HVDC for offshore wind

Nicolaos A. Cutululis

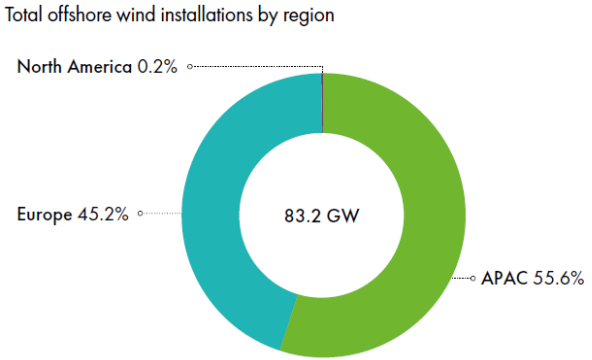
Technical University of Denmark

Agenda

- Offshore wind power
- Grid connection for offshore wind
- Energy hubs (islands)

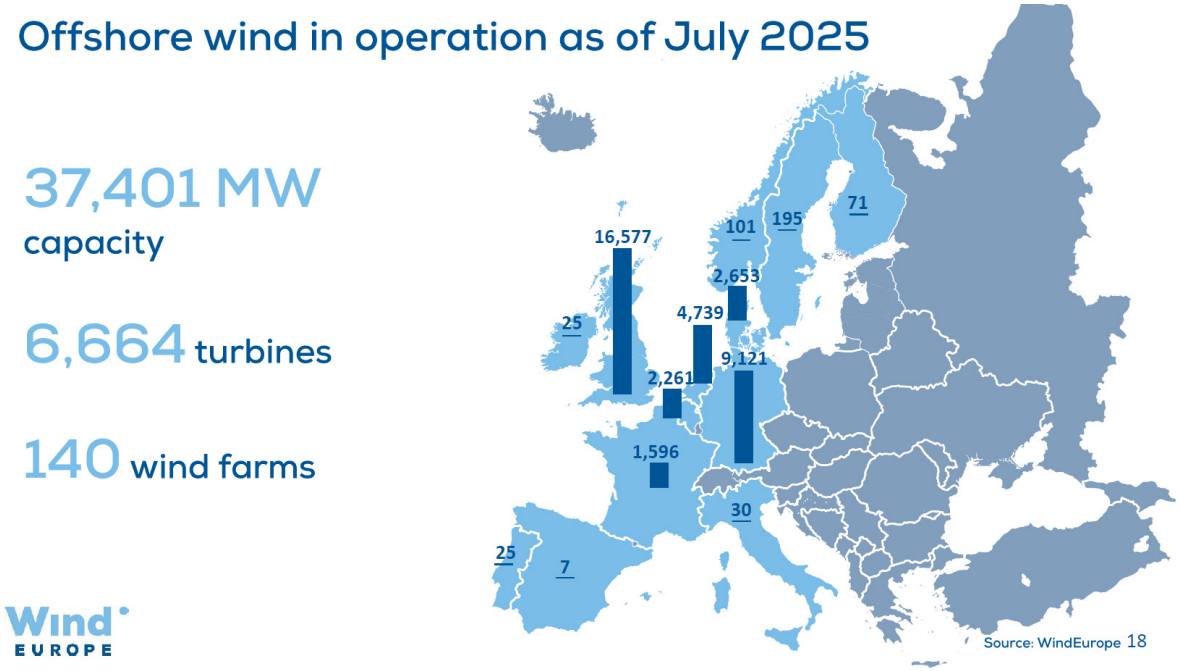
Offshore wind in 2025

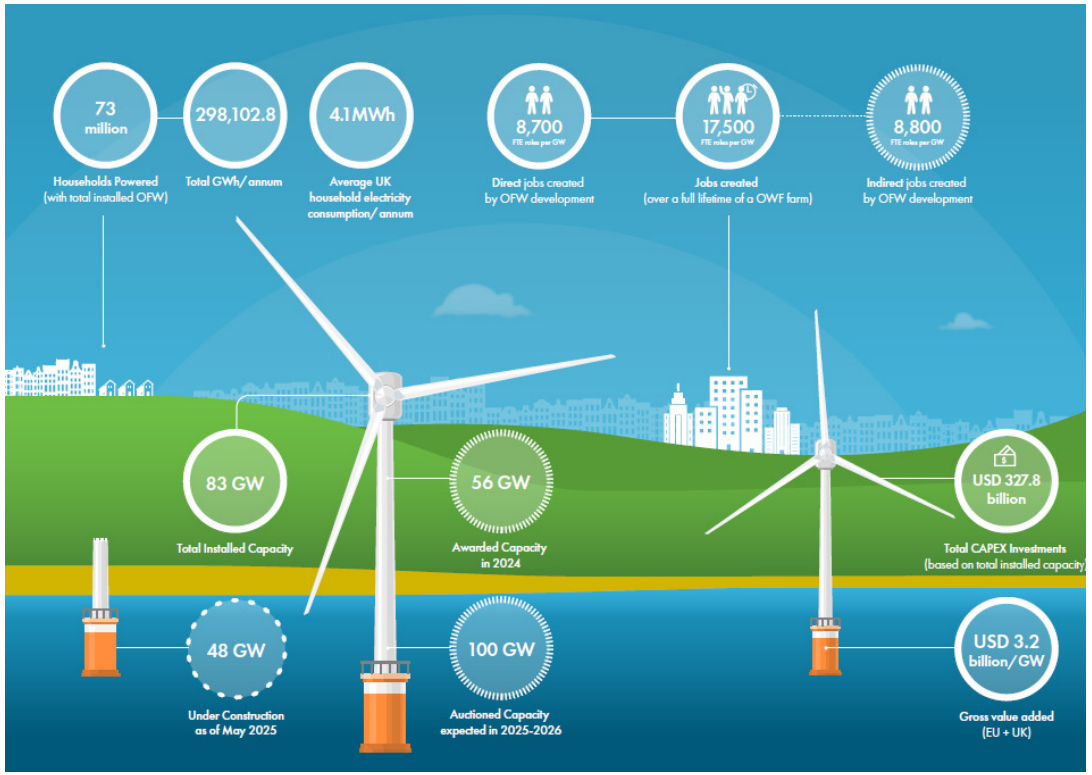
Europe and global



Source: GWEC

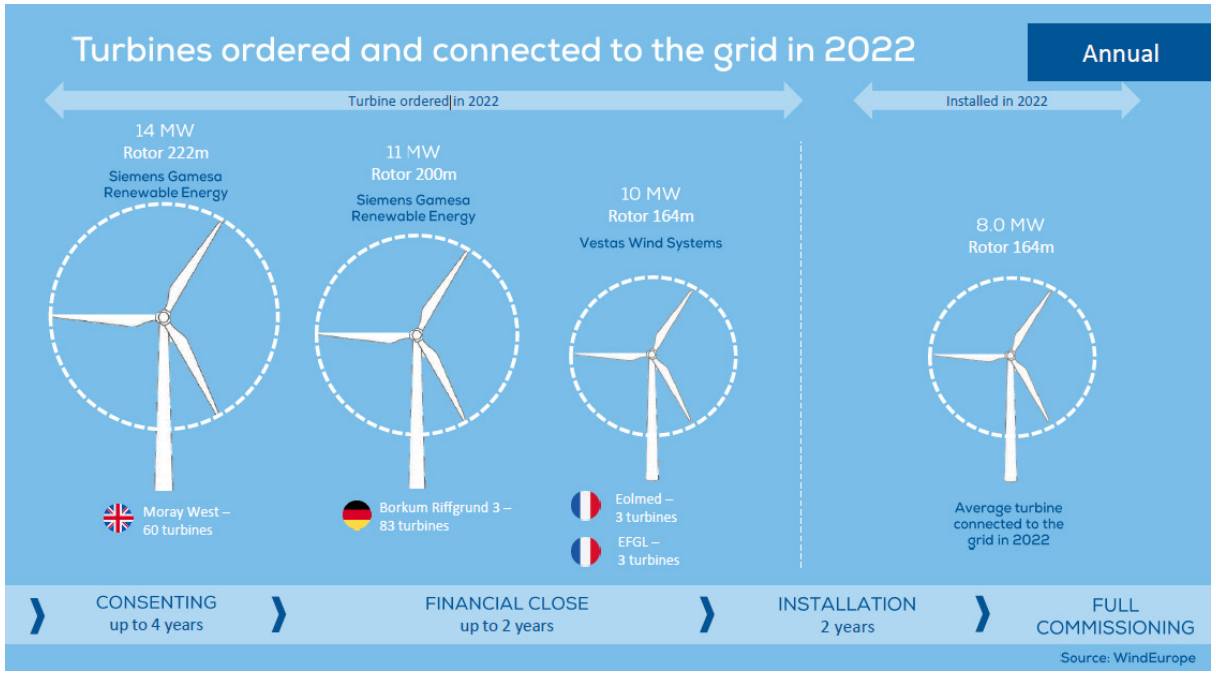
Source: WindEurope

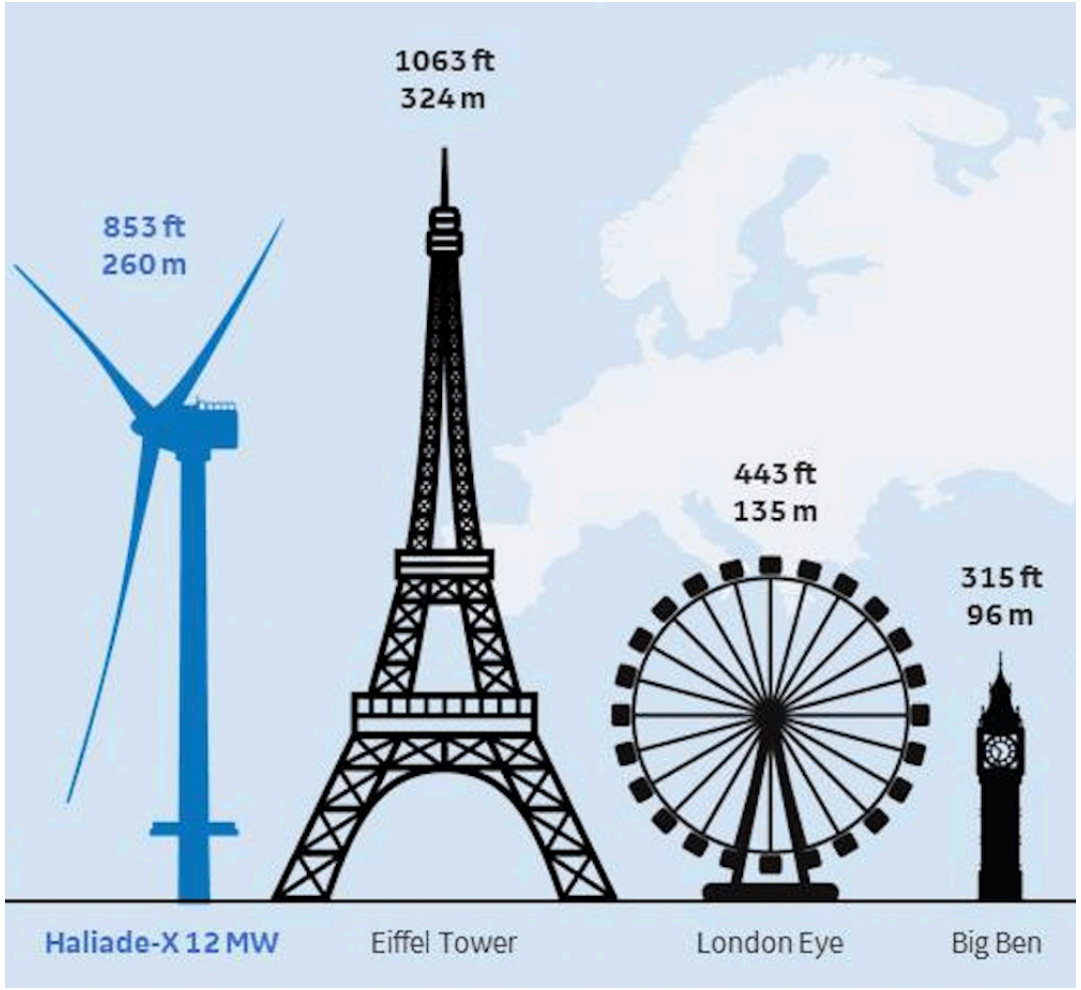




