Future North Sea Wind Power Hub

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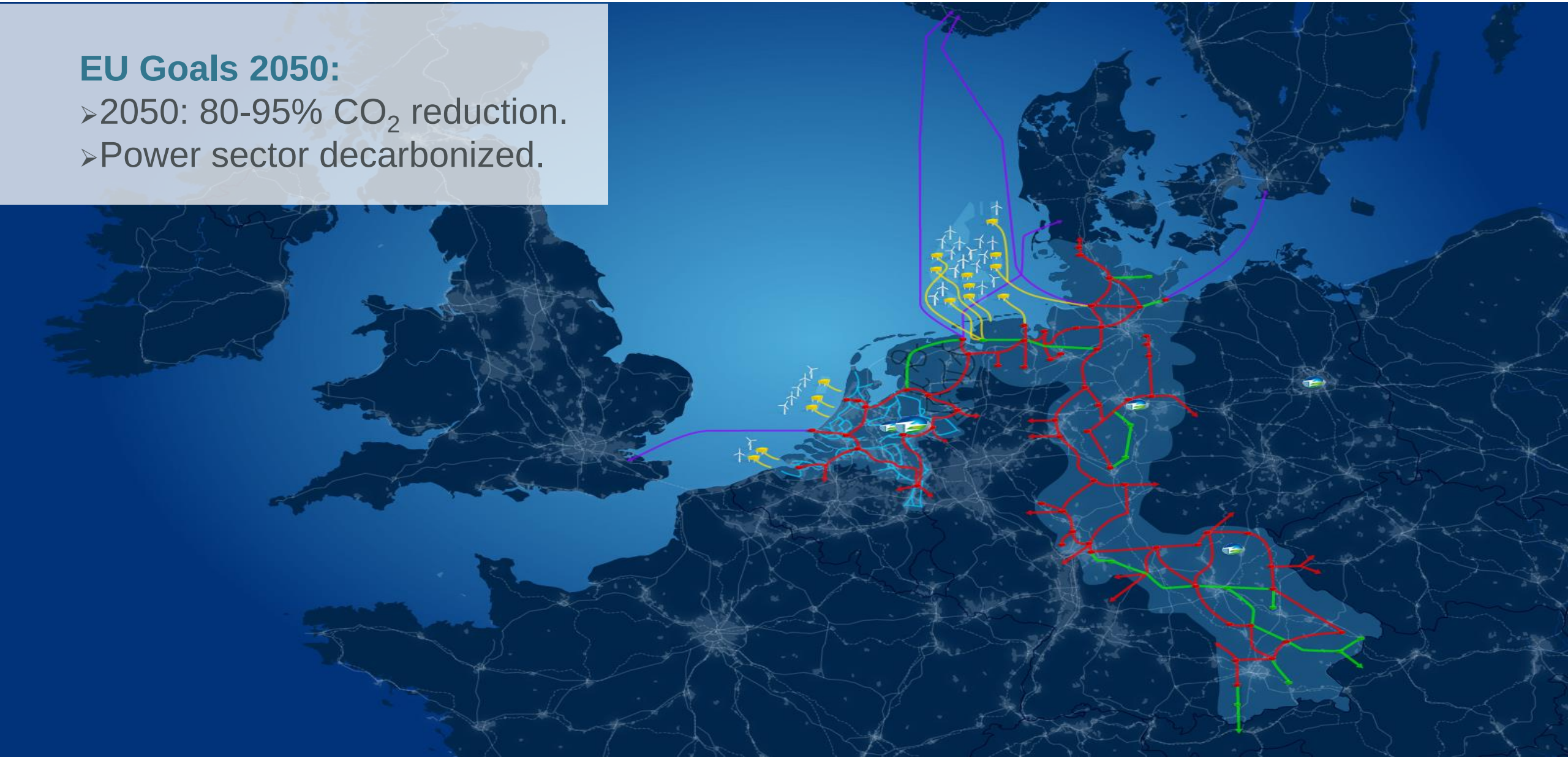
- Intro/background. Why
- Wind connection concepts
- ICRO concepts and cost savings
- Island concepts
- Conclusions

The European energy transition

EU Goals 2050:

- 2050: 80-95% CO_2 reduction.
- Power sector decarbonized.



