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Cutting edge technologies for the Offshore Wind Industry

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“Offshore Wind Energy in Greece”, Conference 12/12/2022, Athens Imperial
HEREMA, ELETAEN, Grant Thorton

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Offshore Wind Farms : Technology Readiness

- Offshore wind farms are **large investments**, to be constructed and operated in a very **demanding physical environment**
  - Reasonable Assumption : **Mature and proven technologies** should be used to reduce risk

- Assuming 2-3 years are needed to advance from one TRL to the next, then for **wind farms to be operational in 2030** only technologies which today have **TRL7 or higher c**ould be used with low technological risk

TRL : Technology readiness level

A method to qualitatively asses the maturity of technologies in order to support decision making (funding, purchase etc).

TRL level	Definition - European Union
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in lab
5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in operational environment
8	System complete and qualified
9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

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Offshore Wind Farms : WT Size

Offshore Wind turbines have to be LARGE to

- reduce **substructure and foundation cost** (estimated at 30% of total CAPEX)
- reduce **operation and maintenance cost**

Large Offshore WT available today (examples)

- **Vestas V164-10MW** – Commercial operation (TRL 9)
  - D=164m, H_{hub} = 123m
  - Permanent magnet generator , medium speed gearbox
  - Main bearings, coupling, gearbox and generator is possible to lift out separately
- **GE-Haliade 14MW** - Prototype operating – onshore (TRL 7)
  - D= 218m, H_{hub}= 135m, Nacelle mass : 600 tn
  - Direct drive generator,
  - Rotor and generator rotating each on separate bearings

Vestas V164-10MW at Seagreen offshore wind farm, Scotland (Photo: SSE Renewables/Total Energies)

GE Haliade 14MW prototype Port of Rotterdam (Photo: GE)

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Offshore Wind Farms : WT-Size

Greece – 2021
3.0 MW
(100m diameter)

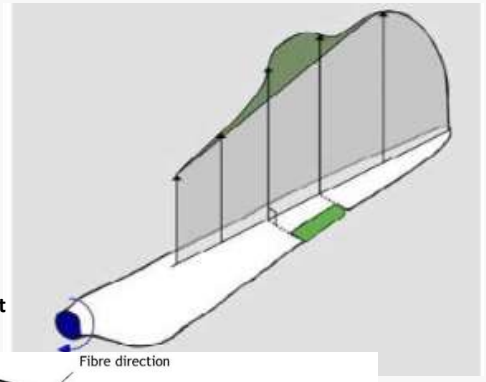
EU – Onshore (2021)
4.0 MW
(120m diameter)

EU – Offshore (2021)
8.5 MW
(150m diameter)

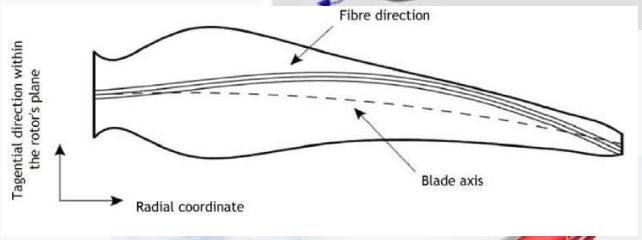
Typical offshore WT in 2030
15 MW
(220m diameter)

Rotor and blade – Innovations

- **Active load control with blade flaps (TRL 4)**
  - Reduce loads on the blades
  - increased cost and demanding driving system
- **Passive load control with blade bend-twist coupling (TRL 4)**
  - By selecting the fiber pattern arrangement in the blade cell, passive twisting of the blade is achieved as the blade bends at high wind speeds , reducing aerodynamic loading
  - 3% decrease in blade mass estimated
- **Recycable blades (TRL 8)**
  - All materials (resins and fibres) to be efficiently separated and re-used after the end of life of the blade)
  - Available on the market since 2022
  - Siemens Gamesa 81m RecyclableBlade already spinning on some SG-8.0-167DD, 8MW offshore wind turbines



