
DTU

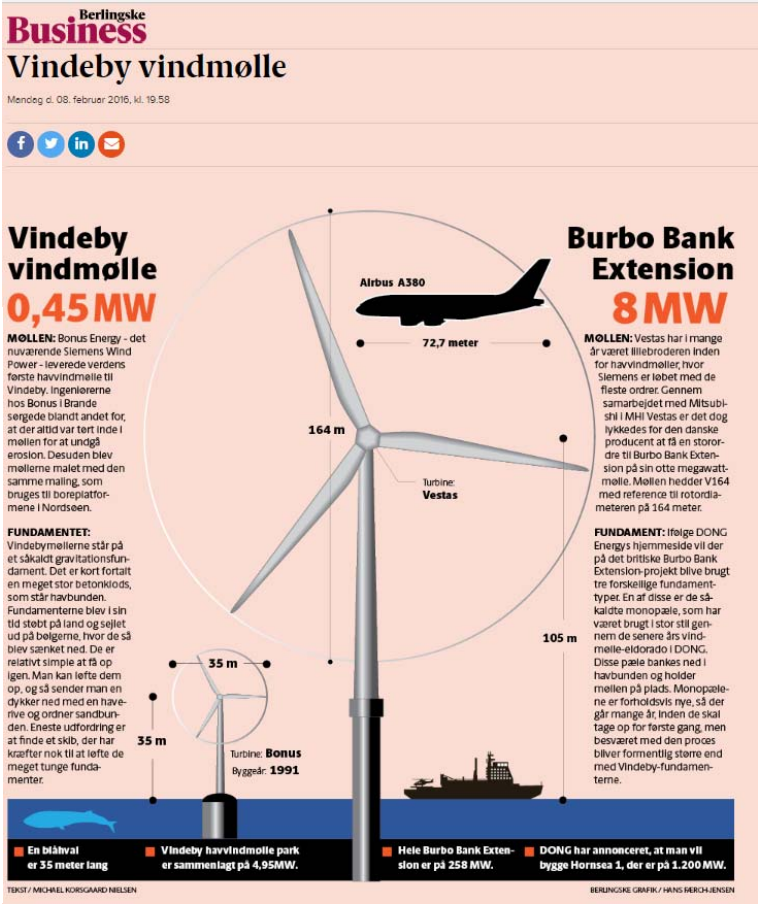
Oscar Saborío-Romano

Grid Connection of Offshore Wind Energy

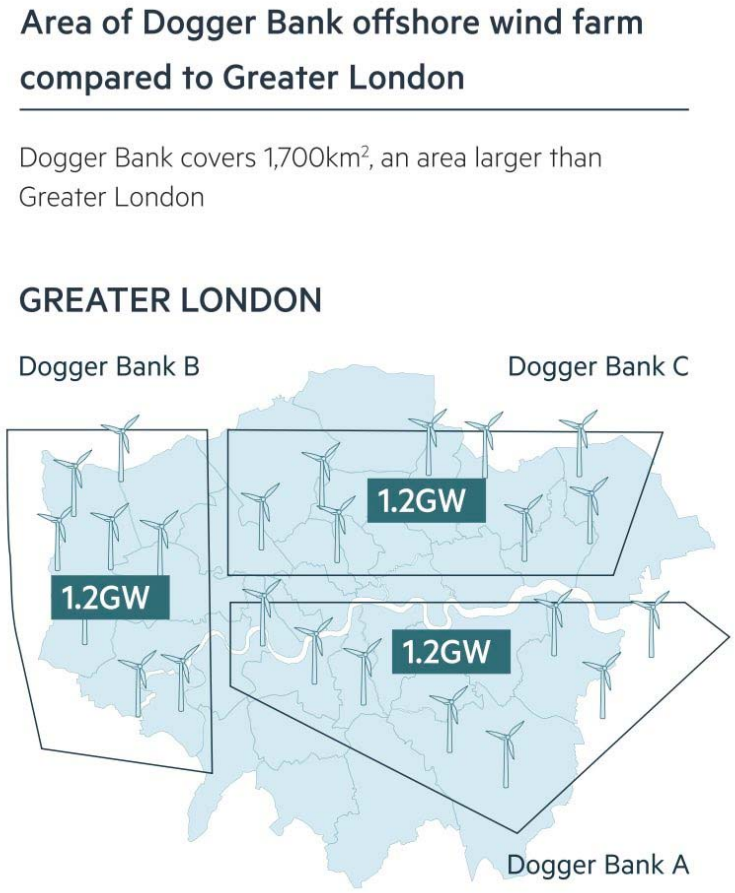
Offshore wind – how big is big?

Ørsted to Use GE Haliade-X 12 MW on US Offshore Wind Farms

Ørsted has selected GE Renewable Energy as the preferred turbine supplier for two of its US offshore wind farms which marks the world's first commercial deployment of GE's Haliade-X 12 MW offshore wind turbine.

