Sensitivity analysis of cost parameters for floating offshore wind farms: an application to Italian waters

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1. Introduction

Over the last few decades, a renewed progress of the offshore wind sector has taken place. In particular, floating wind turbines represent the next frontier in the wind power industry.

The development of this technology is strongly dependent on its economic feasibility. There follows that the development of economic analyses is crucial to highlight the possible greater potential of floating offshore wind farms, and to support their sustainability and technical value.

Currently, only few studies are available on their possible investment cost. Therefore, a cost assessment for floating offshore wind farms is largely necessary to ascertain if this new technology is economically sustainable.

The main objective of this work is to develop a sensitivity analysis of the main cost parameters for floating offshore wind farms. This derives from a proposed general cost model which takes into account all the cost parameters. In this study, the model is applied to the Italian national waters. The proposed study should be helpful for future decision-making processes. Results should provide guidance on how to preliminary assess the quality of a site for floating offshore wind farm installation.

2. Methodology

Economic aspects. The method proposed is based on a model for the life cycle cost assessment of floating offshore wind farms. This includes calculation of Capital cost (CAPEX), C_{Capex}, Operation and Maintenance cost (OPEX), C_{Opex} and Decommissioning cost (DECEX), C_{Decex}. Therefore, the life cycle cost C_{LC} of a floating wind farm is given by:

$$C_{LC} = C_{Capex} + C_{Opex} + C_{Decex}$$

$$C_{Capex} = C_T + C_P + C_{TS} + C_M + C_A + C_{IT} + C_{IP} + C_{ITS} + C_{IMA}$$

$$C_{Opex} = C_O + C_{MD} + C_{MI}$$

CAPEX

- C_T: cost of wind turbine
- C_P: cost of floating platform
- C_{TS}: cost of transmission system
- C_M: cost of mooring system
- C_A: cost of anchoring system
- C_{IT}: cost of wind turbine installation
- C_{IP}: cost of floating platform installation
- C_{ITS}: cost of transmission system installation
- C_{IMA}: cost of mooring and anchoring systems installation

CAPEX is mainly calculated analytically and/or as a function of the installed power of the wind farm.

OPEX

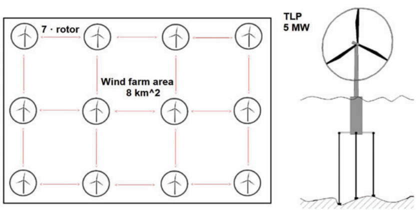
- C_O: cost of operation
- C_{MD}: cost of direct maintenance
- C_{MI}: cost of indirect maintenance

OPEX is calculated analytically and/or as a function of the installed power of wind farm.

DECEX

It is calculated as a percentage of installation procedures costs, corresponds to 70%, 10%, 90% and 90% of the complete floating system, cables, substations and mooring and anchoring system installation procedures costs, respectively.

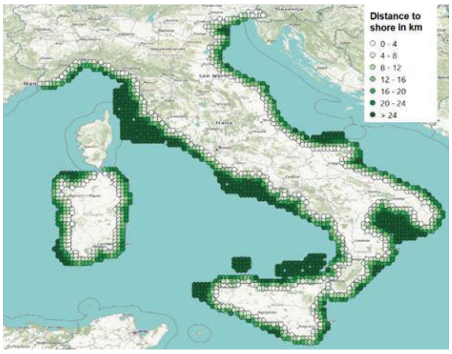
Sensitivity aspects. Sensitivity analysis has been applied to TLP floating offshore wind farm and has been developed in QGIS. A farm made of 12 wind turbines with a nominal power of 5 MW, supported by a TLP floater and located at a distance of seven rotor diameters from each other, is considered. The rotor diameter is 126 m. Moreover, farms are arranged in three rows of 4 turbines, respectively, and each wind farm covers a total area of around 8 km². The layout of wind farm is shown below.



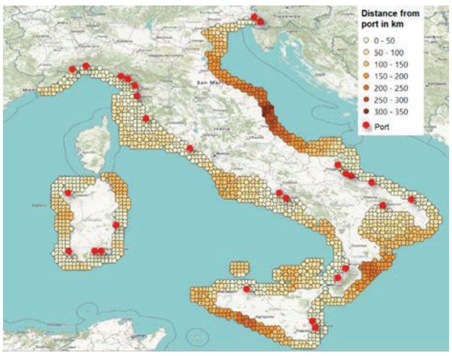
The calculation domain has been defined, corresponding to the space between Italian coastline and the national water limit. In this domain, 1621 sites have been generated corresponding to possible farms positions. Subsequently, has been calculated the total cost for all sites in the reference domain, based on the actual value of the input variables.