Offshore wind turbines

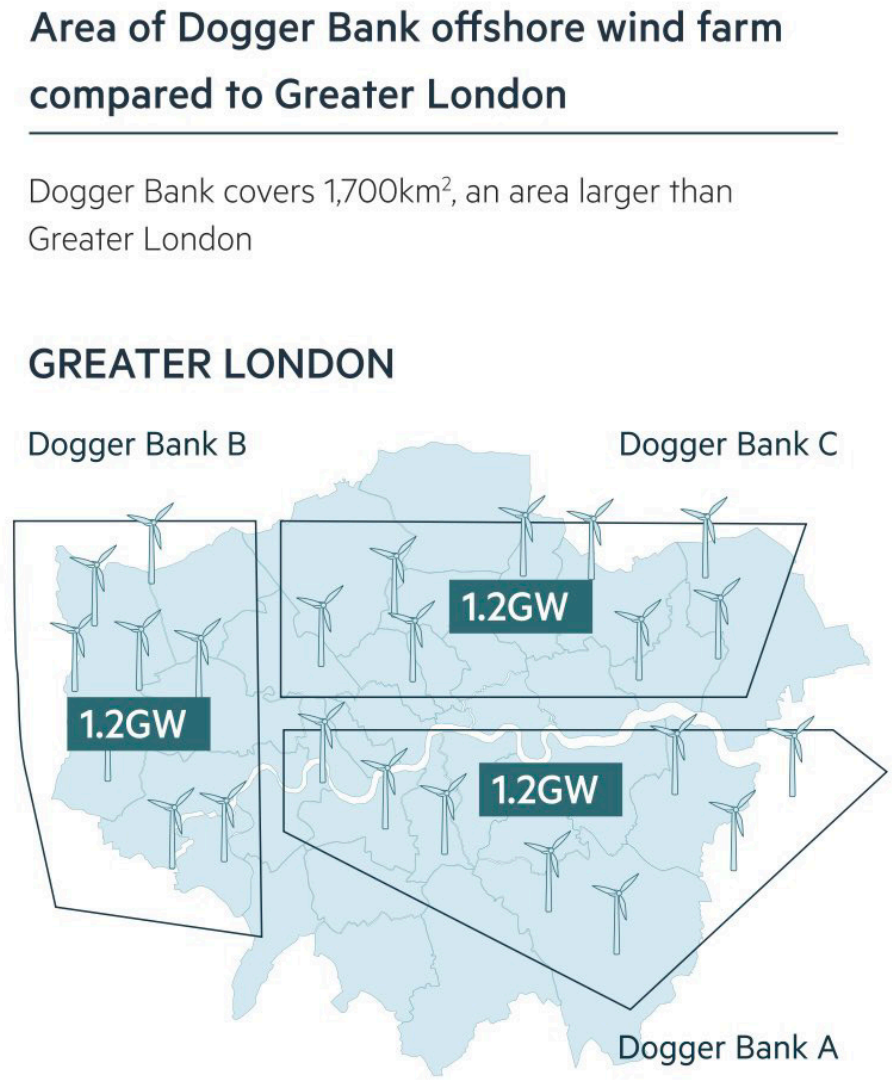
How big is big?





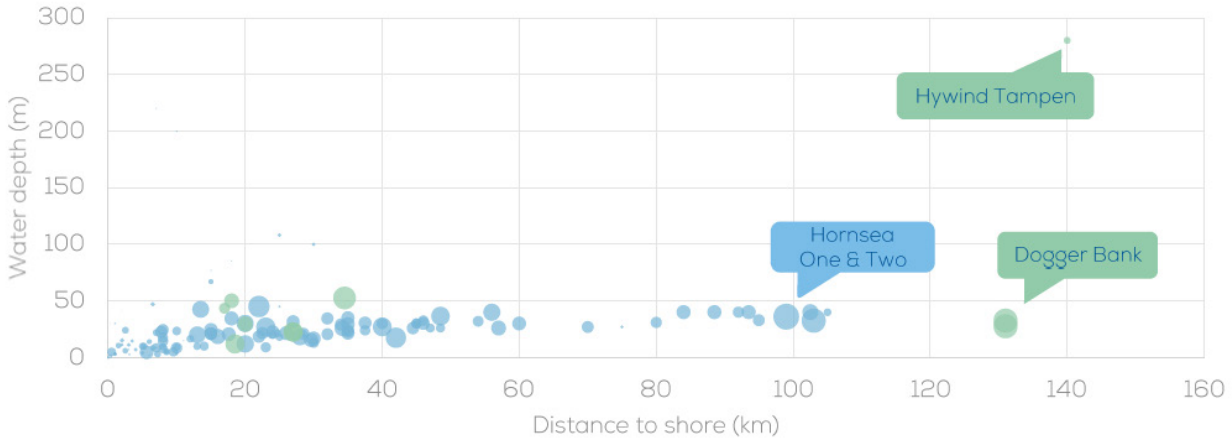
Offshore wind

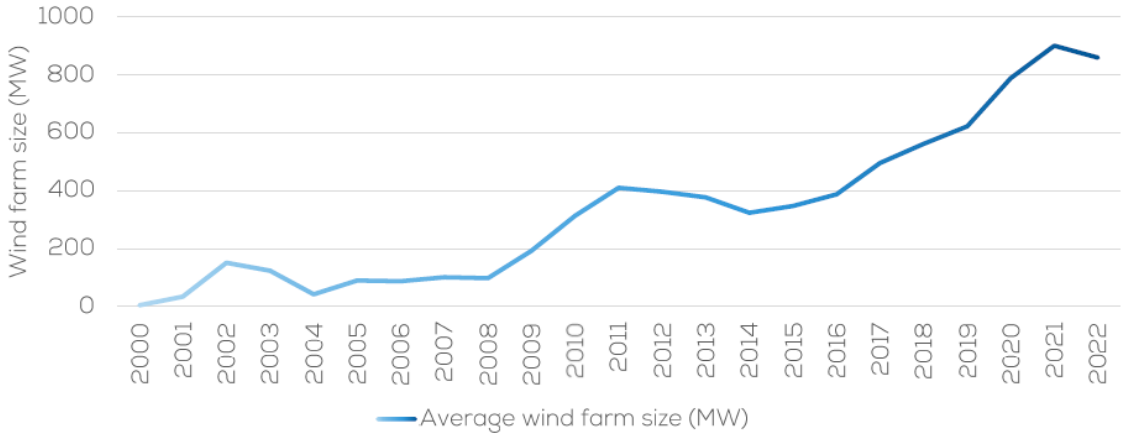
How large is large?



