Proposal for the Floating Offshore Wind R&D Roadmap of Greece

Offshore Wind & Floating Offshore Wind Market

The potential for wind energy in Greece is huge, especially for offshore wind energy. This is one of the reasons why **the Ministry of Environment and Energy revealed that Greece has the ambition to add 2 GW of offshore wind by the end of the decade (2030).**

One of the advantages of offshore wind compared to onshore wind is the fact that offshore wind speeds are typically faster and more consistent than on land. This gives us the possibility to increase the size of wind turbines (taller and larger diameter) and therefore to produce more electricity. As such, fewer turbines are needed to produce the same amount of energy as an onshore turbine. Moreover, offshore turbines don't have as much visual impact as those on land and generally they don't interfere with land usage (e.g. residents protest against the installation of onshore wind farms, expressing their concerns about the impact of such an investment on both the island landscape, biodiversity and tourism).

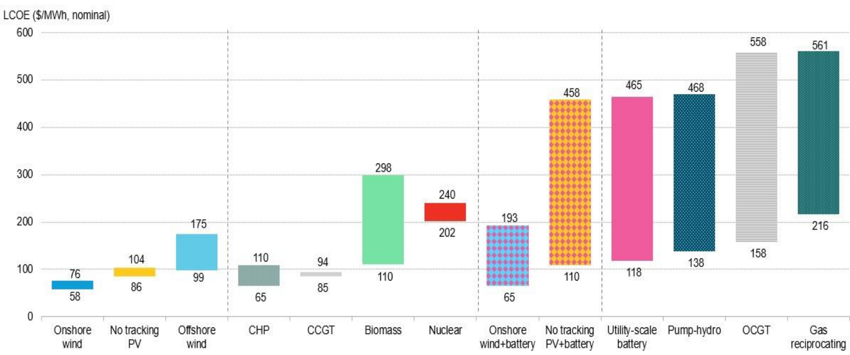

Figure 1 Levelized cost of electricity (LCoE) of major power generation technologies in Europe. (WindEurope 2019)

According to WindEurope, Figure 1 presents the Levelised Cost of Electricity (LCoE) of major power generation technologies in Europe. It can be seen that bottom-fixed offshore wind (BOW) is very competitive compared to other renewable and fossil fuel technologies. Moreover, BOW is on a steady cost reduction pathway with expected costs of €60/MWh and lower by 2025 depending on projects pipeline.

However, the deep waters in Greece mean **floating** wind will be needed for exploiting the offshore wind resources there. Offshore wind initially developed as a bottom-fixed technology in Northern Europe – first in the North Sea and then in the Baltic Sea, where waters are shallow. Costs for bottom-fixed turbines are higher in deeper waters such as in the Mediterranean, but floating wind offers new perspectives. Figure 2 shows that floating offshore wind (FOW) can be a highly competitive solution to conventional (BOW) and other marine technologies. However, in order to be competitive in the long-term, floating wind energy needs to follow the cost reduction pathways that onshore and BOW energy have already experienced. FOW can also benefit from economies of scale of

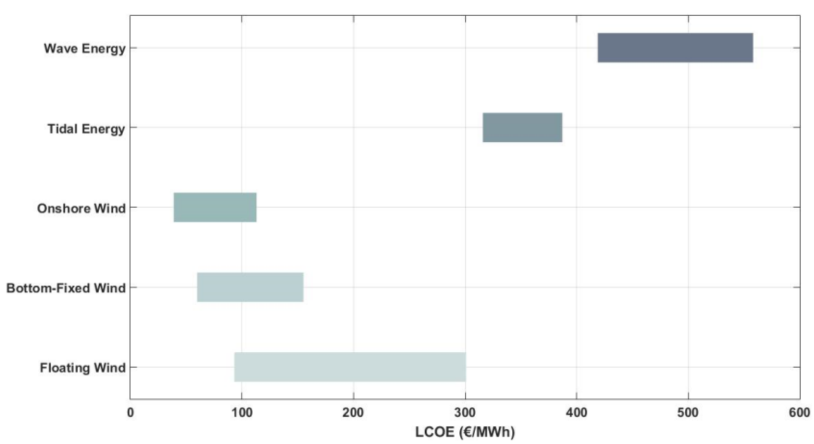

Figure 2 LCoE comparison between marine renewable energy generation technologies. LCoE values are taken from various sources from 2013 to 2019

the well-developed BOW sector since many components are shared by both technologies. Moreover, to reduce the LCoE of FOW, concepts that have been proven in test campaigns and demonstration projects need to be developed further to commercial projects.