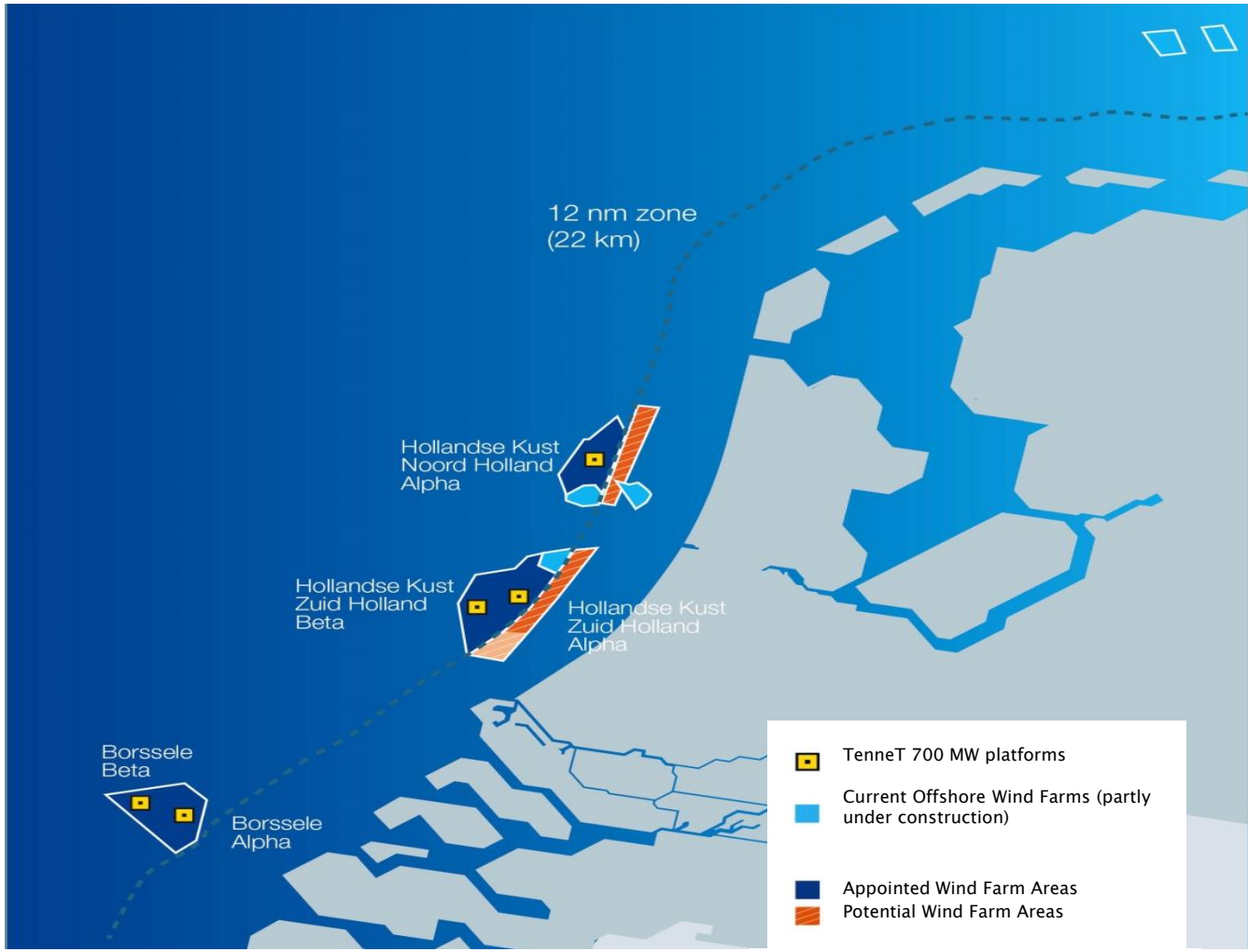
TenneT offshore Germany

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 → **3,5 GW**
- 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)