INNWIND.EU project



SIEMENS-GAMESA

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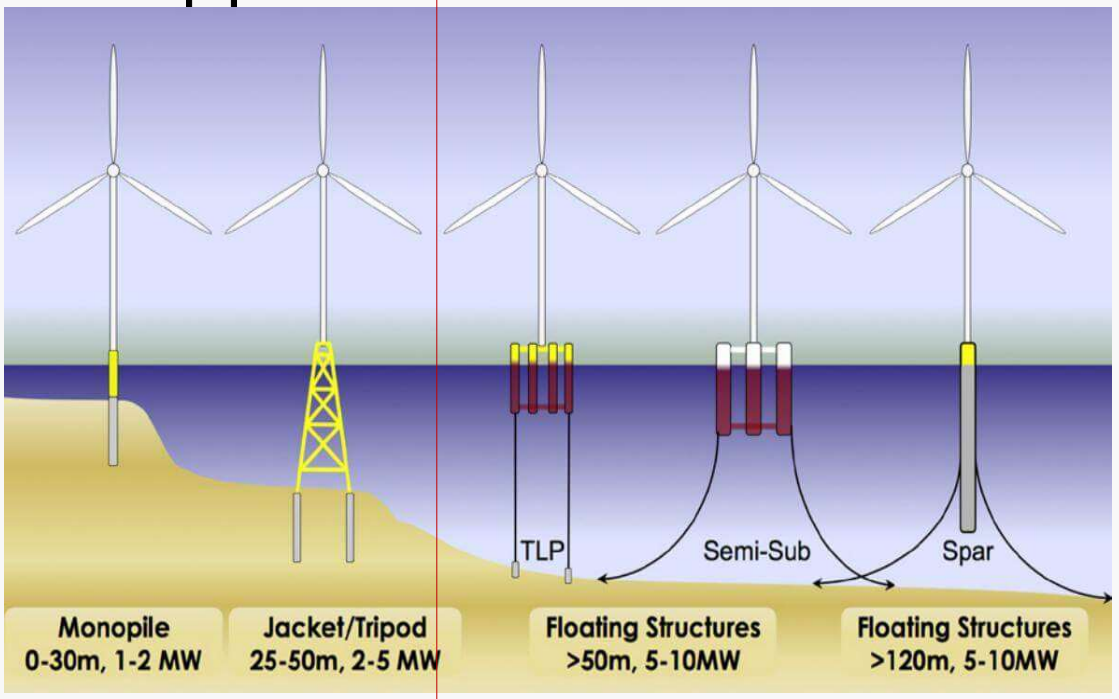
Offshore wind farms : Support structures

Support structure types

- **Bottom fixed**
  - Monopile :TRL 9
  - Jacket :TRL 9
- **Floating**
  - Semi-sub / floater : TRL 7-8
  - Spar / Buoy : TRL 7
  - Tension Leg Platform : TRL 4-5



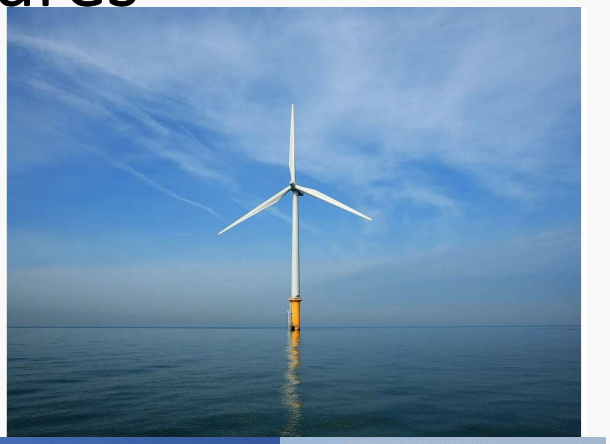
50m limit line
or better
30-60m transition area

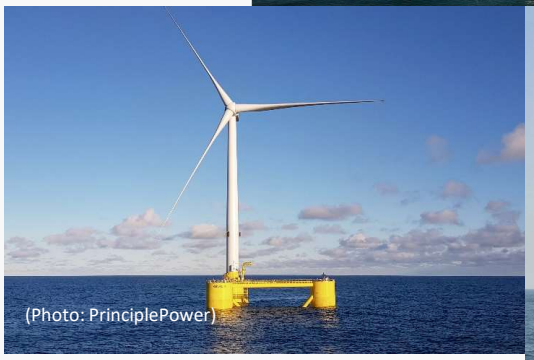
Offshore wind farms : Support structures

- By the end of 2021, there were 5566 offshore wind turbines in EU and UK waters

Of which:

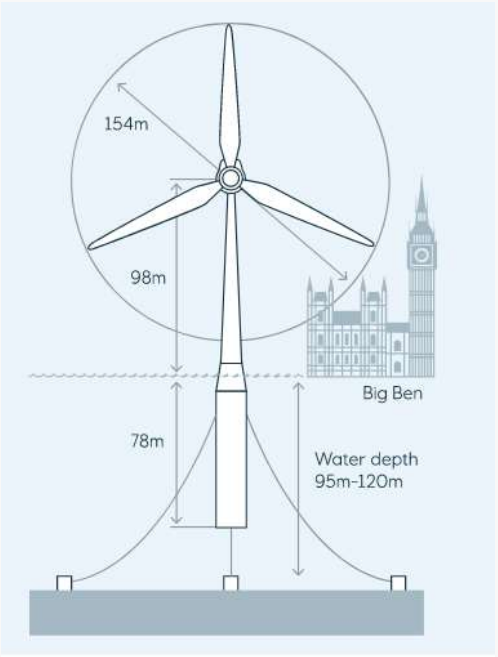
- Bottom fixed
  - Monopiles : 4780 units (TRL 9)
  - Jacket /Tripod : 700 units (TRL 9)
- Floating
  - -Spar : 7 units (TRL 7)
  - -Semi-floater (all types): 9 units (TRL 7)
  - -Tension Leg Platform : 0 units (TRL 4)