Offshore wind

How far is far?





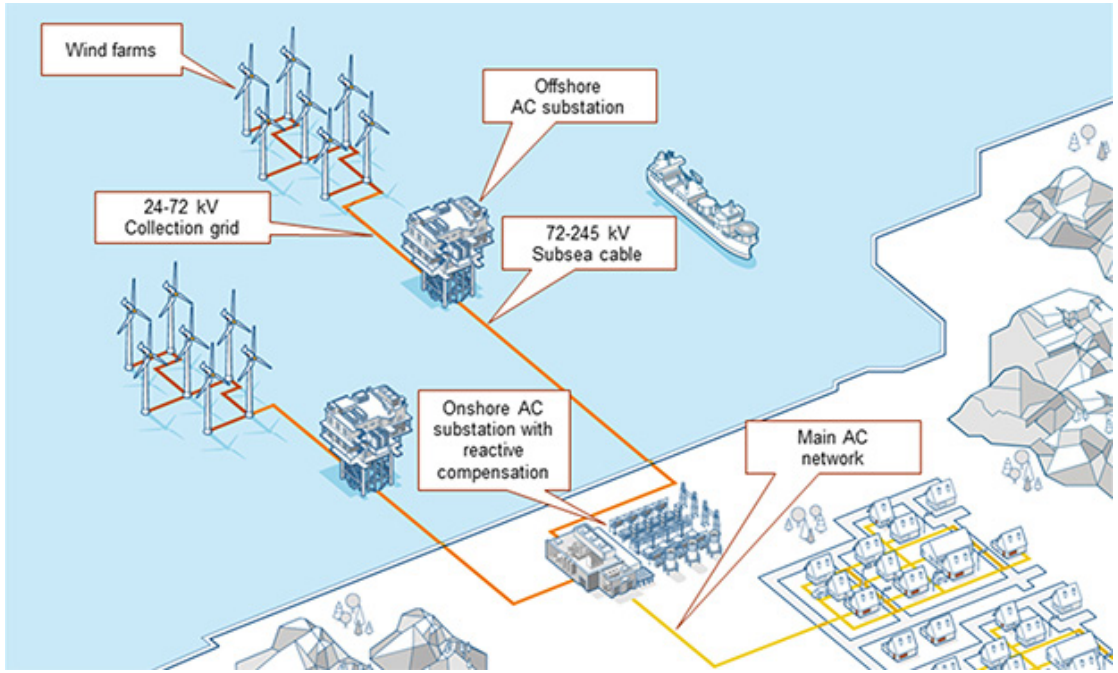
data are for 2022

Source: WindEurope

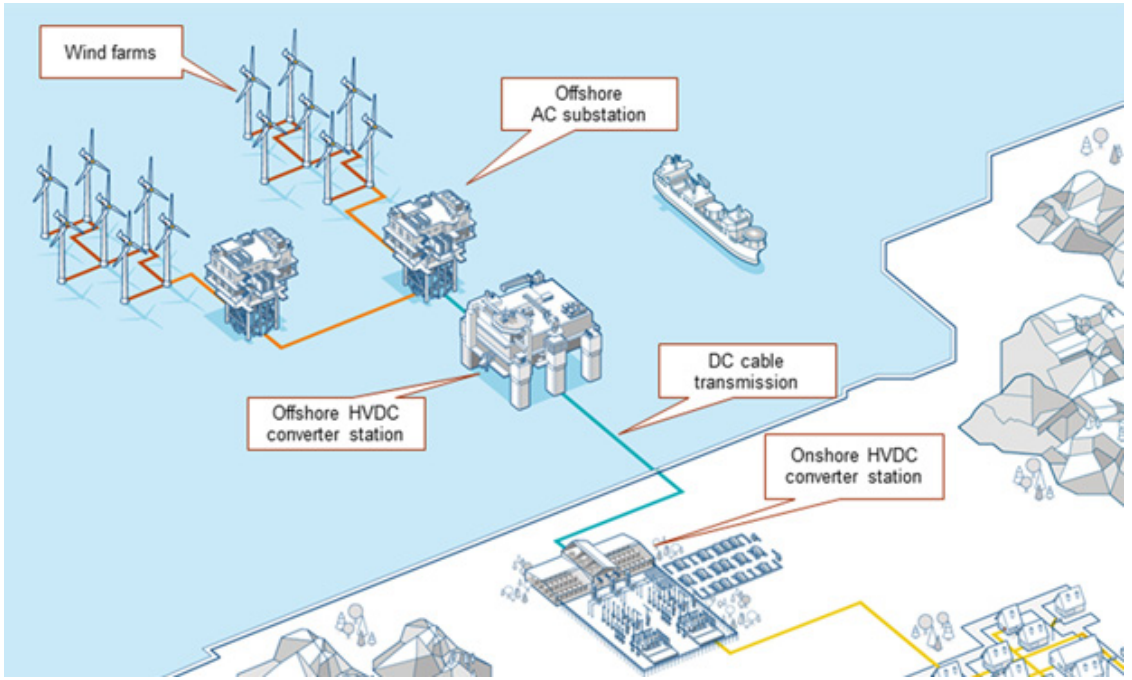
Offshore wind

Grid connection system

HVAC



HVDC



Source: ABB

HVDC in Europe

Interconnectors and transmission

Offshore wind targets - 2050

2,000 GW
of elesitricity the world's offshore wind farms will have to generate to meet the climate targets ouclined in the