By 2023 TenneT will have realised **10.6 GW** of offshore wind connection capacity and **3.8 GW** for interconnectors

Huge amounts of offshore wind for North Sea Countries

COP21 agreements imply a radical change in electricity generation mix for the North Seas countries

Assumptions 2045 study[1]

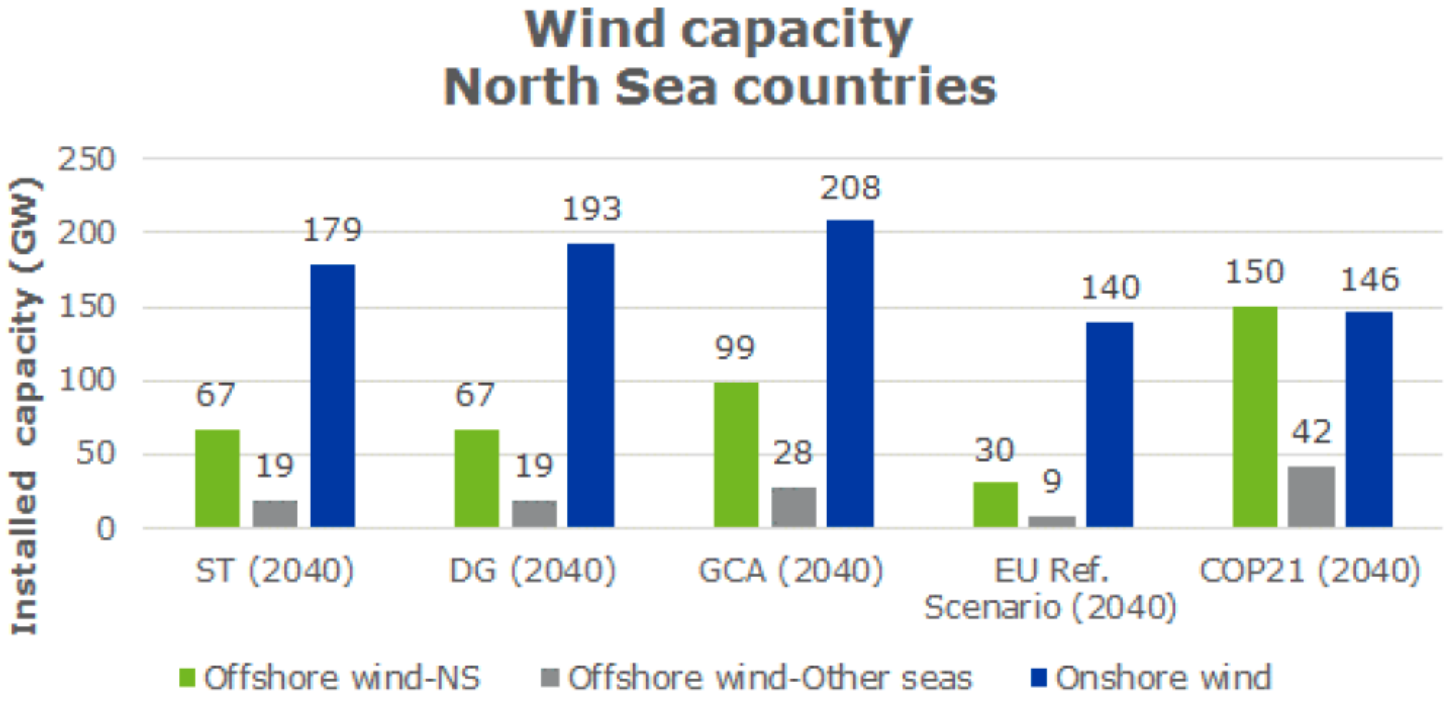
- Full decarbonisation of electricity production
- 50% reduction of the total energy demand by 2045 (relative to 2010)
- Electrification level of 45%