Figure 3 presents a forecast on how the LCOE of FOW could be reduced in the upcoming years, compared to BOW and onshore wind. However, it is required advanced research and development (R&D) for FOW to achieve LCoE of 50-55 euros/MWh by 2030 and become competitive to fossil fuel technologies.

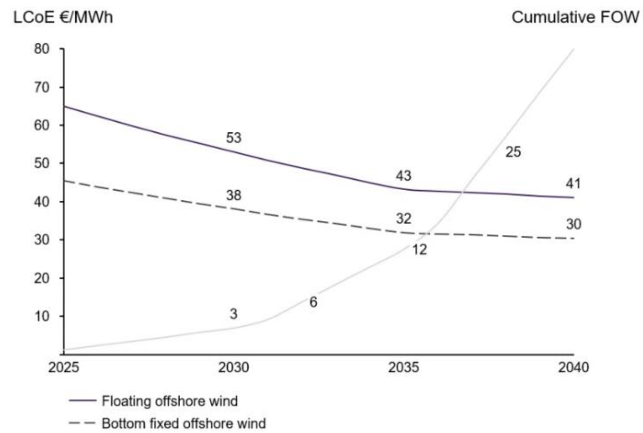

Figure 3 BOW and FOW LCoE projection

Based on the comparison between the CAPEX of the BOW (left) and the FOW (right) in Figure 4 it can be concluded that the substructure cost has a larger portion of the CAPEX for the FOW since it includes not only the floating structure but also the anchor and mooring system. The share of assembly and installation, on the other hand, is lower since FOW turbines enable an assembly in the port and a cost-effective installation offshore by using simple tugboats rather than Jack-up vessels that are used for bottom-fixed wind turbines. Therefore, substructure design and manufacturing optimization of FOW should be prioritized with respect to R&D.

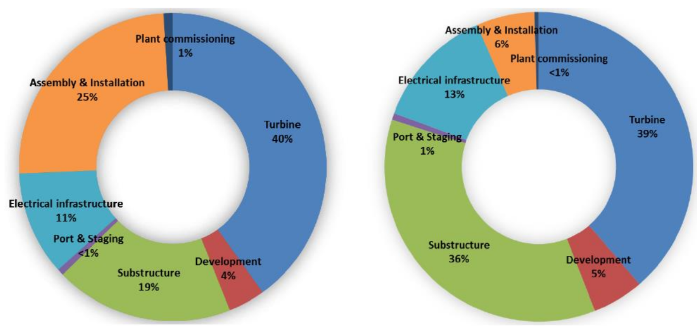

Figure 4 CAPEX breakdown; left: BOW; right: FOW

Recommendations & Guidelines for Research & Development

Design Optimization of FOW substructures

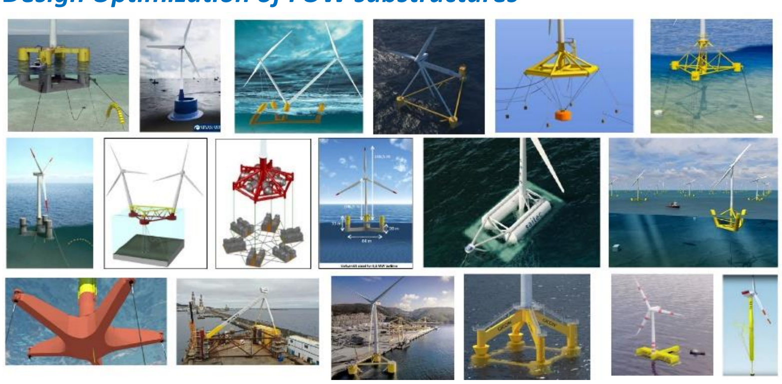

Figure 5 Some of the numerous FOW concepts proposed to date

More than 30 FOWT concepts have been proposed. However, this broad range of floater types being up to now investigated - either as research designs, under development, in prototype stage, or already in demonstration projects - inhibits fast achievement of high technology readiness levels (TRLs). Furthermore**, less diversity in floating support structures would allow more focused research, development of required infrastructure, specification and adaption of suppliers and manufacturers, as well as realization of serial production.** Then, FOWTs could become soon cost-competitive as bottom-fixed offshore wind turbine systems.