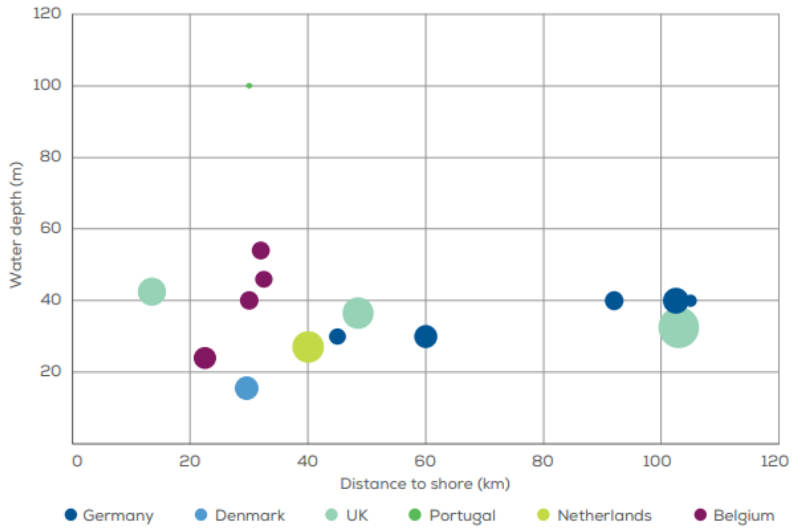


Offshore wind – how large is large?



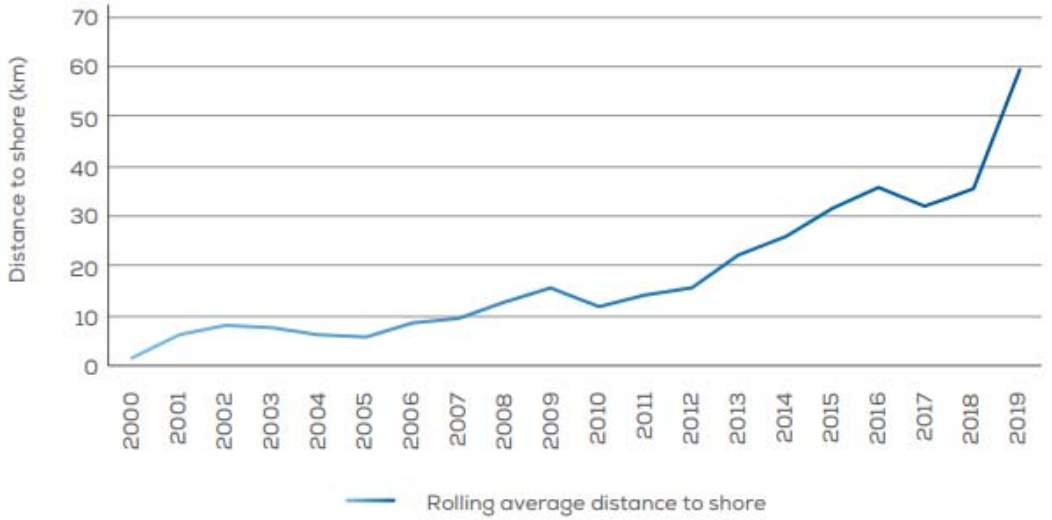
Offshore wind – how far is far?

FIGURE 8
Average water depth and distance to shore of offshore wind farms under construction during 2019. The size of the bubble indicates the capacity of the site