Outcome

- 230 GW offshore wind capacity
- 180 GW deployed in the North Sea
- 50 GW deployed in ‘other seas’ (Baltic, Irish and Atlantic)

[1] **Translate COP21:** 2045 outlook and implications for offshore wind in the North Seas (Ecofys 2017 by order of TenneT and Energinet). Countries: FR, BE, NL, UK, IE, LU, DE, DK, SE and NO)

Results from several studies



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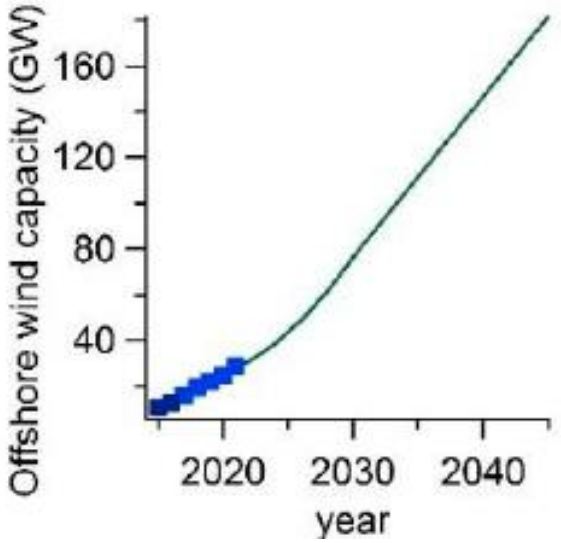
ST – Sustainable Transition

DG – Distributed Generation

GCA – Global Climate Action

How much to build annually?

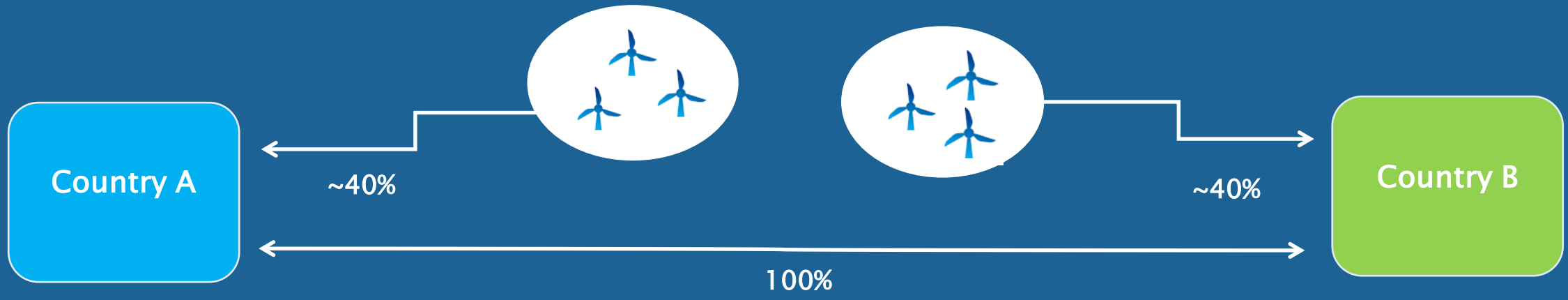


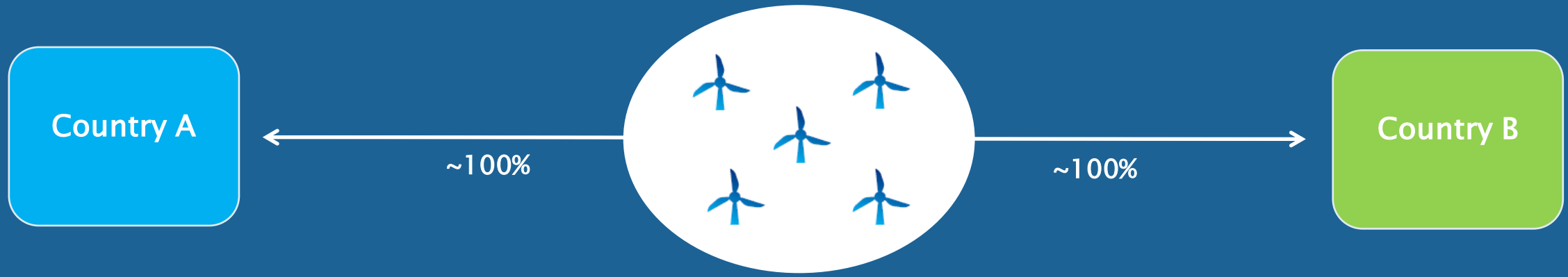
- 7 GW annually 2023-2040
- With 10 MW size (!), this is 700 huge wind turbines each year!
- High share in North Sea
- Further cost reductions needed

