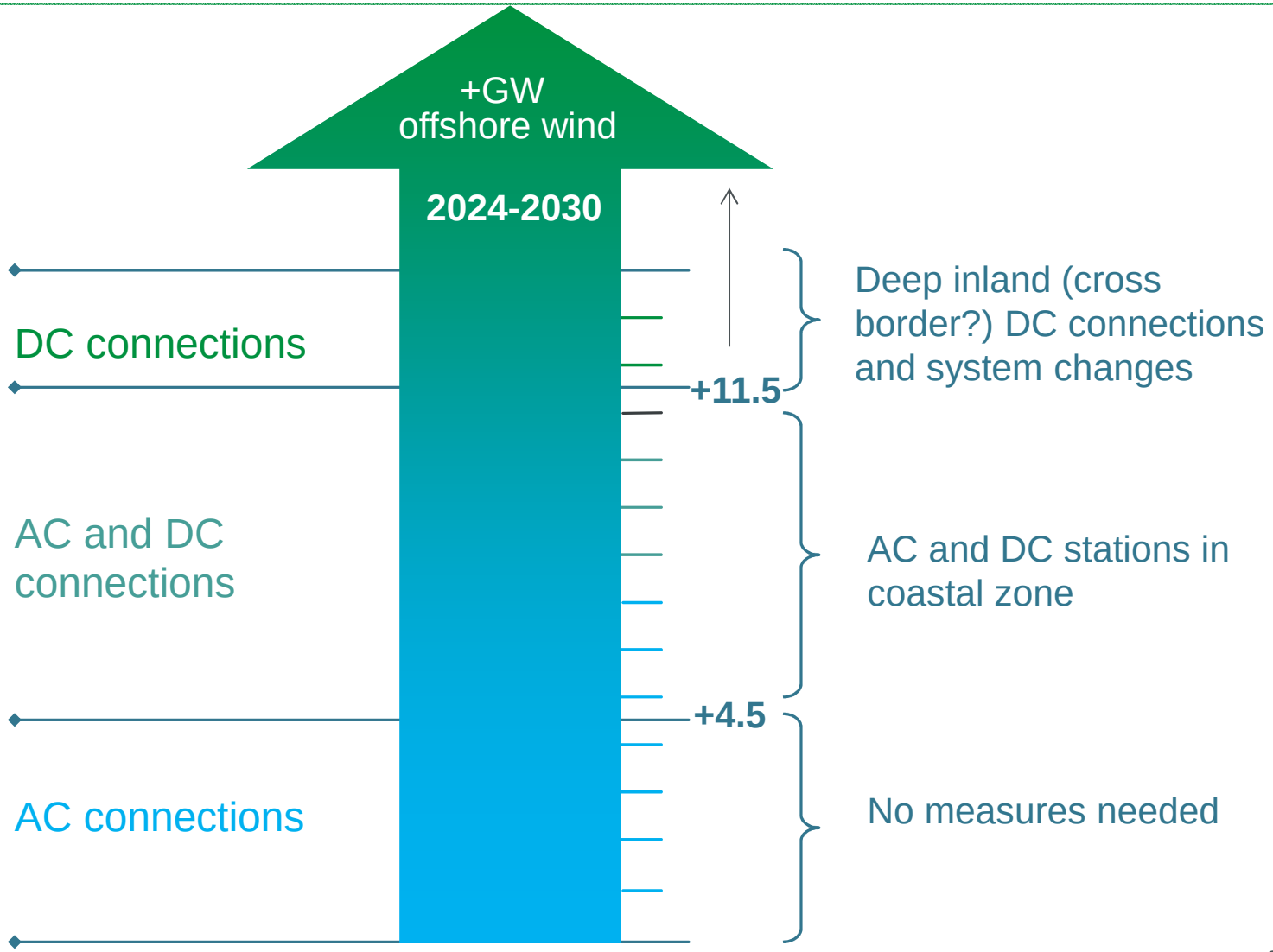


Connecting >7 GW directly to shore results in significant congestion

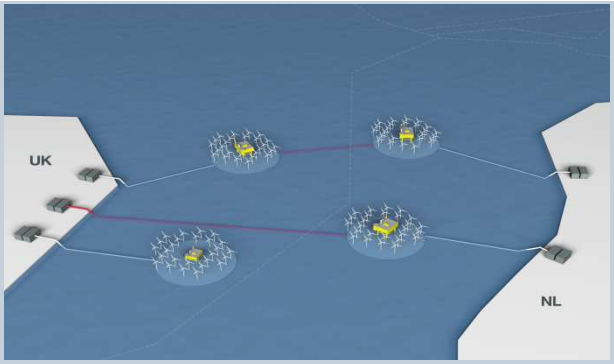
GE challenge: Onshore connections



Conclusion: grid analysis 2024 - 2030