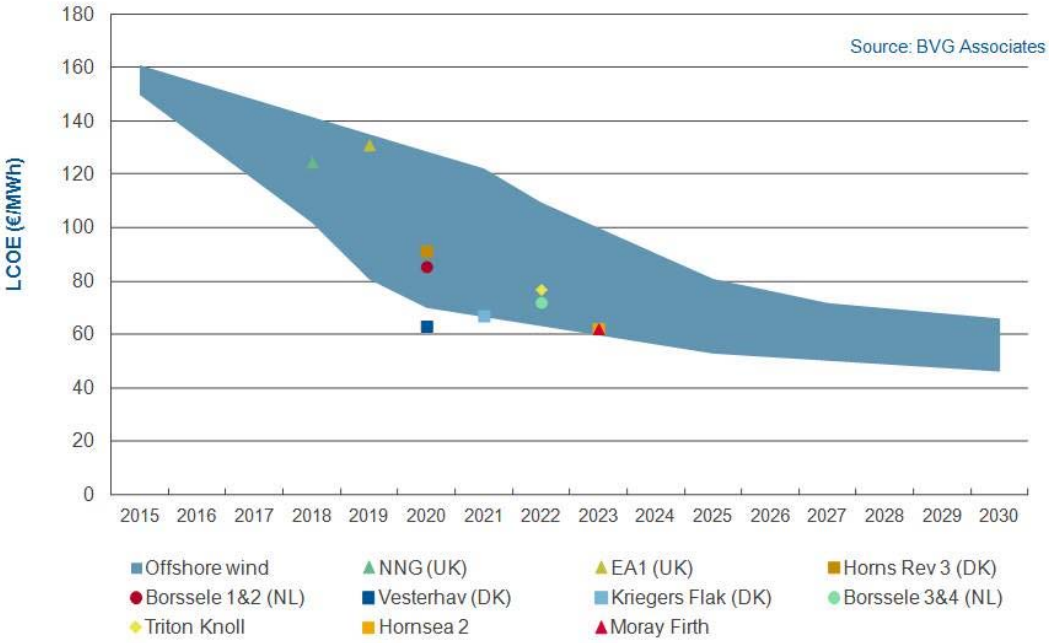
Source: WindEurope

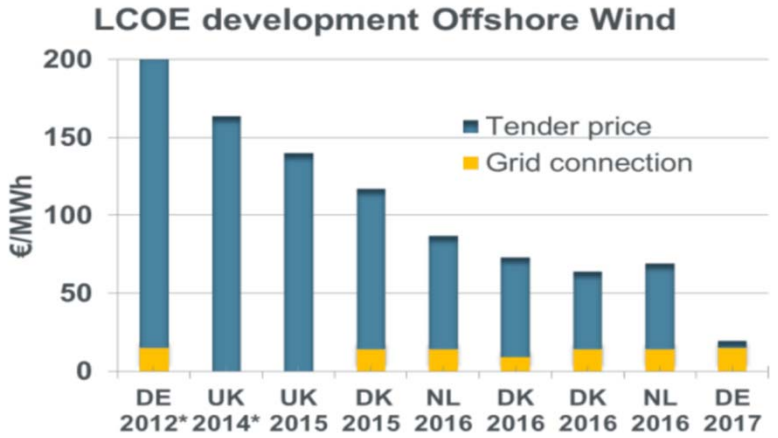
FIGURE 10
Rolling average distance to shore of online offshore wind farms



Source: WindEurope

Offshore wind cost reduction ….but





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

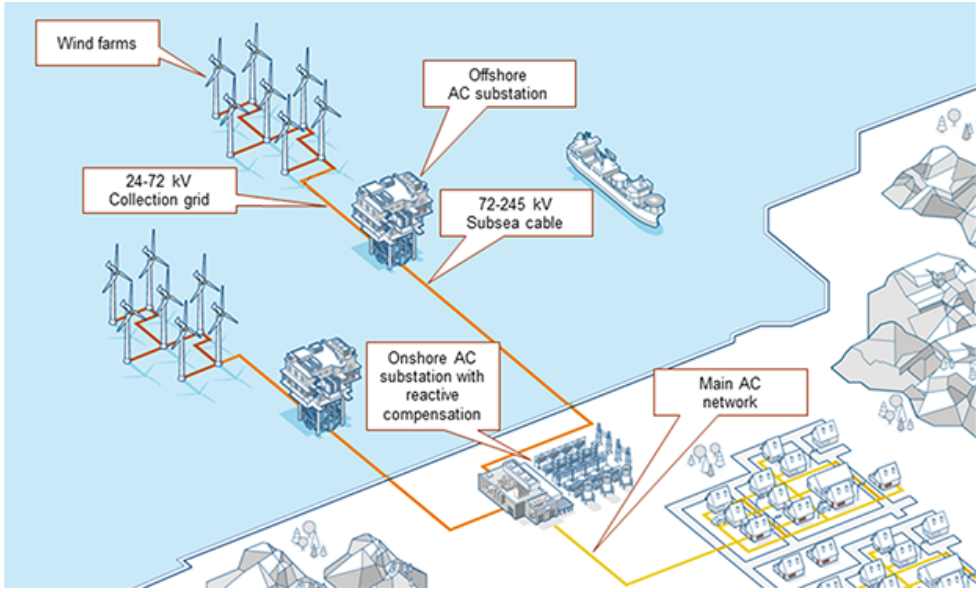
Source: North Sea Energy Infrastructure: Status and outlook, TenneT, Deepwind 2019

[…] *this is mainly from technology innovations in turbines and installation, and reductions in financing costs* […]