30 GW
offshore wind power in North Americs by 250

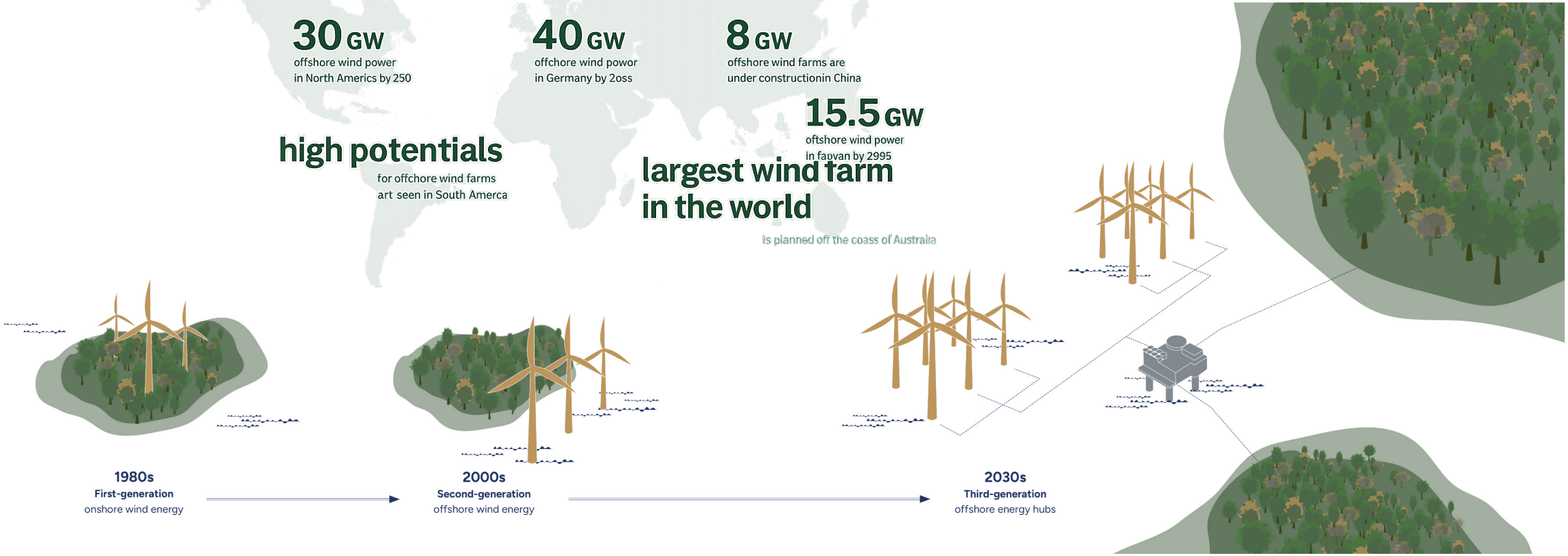
40 GW
offchore wind powor in Germany by 2oss

8 GW
offshore wind farms are under constructionin China

15.5 GW
oftshore wind power in fapvan by 2995

high potentials
for offchore wind farms art seen in South Amerca

largest wind farm in the world
is planned off the coass of Australia



1980s
First-generation
onshore wind energy

2000s
Second-generation
offshore wind energy

2030s
Third-generation
offshore energy hubs

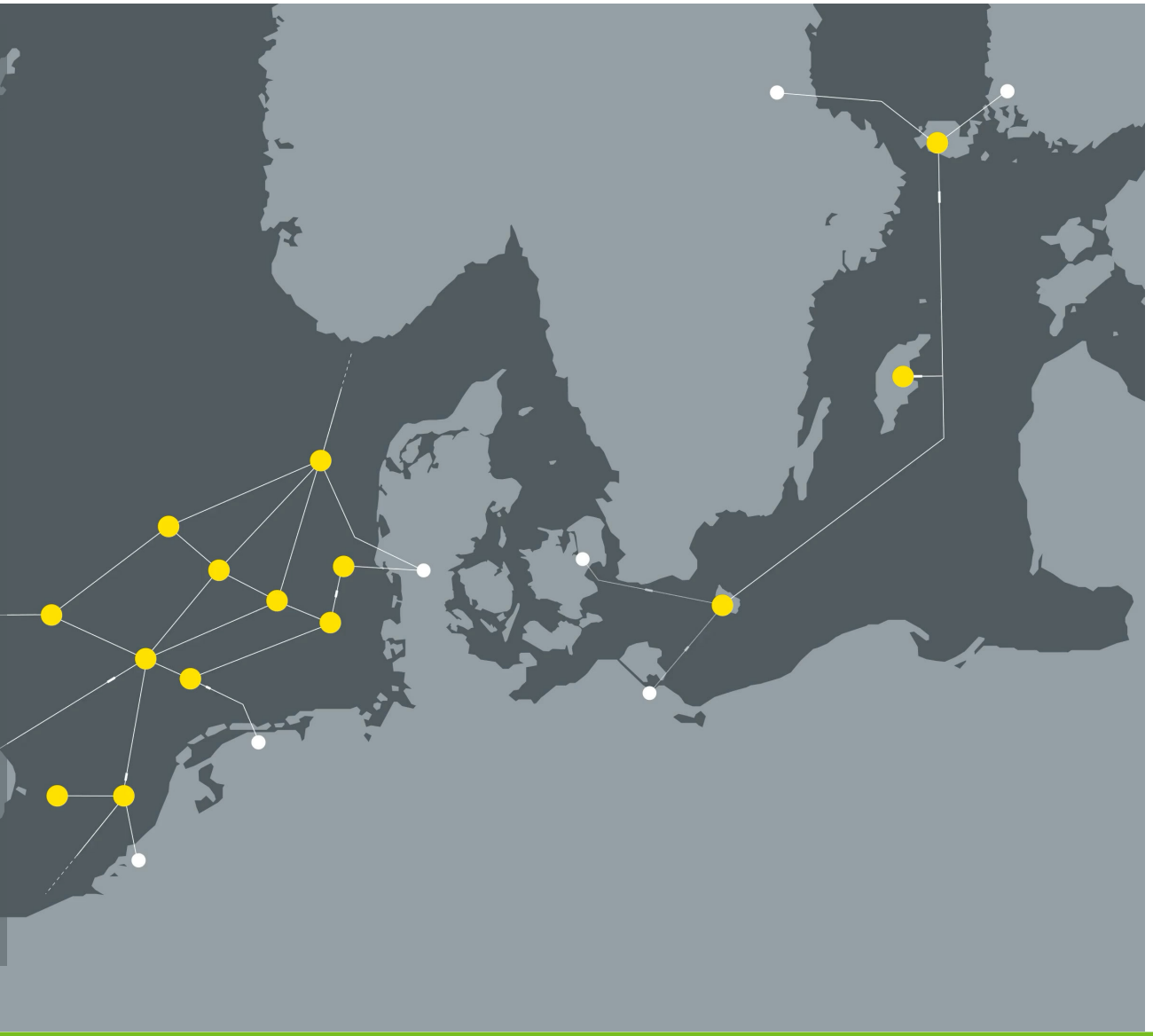
Energy Islands

Energy islands are **hubs** that efficiently collect energy from surrounding offshore wind power plants **far out at sea** (*offshore energy hubs*).