Future development will need innovation



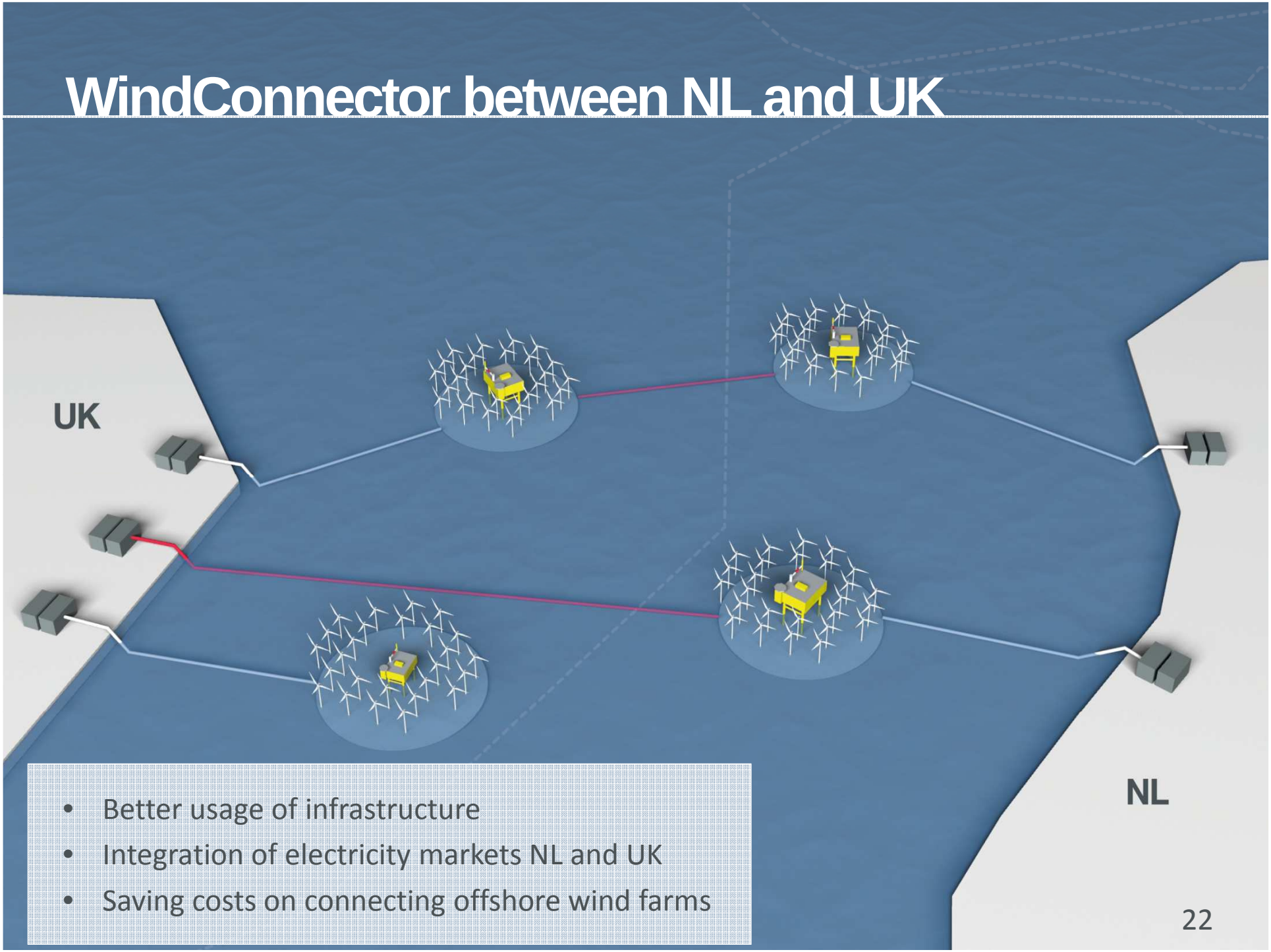
WindConnector

Connection of oil&gas platforms

Island soiutions

More offshore wind

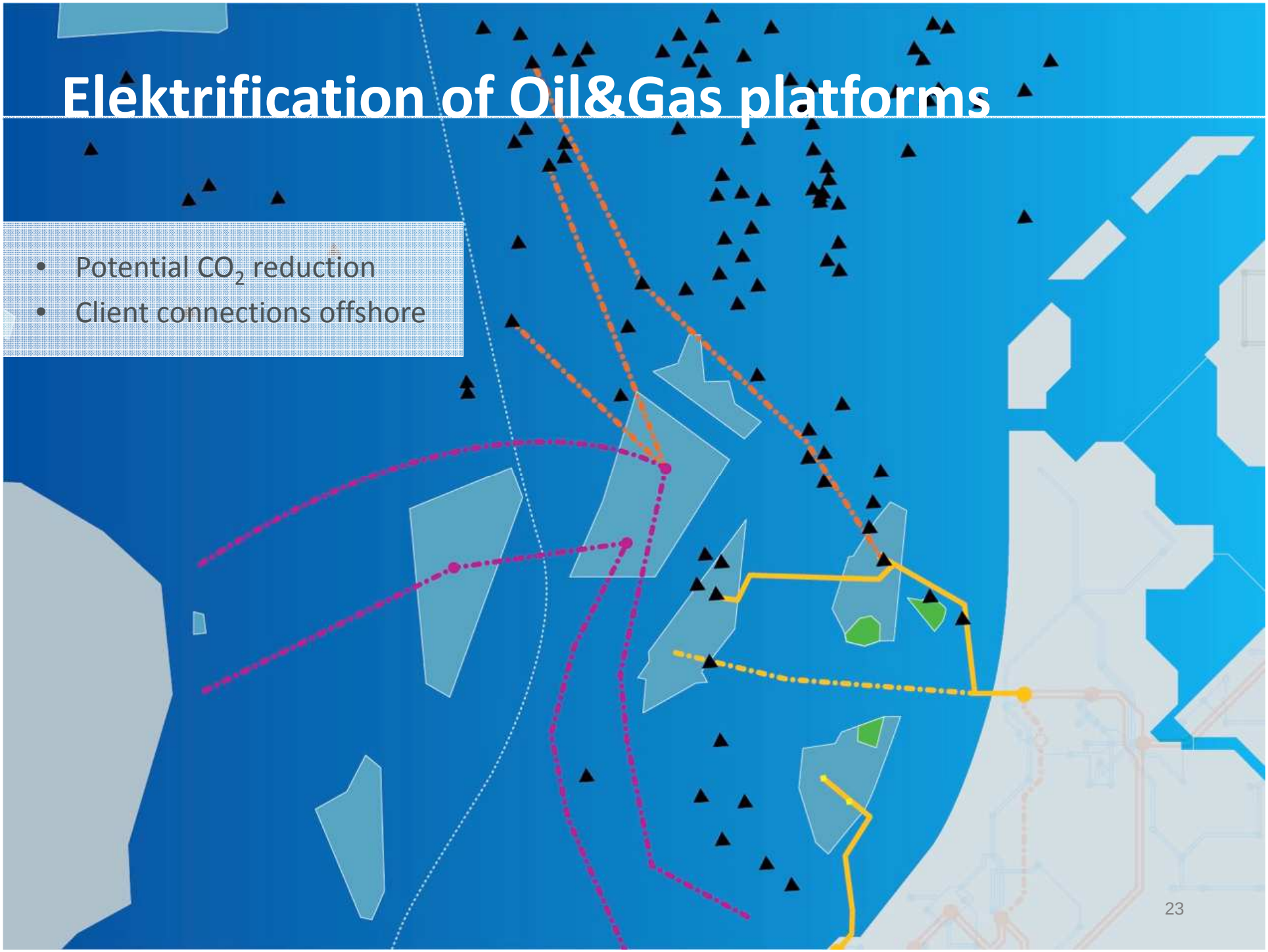
WindConnector between NL and UK



- Better usage of infrastructure
- Integration of electricity markets NL and UK
- Saving costs on connecting offshore wind farms

Elektrification of Oil&Gas platforms

- Potential CO_2 reduction
- Client connections offshore



Cost optimization: jacket or island?