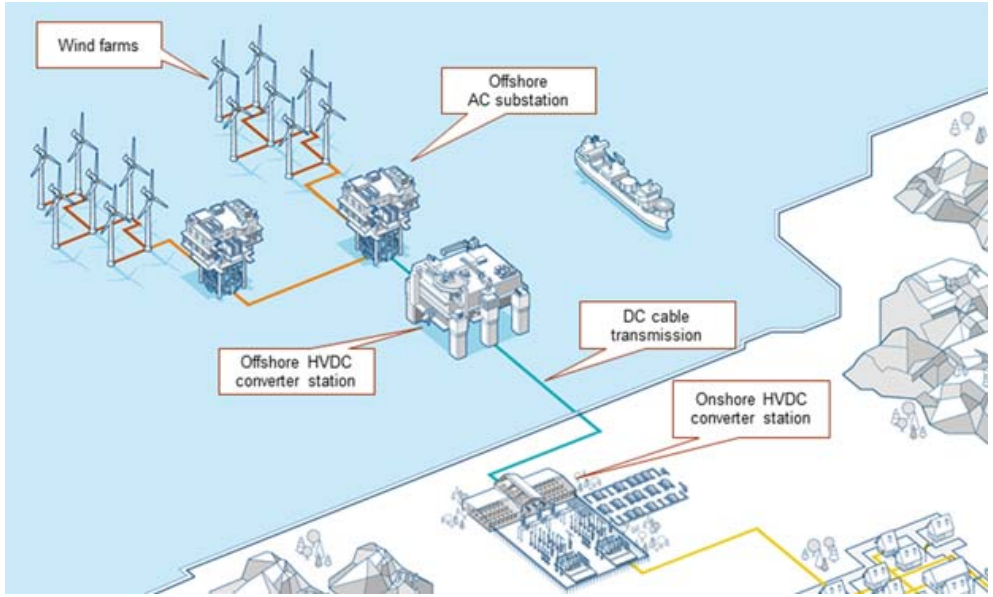
WindEurope

Grid connection – main components

High-Voltage Alternating Current (HVAC) Transmission



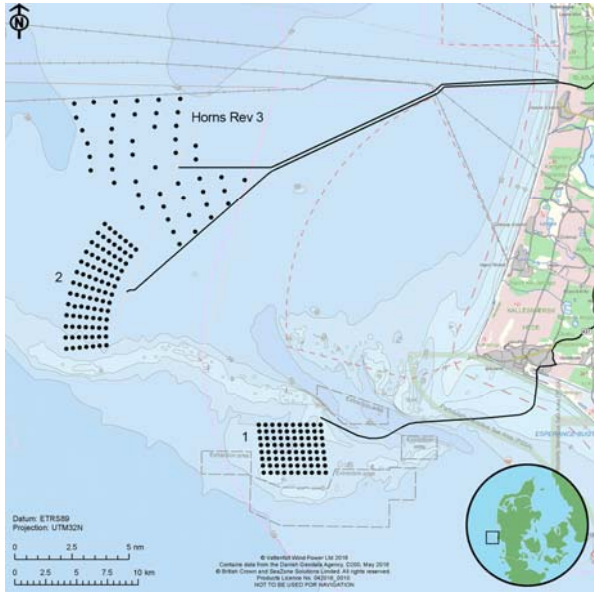
High-Voltage Direct Current (HVDC) Transmission