Large **DC power connections** are used to transport energy to surrounding countries or energy systems.

These connections facilitate the **energy exchange** between countries or energy systems.

The hubs may host production of **green fuels** through Power-to-X processes.

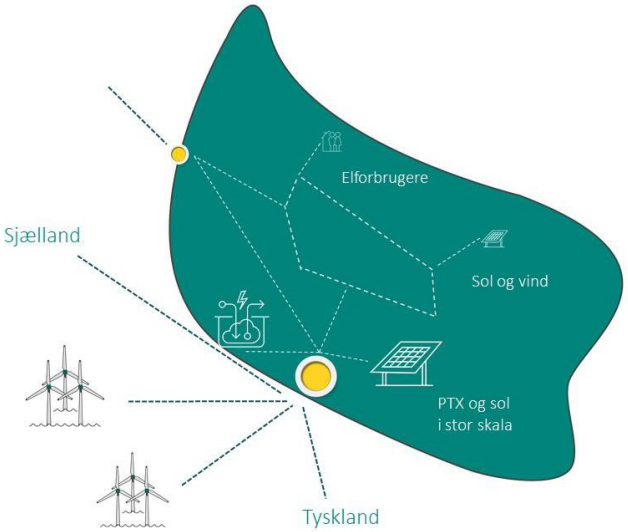


Offshore energy hubs

…they will come in many shapes

Artificial islands

Platform solutions



Existing islands

Offshore Energy Hubs

What so special about them?

- Very high power density
- Zero-inertia system (if no P2X or storage)
- Need for shared control effort – synchronisation and coordination, especially during transients, is crucial

Energy hubs topologies

AC Hub

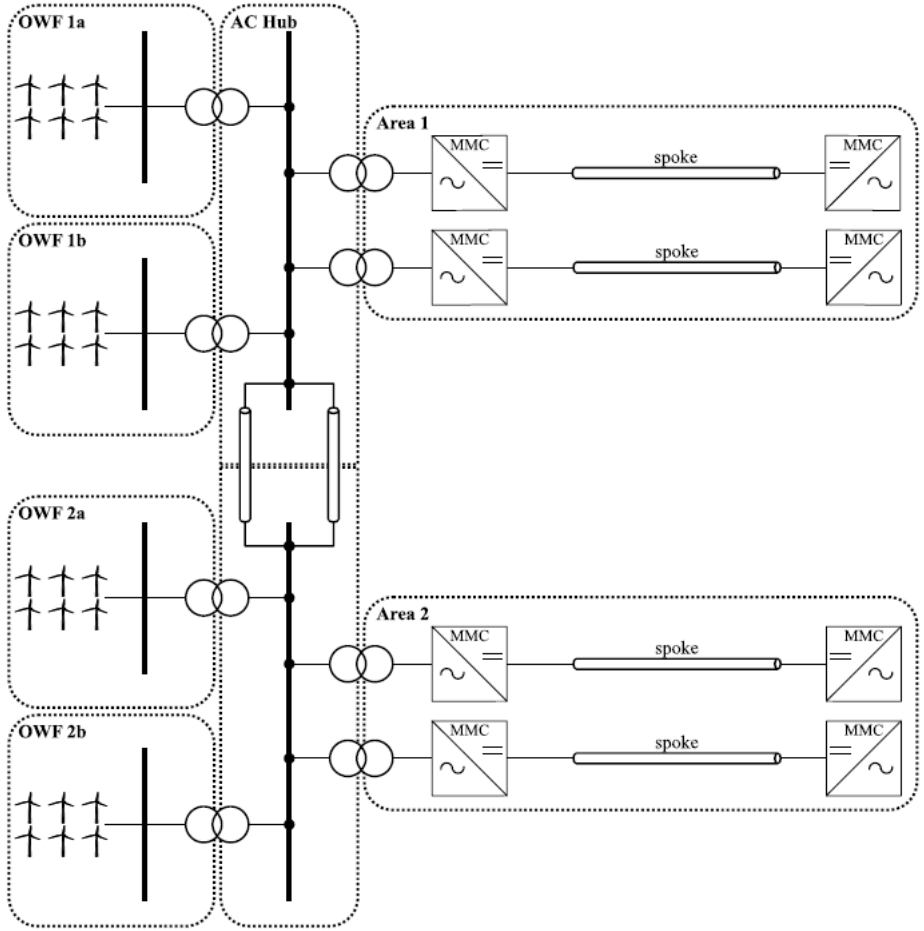
Hub’s electrical system is AC

DC point to point transmission

Loss of largest unit is equal to the rating of one HVDC-pole if a bi-pole configuration is selected