Artificial island as hub for DC offshore infrastructure

Phase III: 2030 – 2050

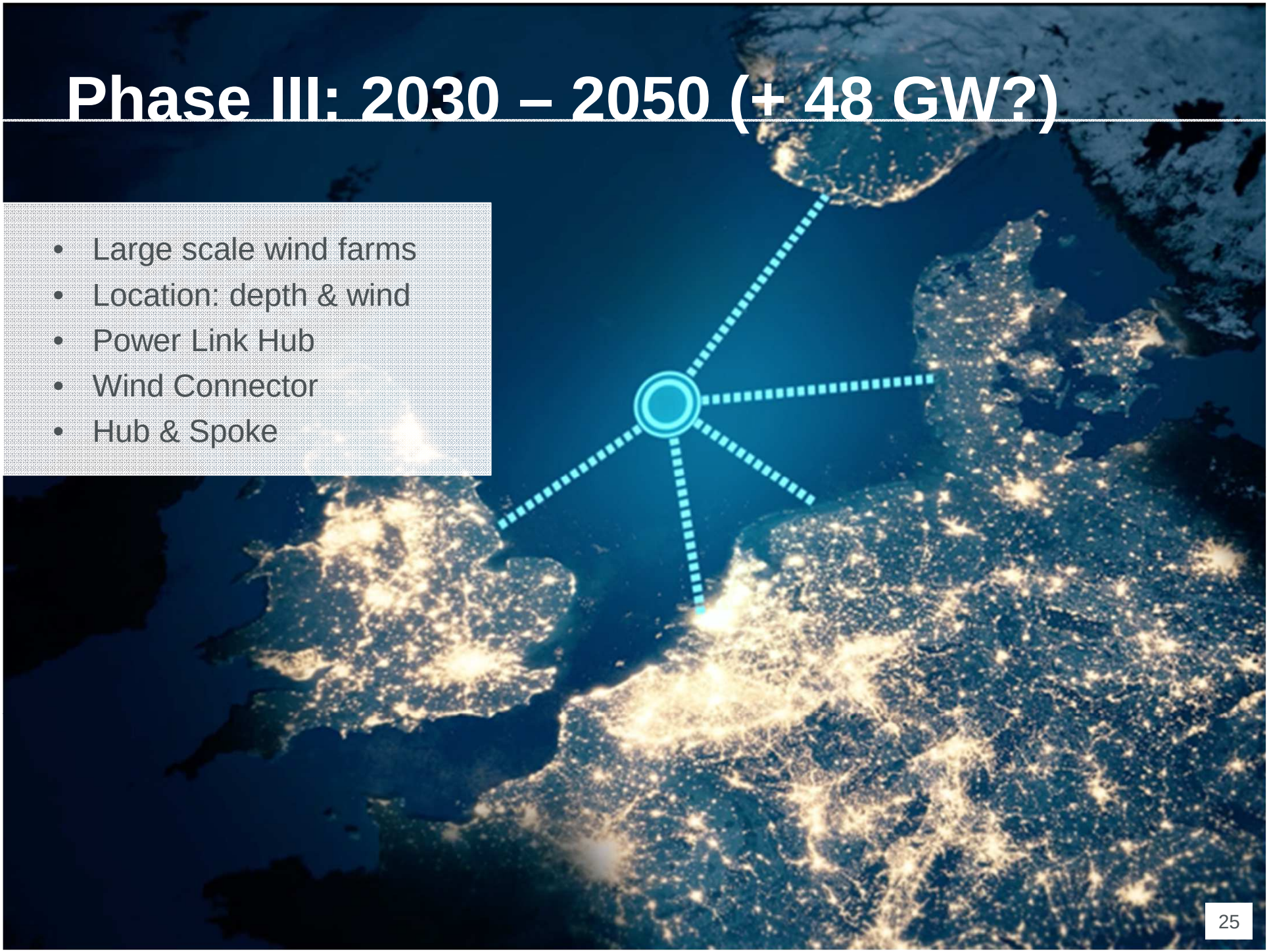
For large scale offshore wind everything is needed

- One international offshore grid
- System integration
- Power to Gas
- Storage
- Electrification of Industry & Transport
- Interconnection
- Most of all: clarity on the way forward!