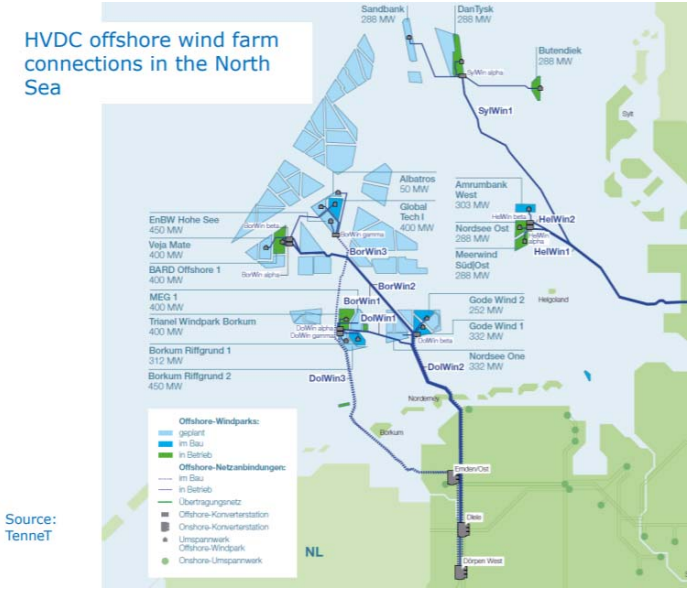
Source: ABB

Grid connection concepts

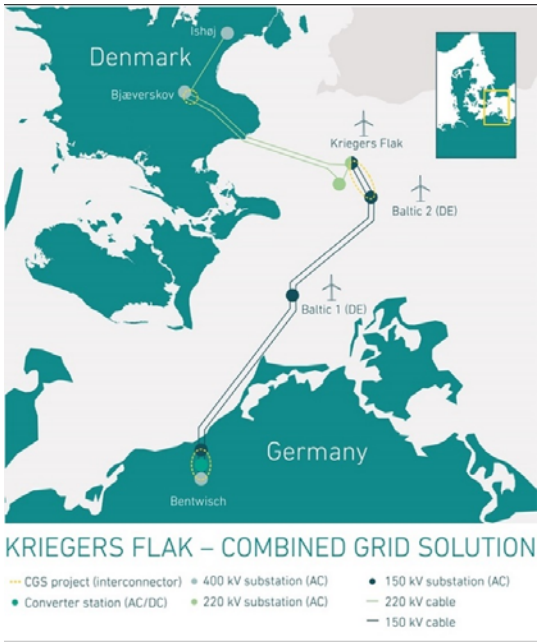
HVAC



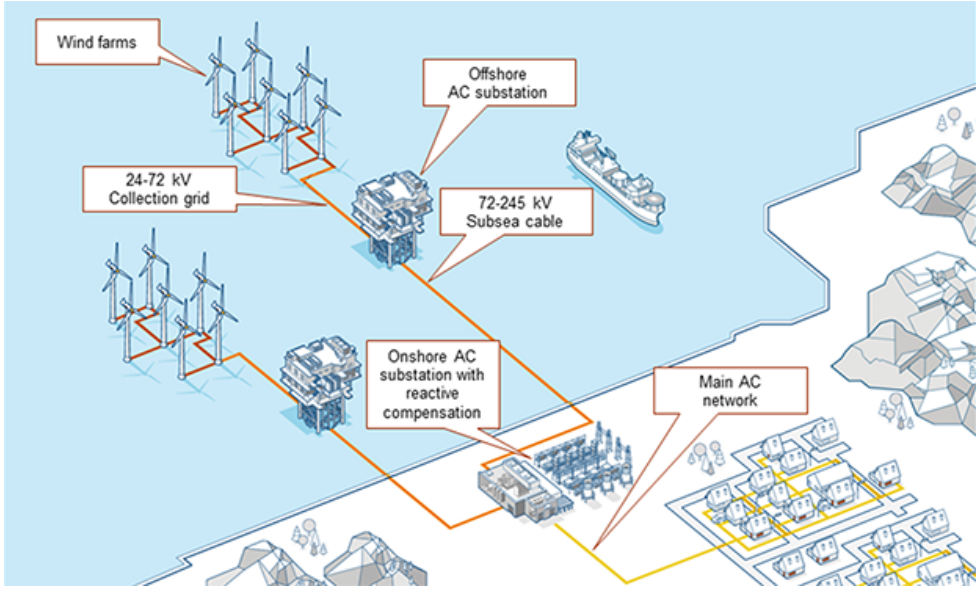
HVDC