Complex AC-system control and protection schemes are required

Connection of load as e.g., PtX plants directly on AC-busbar

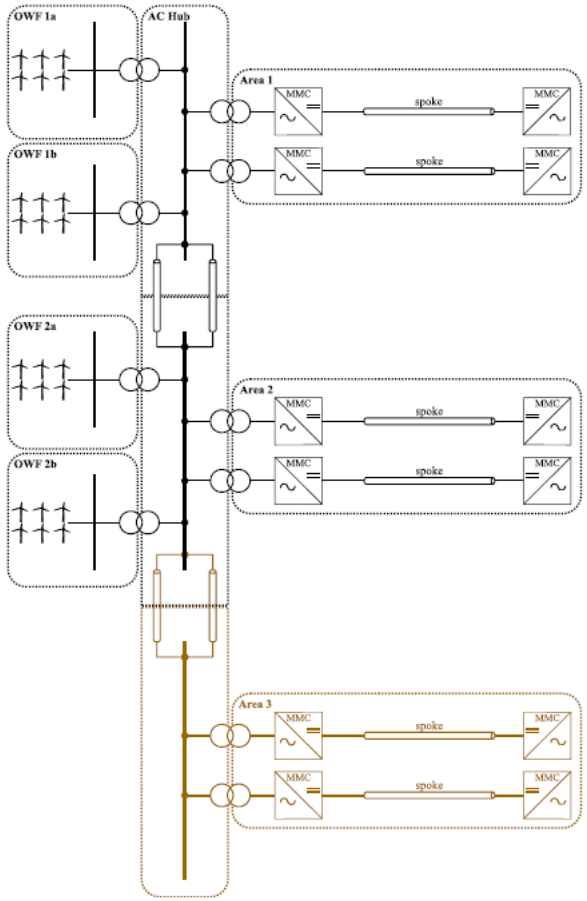


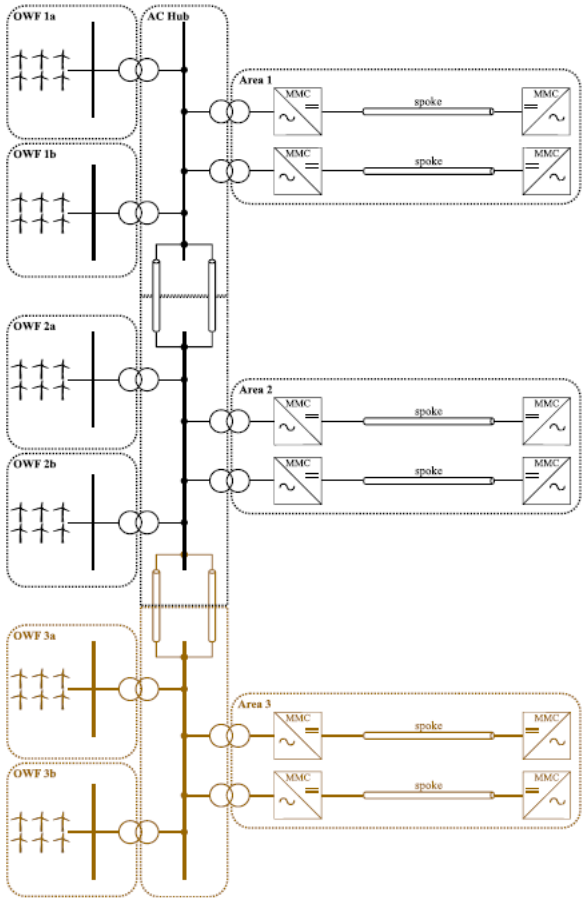
Energy hubs topologies

AC Hub

Expandability

Connecting other hubs requires a full HVDC-link





Energy hubs topologies

DC Hub

The hub's electrical system is DC-based

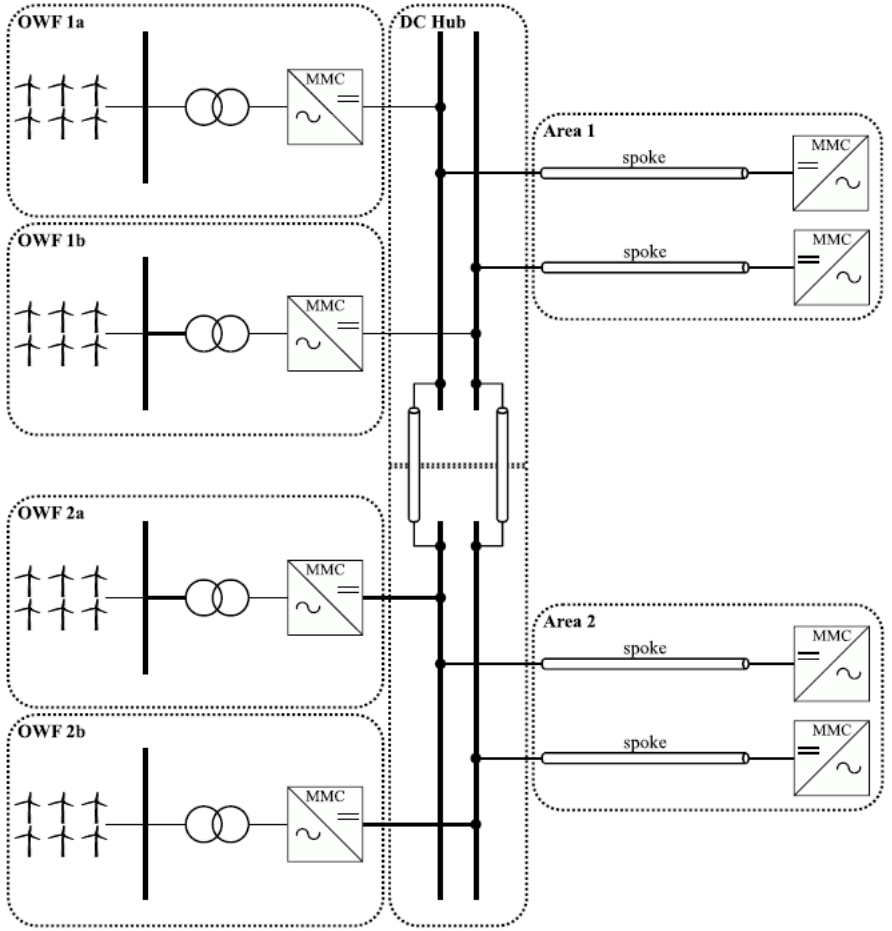
Requires multi-terminal HVDC technology

Loss of largest unit is equal to the rating of one HVDC-pole if a bi-pole configuration is selected