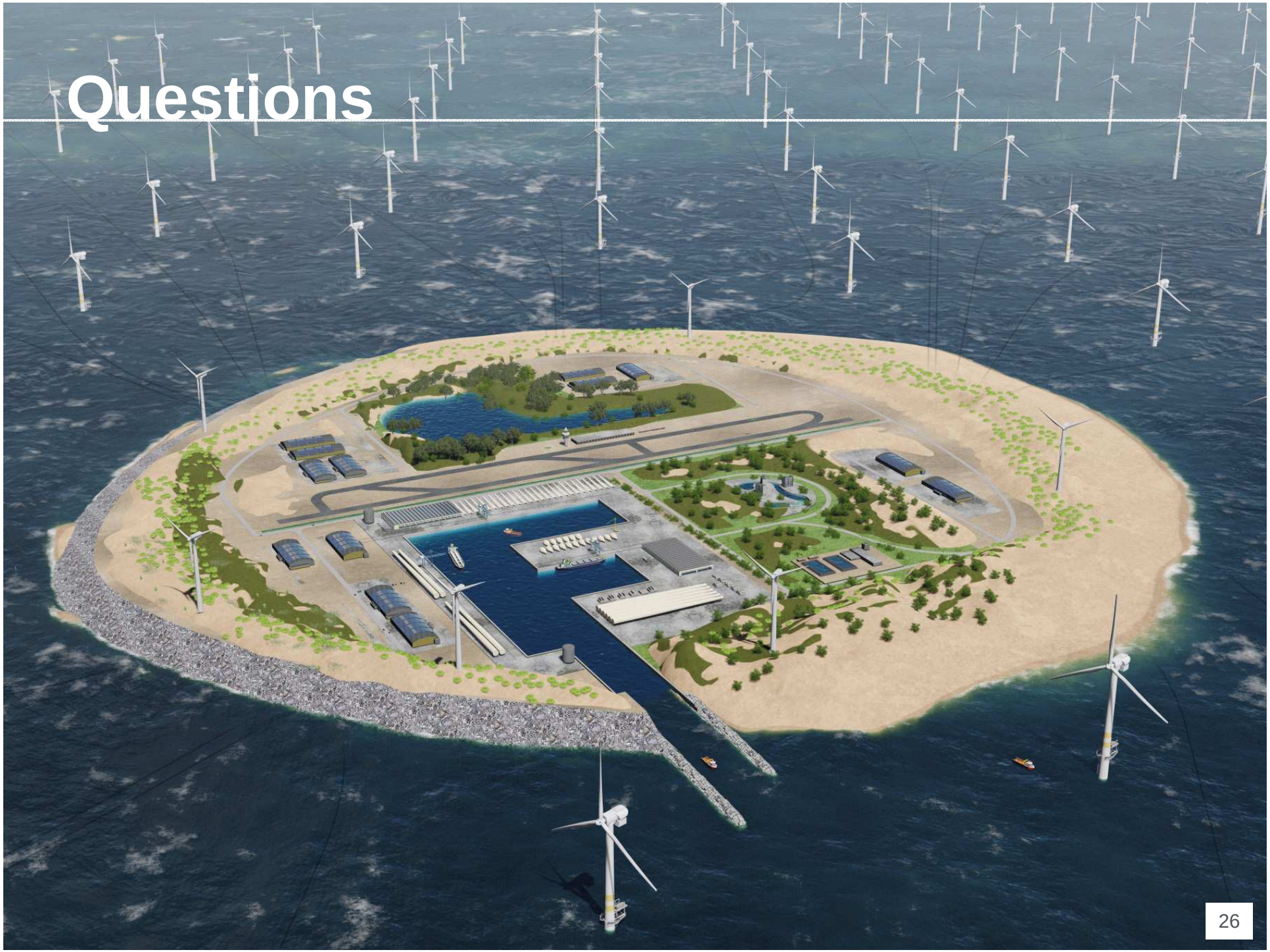
Think Big!

Phase III: 2030 – 2050 (+ 48 GW?)

- Large scale wind farms
- Location: depth & wind
- Power Link Hub
- Wind Connector
- Hub & Spoke



Questions



www.tennet.eu

TenneT is a leading European electricity transmission system operator (TSO) with its main activities in the Netherlands and Germany. With approximately 22,500 kilometres of high-voltage connections we ensure a secure supply of electricity to 41 million end-users.

Taking power further

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