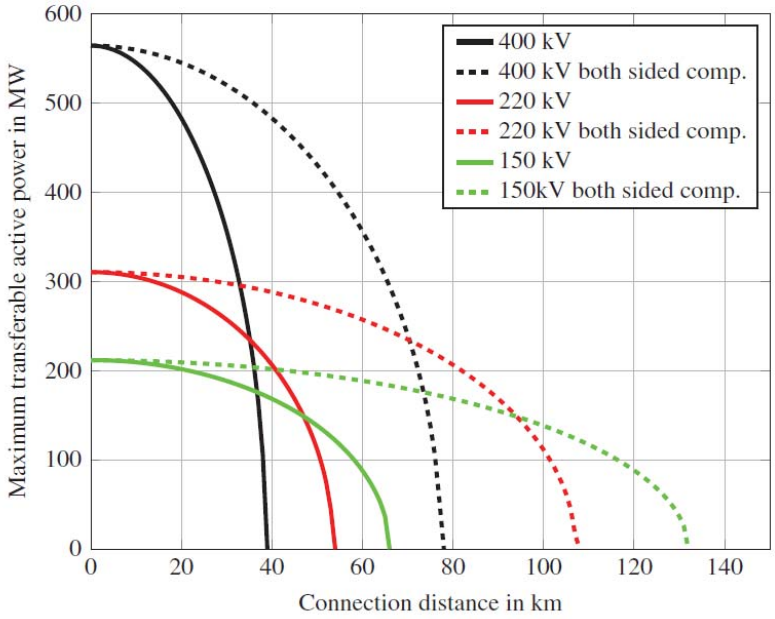
Hybrid



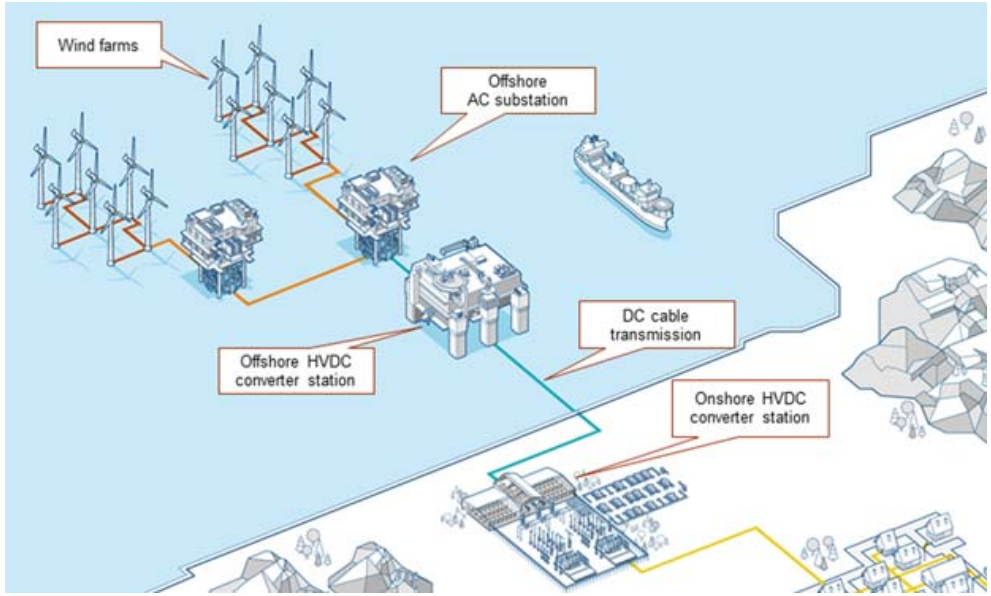
HVAC transmission



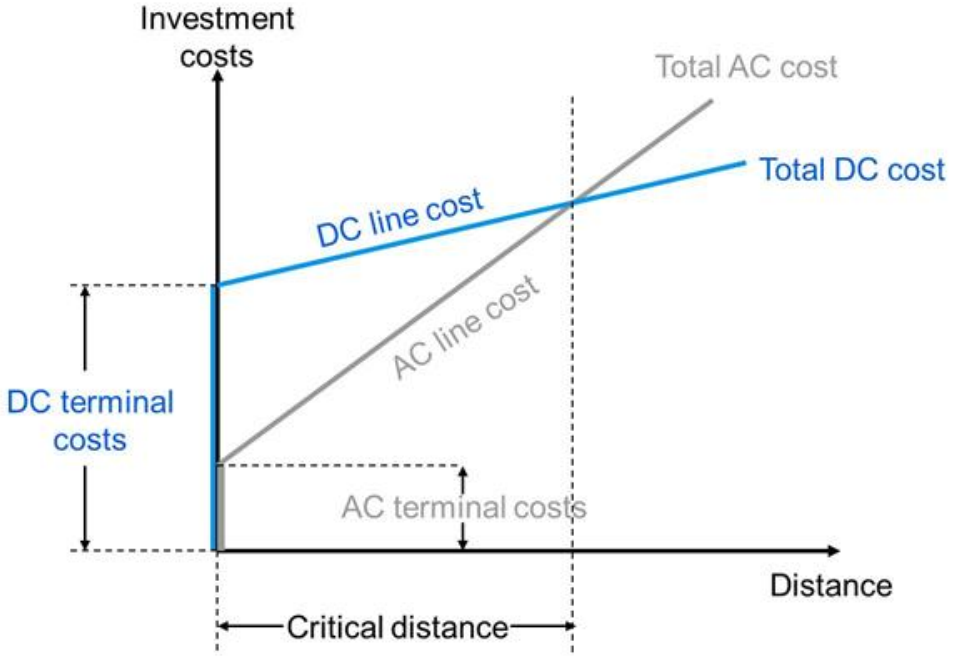
Main limitation:
capacitive current (function of distance)