Combining wind with interconnectors

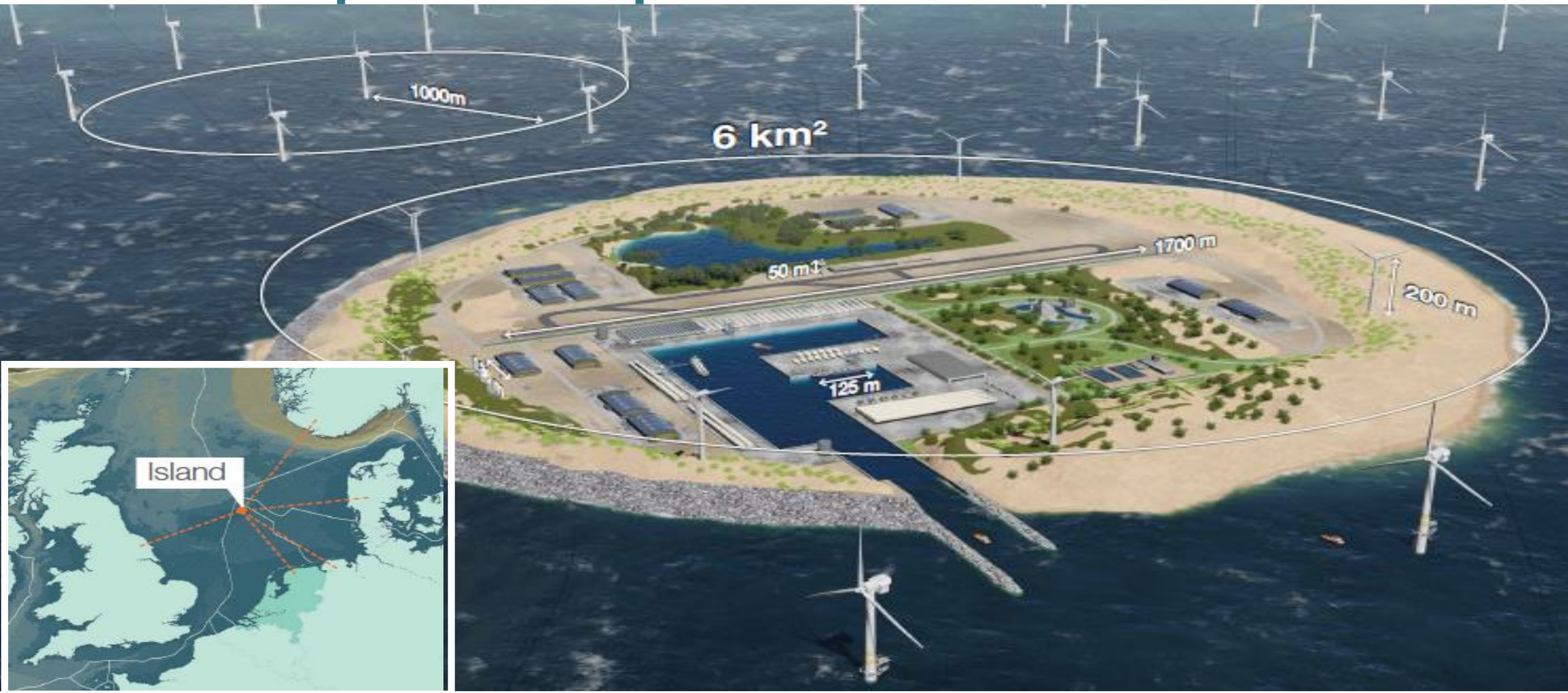
Solution: the Wind Connector

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



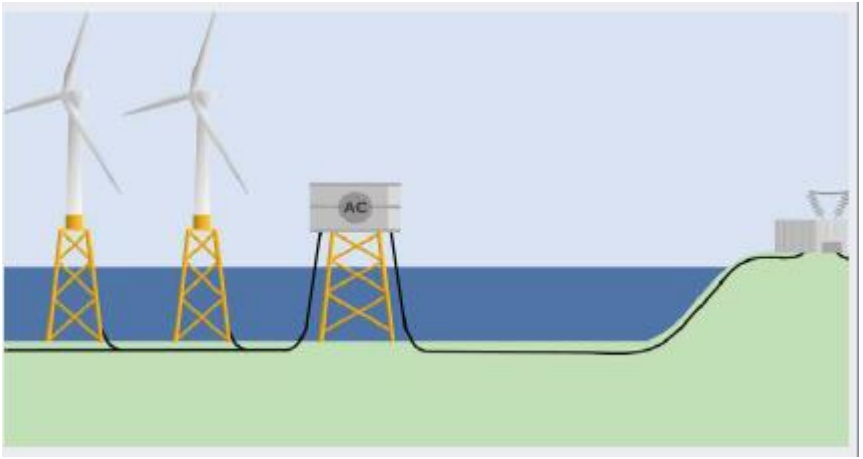


Hub and spoke concept




Dogger Bank