Complex DC-system control and protection schemes are required

Connection of load as the AC-side of one HVDC

For cost efficient expansion, multi-vendor framework is required

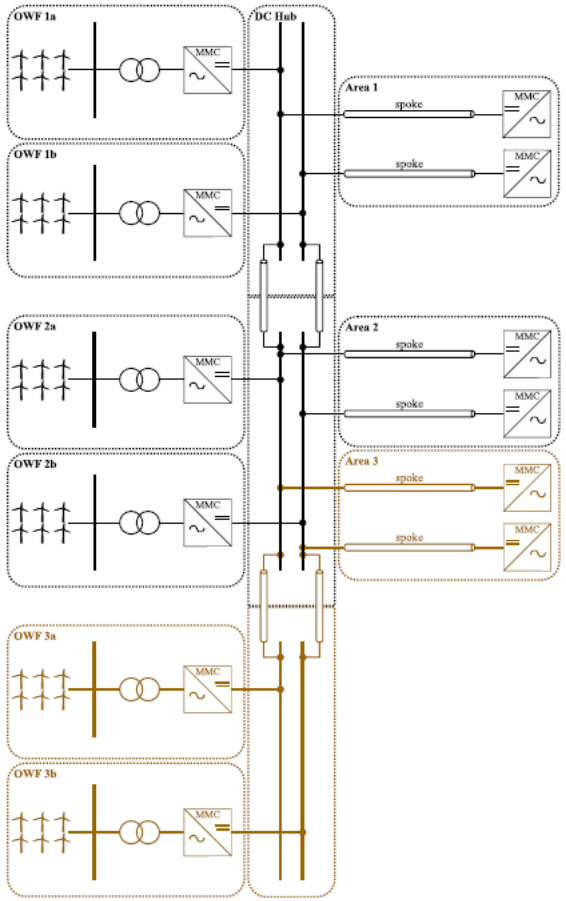


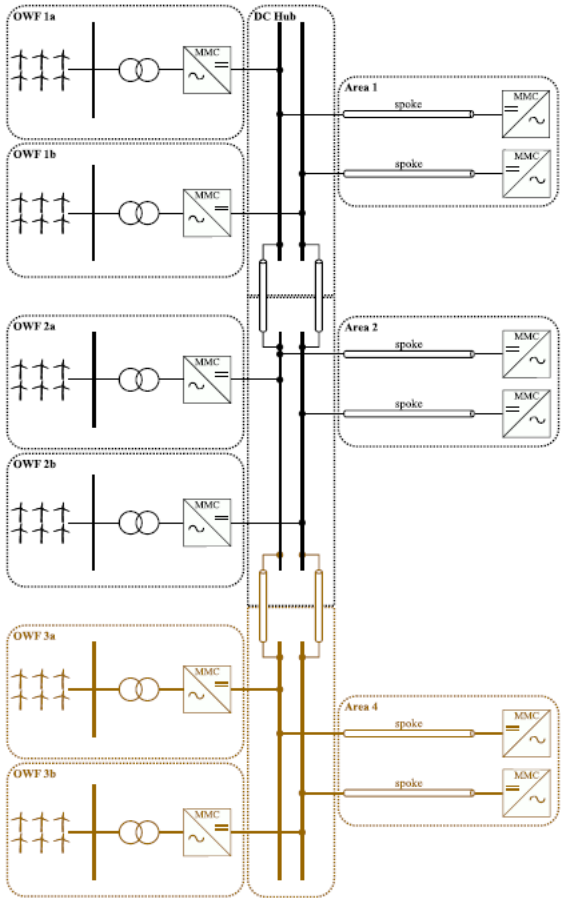
Energy hubs topologies

DC Hub

Expandability

Connecting other hubs requires a DC connection only





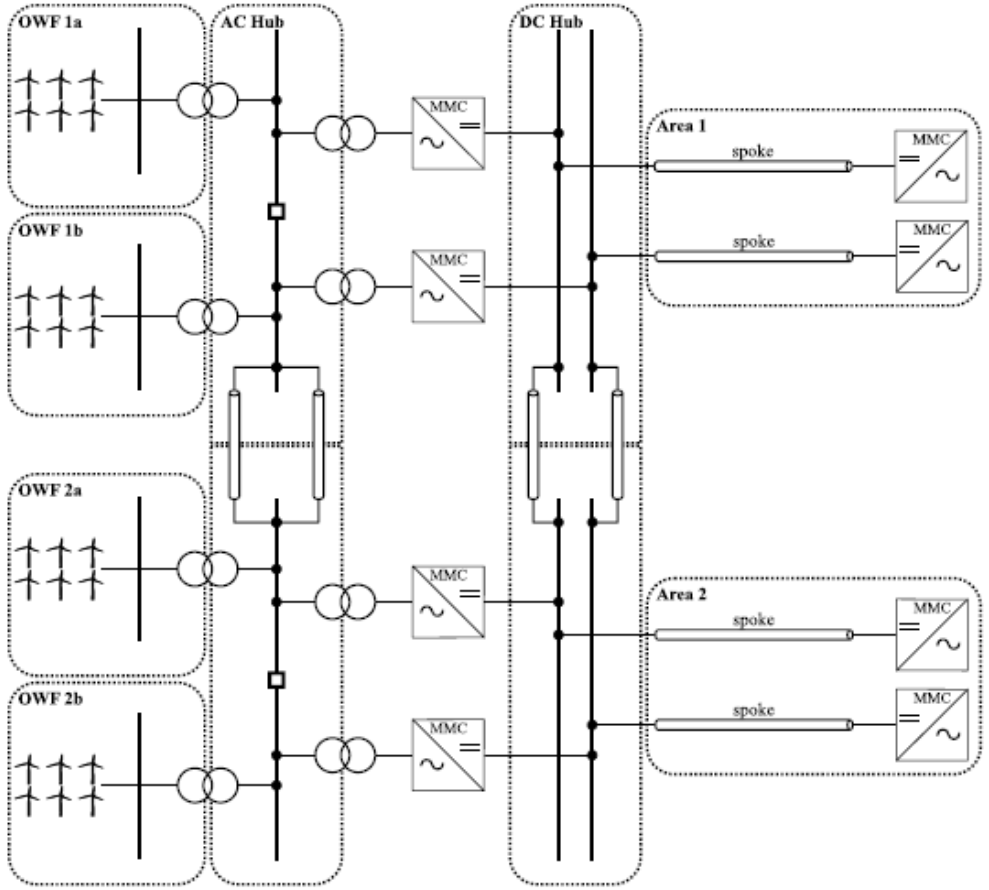
Energy hubs topologies

Hybrid Hub

Combination of AC and DC topology

Can operate in either AC or DC coupled mode

Expensive solution, may make sense as the operational experience of a multi-terminal DC system and DC protection systems is increasing



Summary

- Offshore wind is becoming very large, GW-level plants, far from shore
- Offshore wind is driving the development of HVDC technology, and vice-versa

…offshore energy hubs not possible without HVDC technology

- Offshore energy hubs (islands) is the next generation of grid connection for offshore wind

…and the first (real) steps towards an offshore HVDC grid!

Thank you!

See also:

Panel Session 5 (PS 5.2): Hybrid AC/DC grids for resilient renewable power systems

3:30 PM - 5:00 PM | Shek-O Room, Kowloon Shangri-La

Nicolaos A. Cutululis
Professor, PhD
niac@dtu.dk
DTU Wind and Energy Systems
Technical University of Denmark

References/additional reading

- Cutululis, N. A., et al., (2021). *The Energy Islands: A Mars Mission for the Energy System*.
- Müller, D., et al., (2024) *FEASIBILITY ASSESSMENT OF HUB TOPOLOGIES*