HVDC transmission



Distance to shore is the most important factor



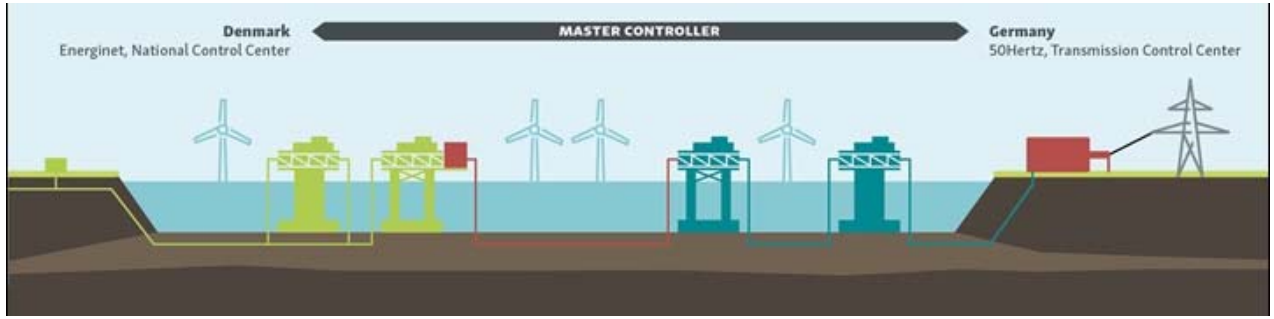
Break-even distance: 50-100 km

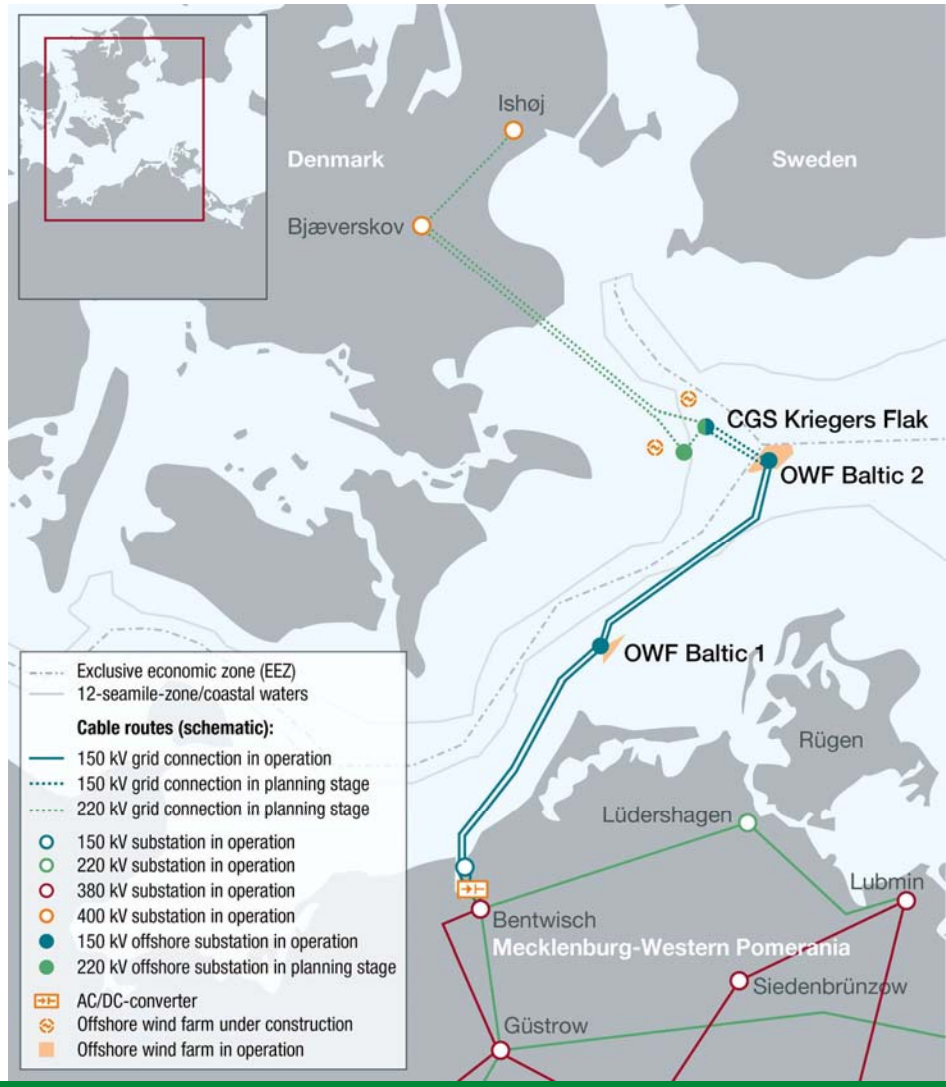
Source figures: ABB

Hybrid

Kriegers Flak - Combined grid solution:

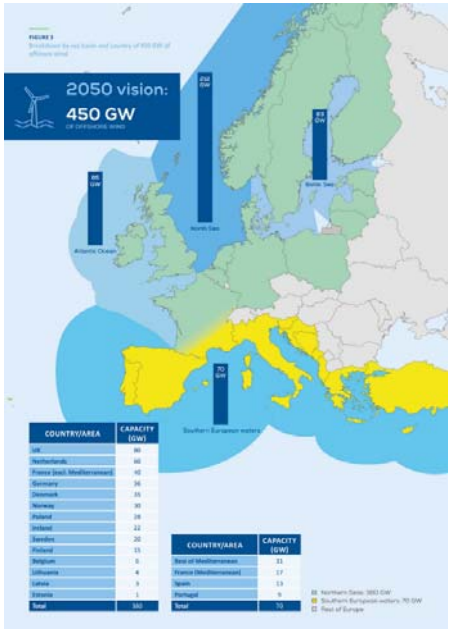
- Connecting offshore wind to the shore
- Connecting two countries
- Connecting two markets
- Connecting two synchronous areas





Very high ambitions

- Around 22 GW installed today
- Expectations for 100 GW by 2030 and 200 GW by 2050