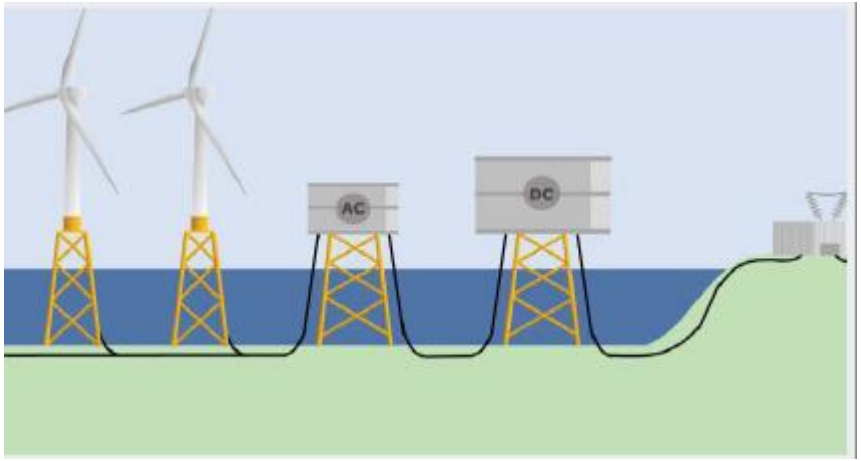
Connection concept 1: 220 kV AC platforms



- Current practice
- Radially connected wind farms
- relatively close to shore, generally <80 km
- AC grid connection.

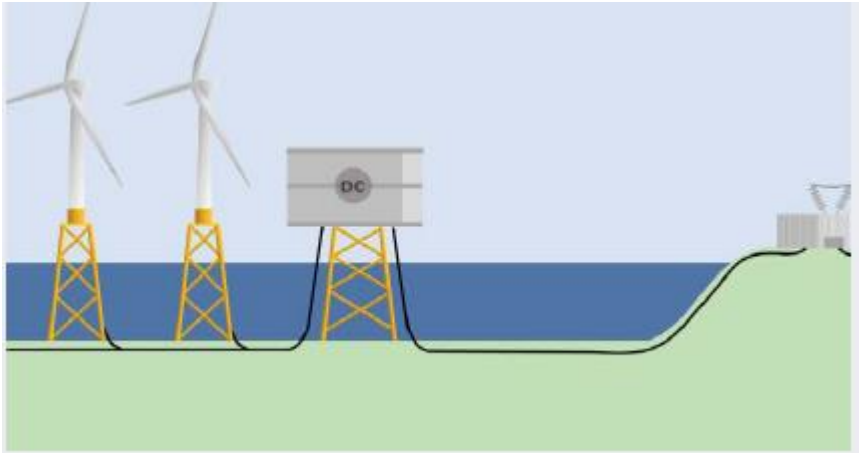
Connection concept 2:

320 kV HVDC platforms, with AC collector platforms



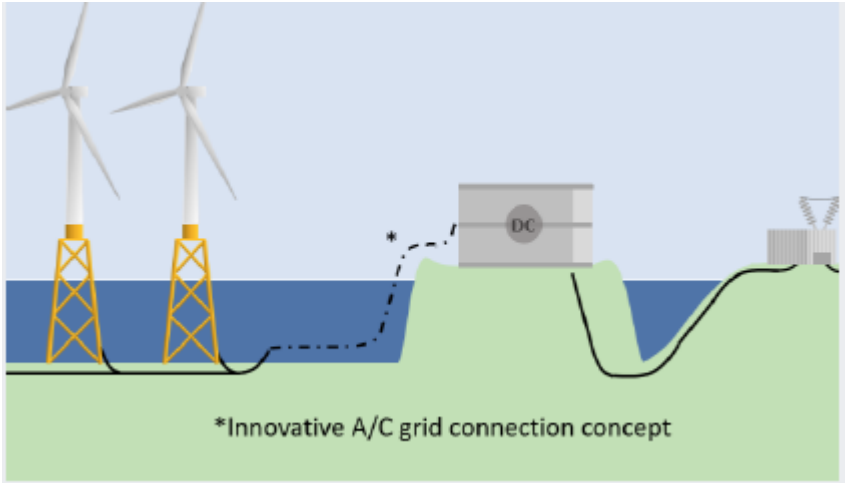
- Current practice
- Radial connection of several wind farms
- More than ~100 km from shore.