Input variables. The main input variables considered in this work are:

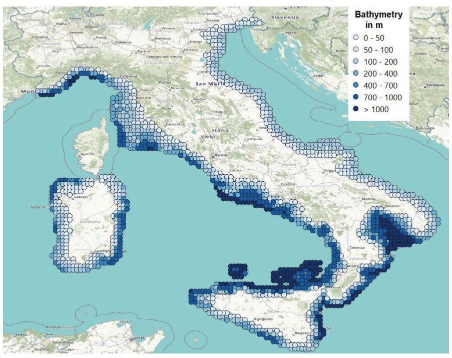
- Distance to shore: it has been defined considering the limit of national waters (within 22 km), with the exception of some places (presence of archipelagos, islands, historical bays). it ranges between 0.6 to 93.5 km.



- Distance from port: it has been considered 28 ports. The range of distance between the floating offshore wind farms and the nearest ports is between 5.9 and 321 km.

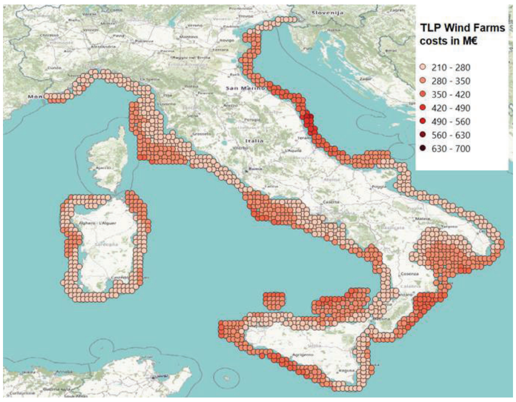


- Bathymetry: it ranges between 0 and 3500 m.

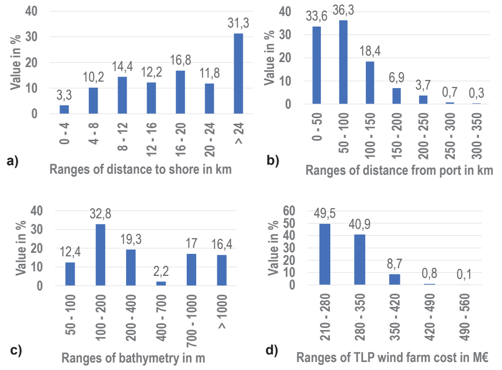


3. Results

The main result of this work is a cost map for the Italian national waters. Based on the draft length of TLP, the map was limited to the sites were the water depth exceeds 55 m. Consequently, from a total of 1621, only 1388 are considered, as shown in the Figure below.



Histograms shows the occurrence ranges of the distance to shore, distance from port of operation, the bathymetry and the TLP wind farm costs of the sites considered in the analyses.



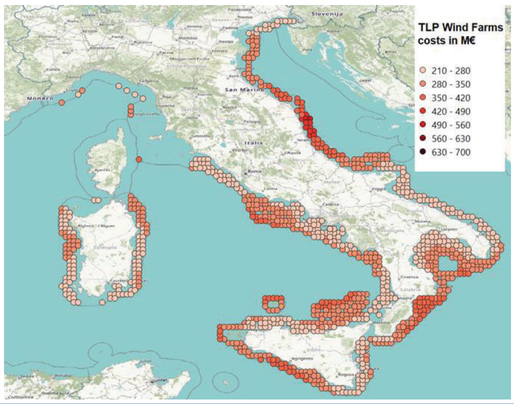
Referring to the wind farm cost the lower ranges are located in areas close to shore and to the port of operation, and in relatively shallow waters.

The domain defined between the Italian coastline and the national water limit includes also:

- Protected areas
- Navigation limitations

Consequently, the possible sites further decrease, becoming 1026.

In the Figure below an overview of the life cycle costs of the TLP wind farm is shown, to be compared with the benefits coming from producibility. Therefore, a similar map of producibility need to be prepared, which is beyond the scope of this paper, and comparison of then two maps would allow drafting a third map, containing the distribution of the values of the Levelized Cost of Energy (LCOE). This final result is the tool to be used in the planning of possible investments installation of offshore wind farms.



4. Conclusion

An application of sensitivity analysis of the main cost parameters for TLP floating offshore wind farms has been presented. The total life cycle costs of the farm were evaluated through a cost model, considering CAPEX, OPEX and DECEX.

In the analysis, bathymetry constrains deriving from the minimum TLP draft, the environmental aspects, i.e. the presence of protected areas, as well as navigation limitations were taken into account.

The final result is in the form of a life cycle cost map, giving a bird's-eye view of the variation of the costs of the farm, to be compared with a similar map describing the variation of producibility, beyond the scope of this research.

Comparison of the two maps allows evaluation of the distribution of the LCOE for a specific project, therefore giving a first idea of its feasibility.

Therefore, the approach presented here is to be considered for use in the early stage of the decision-making process, as a tool for the preliminary assessment of feasibility and of political evaluation.

References

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