Assuming 5 GW links

FIGURE 3
Breakdown by sea basin and country of 450 GW of offshore wind

2050 vision:
450 GW
OF OFFSHORE WIND

212 GW

85 GW

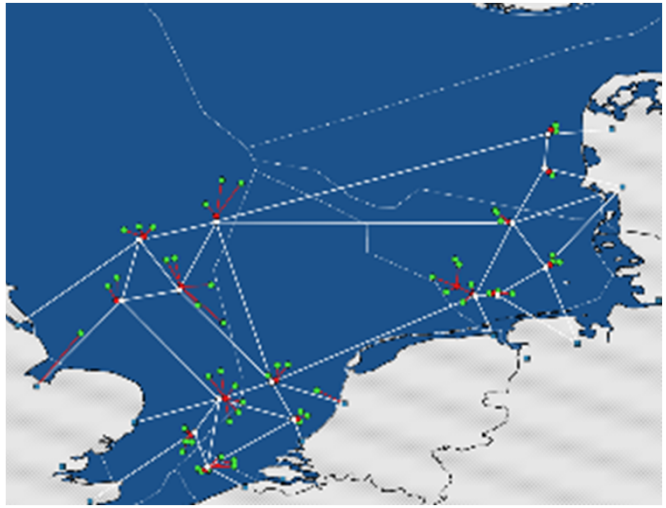
83 GW

Baltic Sea

Atlantic Ocean

Inspired by Prof. Dirk van Hertem, KUL

Meshed offshore HVDC grids…



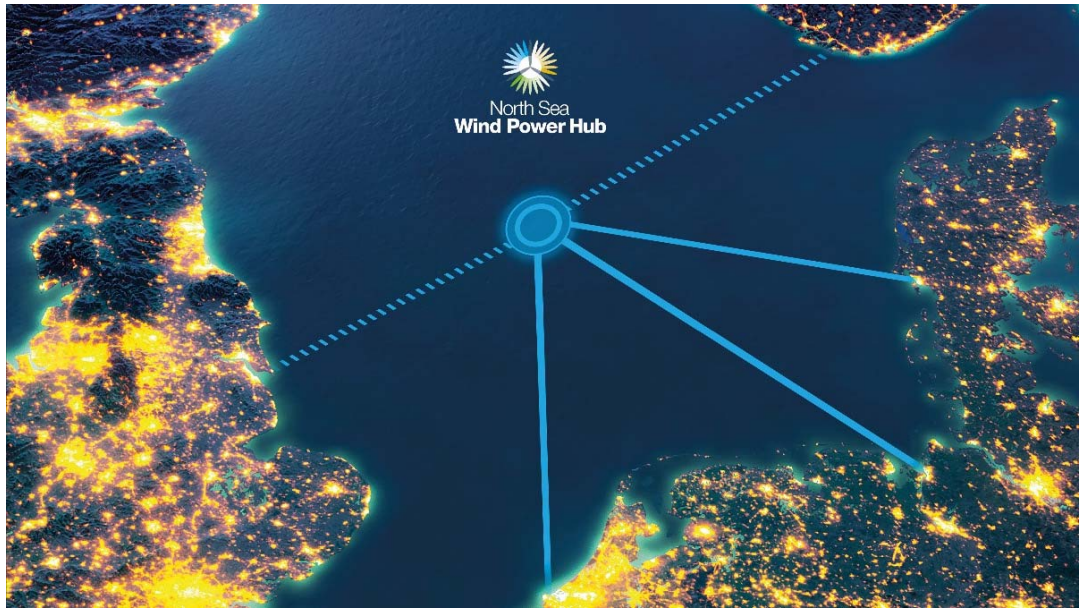
PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

- Critical components like DC circuit-breakers
- Higher voltages, better capacity, better redundancy
- Fully interoperable systems
- Further developments in technology (diode-rectifies, DC collection grids, …)
- Hybrid transmission and fully interconnected systems

Energy islands/hubs

- North Sea Wind Power Hub Consortium
  - TenneT (NL-GE) - TSO
  - Energinet (DK) - TSO
  - Gasunie (NL) – Natural gas
- Launched the initial concept of an energy island
- Proposing “Modular Hub-and-Spoke concept”
- Produced a number of studies

https://northseawindpowerhub.eu/category/studies/



Danish Energy Islands/Hubs

- In June 2020, Danish parliament decided […] the construction of two energy islands in Denmark – in the North Sea and in the Baltic Sea. The energy island on Bornholm will have a capacity of 2 GW, while the one in the North Sea will have a capacity of 3 GW in 2030, and 10 GW in the longer term.

North Sea – 3 GW by 2030, aim for 10 GW by 2050

Bornholm island – 2 GW

North Sea Energy Island

VindØ consortium

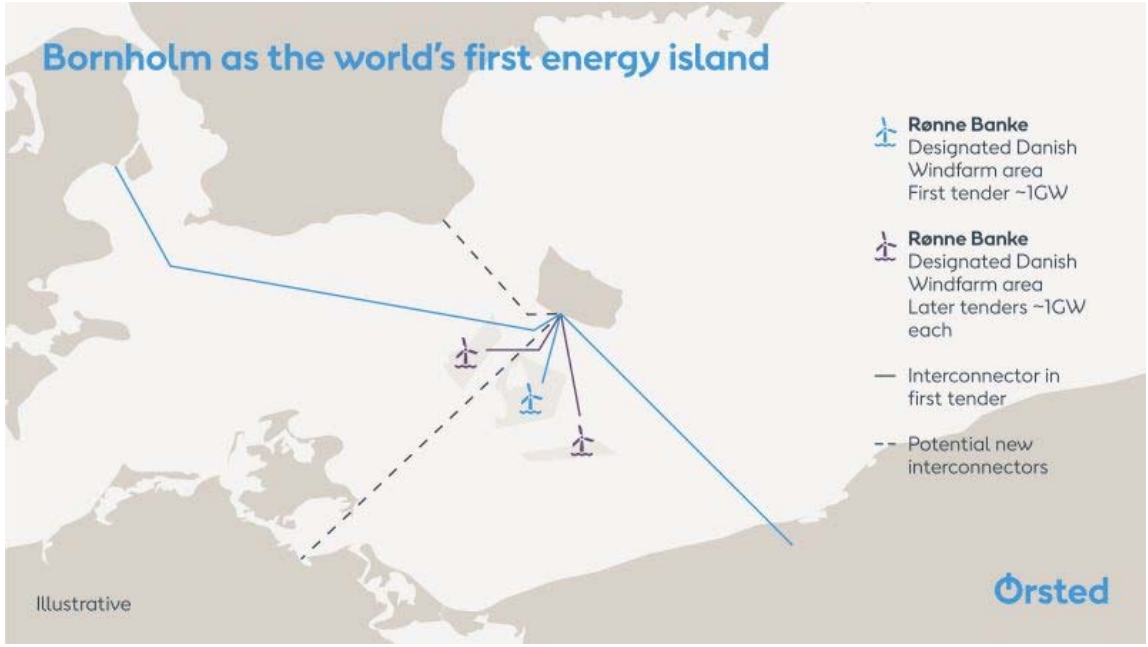
- Electrical infrastructure:
  – HVDC converter stations
- Living quarters
- Energy storage
- Power-2-X facilities

Rendering launched recently:
https://www.youtube.com/watch?v=0MO9pdZTEzc

Bornholm Energy Island

Ørsted:

- Placed on an existing island
- Mainly for electrical infrastructure

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