Connection concept 3:
66kV lines directly connecting to a 525 kV HVDC platforms



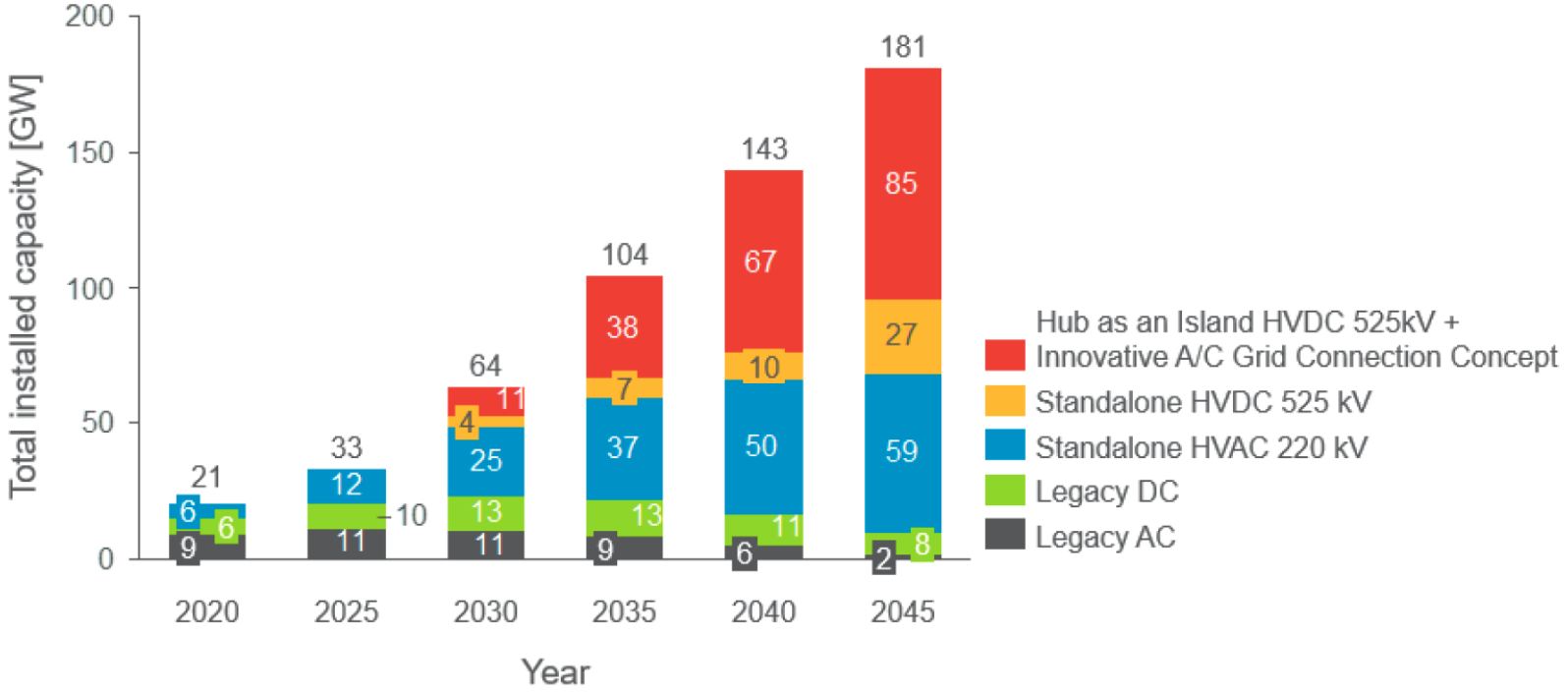
- Higher DC voltage increases the capacity of single export cables
- Wind farms connected directly to HVDC platforms via 66kV AC cables
- Additional cost benefits over connection with AC collector platforms and intermediate cabling between the AC and DC platforms.

Connection concept 4:
66kV collector lines to island hub with 525 kV HVDC assets



- For windfarms exceeding 4 GW in size
- AC/DC converters on island
- Several hubs/islands can be connected
- Interconnections can be realised in a cost-effective way
- Hub and Spoke

Projected development



Potential cost saving of Hub and Spoke concept

- National Incremental Roll Out (NIRO)
- International coordinated Roll Out (ICRO)
  - 2 % reduction of export cable costs
  - 15 % reduction due to wind farm transmission asset costs
  - 5 % reduction of offshore interconnector costs
  - 8 % reduction of onshore grid reinforcement costs

Lean island

- Cost efficient support for electrical infrastructure
- IJmuiden Ver, ~100 km offshore
- 6-10 GW wind
- Innovative AC grid connection
- Cost reduction~10 %
  - Compared with BAU
- Extended functionality not beneficial

Expanded island

- Far from shore, 250-300 km
  - E.g. Doggerbank
- Prospective size 4-6 km^2
- Facilities to support wind turbine O&M
- Personnel accomodation
- Harbour, runway
- Power2Gas – storage
- (reservoir has been considered, not profitable so far)

North Sea Infrastructure

Relevant properties

Cooperation	North Sea 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 existing AC connection technology
Logistics	optimization by means of island
Storage/conversion	Power-to-gas plus existing infrastructure or water bassins
Modularity	guaranteed continuity and stable pipeline for market, lowering financial risks

Consortium North Sea Wind Power Hub
Knowledgebase: power, molecules, heat

Concluding words - North Sea Wind Power Hub

To keep the power system stable and affordable at high VRES:

(inter-)connect (multi-national wind connectors)

Buffer (time shift, convert, store)

Cooperate (organic)

- ✓ System Operators (forecasting, visibility, flexibility, market facilitation)
- ✓ North Sea States (common VRES goals, regulation, legislation)
- ✓ Sector coupling, heat (homes, processes), gas (mobility, industry), liquid (aviation)
- ✓ NGOs, fishermen and people

Future North Sea Wind power Hub

enabling the change

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