Offshore Wind Farms : Support structures - Floating

- **Floating – Examples**
  - **Hywind –Scotland**
  - 5 x SiemensGamesa 6MW
  - Spar buoy floater
  - 95-120m water depth
  - Operating since 2017
  - First prototype (Hywind-Norway, 2.3MW) operated from 2009 to 2018



(Source https://www.equinor.com/energy/hywind-scotland

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Offshore Wind Farms : Support structures - Floating

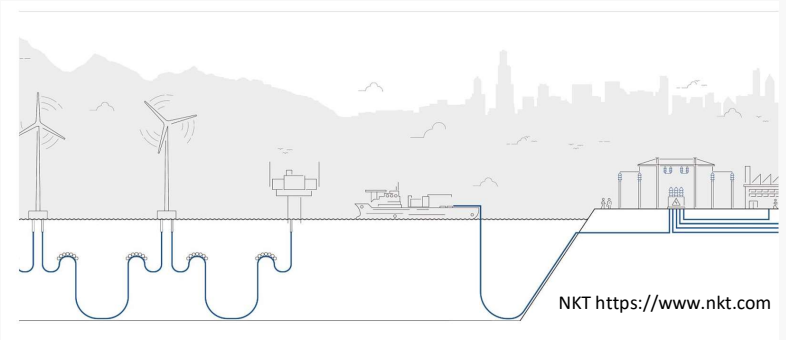
Offshore Wind Farms : Electrical infrastructure

Challenges :

- **Interconnection to main transmission grid : TRL 9**
  - High capacity subsea cables, covering long distances at deep waters
  - Example : Kriti I & II interconnections
- **Offshore HV substations**
  - Bottom Fixed : **TRL 9**
  - Floating **TRL 7**
- **Inter array cables**

  Medium voltage sub sea cables
  - Bottom fixed W/T : **TRL 9**
  - For floating W/T : **TRL 7**

  Crucial detail for floating: **"Dynamic cables"** needed, capable to withstand increased fatigue loading at the transition part between the floating platform and the stationary cable laid at the bottom of the sea



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Offshore Wind Farms : Installation

- **Bottom Fixed**
  - Assembled on site with "onshore-like procedure"
  - Proven method, TRL 9
  - Challenges :
    - Sustainable supply chain
    - Limited availability of specialized ships/cranes
    - Support infrastructure – ports


(Photo: GoldWind)

Offshore Wind Farms : Installation

➢ **Floating.**

- "**Assemble by the dock** , tow to position and connect to pre-laid anchors & cables"
- TRL : 7
- Critical : Port infrastructure
  - Dock front length : 300m
  - Dock depth : 9-15 m
  - Docks with heavy loading capability (15-20 T/m^2)
  - 150 000 m^2 area for storage of WT components.
  - WT integration throughput: 300-500MW/year, 15MW WTs

(indicative values)

(Source : Mott MacDonald | Coos Bay Offshore Wind Port Infrastructure Study)

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Offshore Wind Farms : Support infrastructure

➢ **As a (GoogleEarth) Case study**

- Port of Alexandroupolis, North Aegean

Requirements

- Dock front length : 300m
- Dock depth : 9-15 m
- Docks with heavy loading capability (15-20 T/m^2)
- 150 000 m^2 area for storage of wt components
- WT integration throughput: 300-500MW/year

(indicative values)

Offshore Wind Farms : Installation

STOP PRESS !!

- **Floating installation method for fixed bottom wind turbines**
  - Crane-Ship (**not jacked up**) with dual heavy cranes used in the 275MW Arcadis Ost wind farm in Baltic sea (Germany)
  - Tower assembled on the crane-ship and lifted as one piece to the foundation
  - Nacelle with rotor assembled on the crane-ship on a support tower, and then lifted as one piece to the actual tower
  - Floating crane ship & services provider: HEEREMA
  - Wind turbine : Vestas, V174-9.5MW
  - Developer : Parkwind
  - First turbine installed : November 2022

Source : Parkwind

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Offshore Wind Farms : Operations & Maintenance

➢ Operations and maintenance :Challenges

- Distance from home port / base
  (40 km equal to 1-1.5 hour traveling time by crew transfer vessel)
- limited weather windows,
- increased risk for personnel / special training needed
- **Increased cost**

➢ Mitigation measures

- Preventive maintenance – advanced decision support tools (TRL 6-7)
- Innovative Inspection / surveillance methods using long range UAV (drones) (TRL 6??)

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Thank you for your attention

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The Hywind Scotland floating wind farm. (Photo: Øyvind Gravås / Woldcam - Statoil ASA)