In addition, it is important to:

- Perform socioeconomic, environmental, SWOT (strengths, weaknesses, opportunities, and threats) and MCD (multi-criteria decision) analysis.
- Choose FOW concepts based on the area of development and its environmental conditions. Specifically, for the FOW R&D roadmap of the country the following should be taken into consideration:
    - Ports, shipyards and general infrastructure
    - Local industrial sector (Greece has strong concrete and cable industry) – local content
    - Environmental conditions (mainly water depths, wave and wind conditions)
- Optimize the chosen concepts or create synergies between different concepts (advantages of different systems can be combined in one floating structure).
- Optimize the engineering process for the design of FOW with strong focus on:
    - Non-linear time-domain simulations under combined loads (turbine control, wind, waves, motion induced loads)
    - Floater and Tower Design Geometry optimization
    - Integrated system analysis including wind turbine controller, motion characteristics of floater, mooring system and dynamic cable.

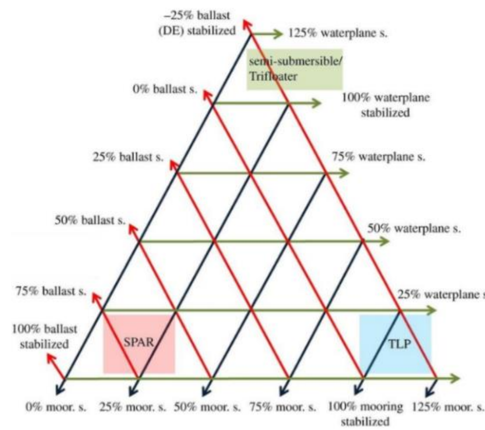

Figure 6 Stability triangle for floating structures

Cost reduction potential through industrialization

Industrialization is key to reduce cost of Floating Wind and R&D is the cornerstone for the healthy growth of the FOW industry. It is proposed to support the development of the following points:

- Centralization of production at offshore hubs and shipyards for utilization of expensive equipment and facilities
- Mass production with distribution of fixed investments over a large number of units
- Standardization of components, procedures and guidelines to increase production efficiency as well as reduction of uncertainties and risk
- Digitalization of operations, traceability of products from raw materials up to the final component and its location on the wind farm and automation of quality inspections.

Materials and monitoring for FOW

Effective ways to decrease the LCoE of FOW are to obtain highly durable structures, which can resist the harsh marine conditions for 25 years or more, and to improve the performance of structural materials and coatings. To achieve the aforementioned targets the following developments are proposed:

a) new advanced steel grades (e.g. HSS) for structures and mooring systems with superior corrosion and mechanical properties
b) combined high performance extruded polystyrene (XPS) foams and concrete (multi-material approach) to reduce the installation costs and improve floatability capacity of current concrete floating platforms
c) novel sandwich materials for secondary parts for further weight reduction

d) in-situ monitoring devices (embedded sensors for online monitoring) for structures and coatings (e.g., smart coating functionalities can be implemented through fully embedded sensors to assess in real time structural health status)
e) material solutions for turbine blades with increased recyclability with respect to current state-of-the-art (e.g., recyclable PU resin, debonding on demand adhesives and novel 3R thermoset resins composites)

New FOW concepts

Figure 7 Example of Hybrid Wind Wave System (W2Power by Pelagic Power)

1) Hybrid Floating Offshore Wind and Wave Energy Systems (WES)

a. *Floating Offshore Wind Platform Motion Suppression:* Wave systems can be used to reduce the motion of offshore wind turbine platforms both actively and passively and thus dampen the wave field.

b. *Local Offshore Wind Power Needs*: In addition to reducing structural loading, WESs can be used to provide local power for floating offshore wind turbine systems.

c. *Increase power density*: the power density can be increased and the fluctuations in the power production can be balanced to some extent. (even though the power generation from WES is an order of magnitude smaller than from FOW)

2) *Vertical Turbines:* Vertical-axis wind turbines for FOW energy could have several benefits, including:
   a. Lower center of gravity, which reduces platform costs (Substructure costs now represent the largest single contributor to LCoE-see above)
   b. Improved efficiency over Horizontal Axis Wind Turbines at multi-MW scales
   c. Reduced Operation and Maintenance costs through removal of active components and platform-level placement of drivetrain (e.g., blade pitch control, yaw, etc.)

Figure 8 Example of Vertical Axis Floating Wind Turbine

For both aforementioned concepts it is important to perform R&D and comparative financial investigations, in order to identify improvement points and to examine the financial feasibility of those concepts, compared to the existing FOW concepts.

References

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