Evaluation of an Offshore Wind Power Project: Economic, Strategic and Environmental Value

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***Abstract*—**The use of wind energy for electricity generation is growing rapidly across the world and in Portugal. However, the geographical characteristics of the country along with the average wind regime and with the environmental restrictions imposed to these projects create limitations to the exploit of the onshore wind resource. The best onshore wind spots are already committed and the possibility of offshore wind farms in the Portuguese cost is now being considered. This paper aims to make a contribution to the evaluation of offshore wind power projects in Portugal. The technical restrictions are addressed and the strategic, environmental and financial interest of the project is analysed from the private company and public points of view. The results suggest that additional support schemes are required to ensure private investors interest for these projects. Assuming an approach of direct substitution of energy sources for electricity generation, the avoided CO_2 equivalent emissions for an offshore wind power project were quantified. Based on the conclusions, future research is proposed to address the environmental and social impacts of these projects.

***Keywords*—**Feed-in tariff, offshore wind power, project evaluation.

I. INTRODUCTION

THE wind electricity generation sector is essential for the attainment of the European renewable objectives. According to the EU forecasts, the large hydropower will maintain its dominant position in renewable energy sources (RES) for electricity generation for the near future. However, the use of wind energy will continue expanding and, in 2020 the wind electricity generation capacity will overcome the hydro sector in the EU-27 [1].

The offshore wind power sector is emerging and governments and private companies start to show interest on these projects. Wind turbine technology is a proven technology and has been applied offshore with some success [2]. However, as pointed out by [3], offshore investments are clearly different from the onshore ones. The planning process is much more complex and time consuming. Also, the construction, maintenance and grid connection call for new solutions. The offshore wind projects are still an innovative and risky business, requiring resources and organizational skills frequently associated with big companies operating in the energy sector. So far, the development of wind power offshore technology is being mainly concentrated on the North of Europe. However, according to the Portuguese projections, the possibility of investing in the next 10 years on this technology is already being considered [4].

The electricity generation projects are highly complex, involving several decision makers and presenting significant external impacts. Although there are already some offshore wind farms in operation, the experience of electricity power producers with this technology hardly may be compared with the one for onshore technology. The study of an offshore project requires firstly a technical analysis, in order to identify the wind power potential of the location, the available equipment and possible implementation. The strategic analysis is also fundamental, aiming to characterize the sector and internal capacity of the companies involved in the project. Based on the technical and strategic studies, the financial evaluation of the project may then be conduct, concluding if the necessary conditions to ensure its viability are expected to be present.

The main objective of this paper is to analyze the economic viability of a hypothetical offshore wind power project in Portugal. The present market conditions and feed-in tariffs are considered and the strategic and environmental value of the project is also evaluated. Next section briefly describes the offshore wind power development and main characteristics. Section 3 presents the empirical study based on the technical, financial, strategic and environmental evaluation of a proposed project. A sensitivity analysis is performed in section 4 and the main conclusions are summarized in the last section.

II. THE OFFSHORE WIND POWER

The wind power had a massive growth since the 90's till the present. Between 1993 and 2009 the total wind power installed in the world grew at an average annual rate of 28%, equivalent to about 9670 MW/year. In 2009, reached a value

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close to 158 000 MW and almost half of it were installed in Europe [5]. As for the offshore technology, it is still giving the first steps. The installed offshore wind power in the EU-27 was 1914 MW in 2009, representing then about 2.5% of the total installed wind power. The development of offshore wind has mainly been in northern European counties, around the North Sea and the Baltic Sea, in relatively shallow waters and close to the coast (less than 20 km), in order to minimize costs [6].

Between 2011 and 2020, [7] expects the total installed offshore wind capacity to grow steadily to reach 40 GW in 2020. According to these projections in 2020, offshore wind power would generate electricity equal to between 3.6% and 4.3% of EU electricity consumption, depending on the development in electricity demand. Including onshore, wind energy would produce enough to meet between 14.3% and 16.9% of total EU electricity demand by 2020.

The investment cost of an offshore wind power project is much higher than the one for the onshore technology due to aspects like the higher complexity of the logistic process, the need for expensive foundations, higher turbine cost and the cable complexity for the connection to the grid. This cost depends heavily on aspects like the depth and distance to coast which turns difficult to assess average values. The [7] report analyzed several offshore wind projects and concluded that the investment cost ranged between 1.2 million €/MW to 2.7 million €/MW. This study used a sample of projects in different countries but all of them installed in relative shallow waters (less than 20 m depth) and less than 20 km from the coast. Reference [8] used a larger sample where a few depth water projects were included. Even so, the study is limited by the reduced number of available projects to be included, compromising this way the statistical significance of the results. However, it is clear that projects in depth water may have an investment cost much higher than the values previously mentioned and can reach values close to 3.7 million €/MW. Reference [9] analyzed the investment costs of offshore wind as a function of water depth and distance to coast and reached values of about 2 514 €/kW for a water depth of 40-50 m. As for the operation and maintenance costs, [7] points to values around 16 €/MWh. This report calculated the levelised production cost for selected offshore wind, obtaining values ranging from around 60 €/MWh and more than 90 €/MWh.

The costs of the offshore wind power technology are much higher than the ones for onshore. Nevertheless this difference may be partly offset by the expected more favorable wind regime, resulting in higher electricity generation values and consequently in higher revenues. Reference [10] estimated that while onshore wind power plant can typically be utilized about 2000–3000 h per year, an offshore wind power plant can have 3000 to 4000 operating hours per year.

Besides the financial aspects, the assessment of the public acceptance of wind power projects is also fundamental for a comprehensive project appraisal. On-land turbines are frequently associated with visual damages on the landscape, noise annoyance, impacts on birdlife and other types of negative impacts on the ecological environment [11]. The visual impact is also relevant for the offshore wind power projects along with the navigational constraints, as discussed by [8]. These authors argue that the negative environmental consequences are generally local, whereas the positive environmental consequences are global. On the other hand, [12] concluded that offshore wind power environmental impacts can be mitigated through good sitting practices. The authors also argue that there are opportunities for environmental benefits through habitat creation and conservation protection areas. Studies like [11], [13]-[15] among others addressed the public acceptance of offshore wind power project and demonstrated that this is not a consensual issue. Attitude formation towards offshore wind farms appears to be dependent of a set of socio-economic characteristics, subjective values and opinions, the proximity of the respondents to the wind farm, the use of the coast/beach, among many others variables.

The projections for offshore wind power show the almost unlimited potential of this technology. However, being a new technology, considerable challenges exist on the financial, environmental and social dimensions. From the point of view of private investors these challenges are translated in additional risk factors that must be assessed and properly included in the business case.

III. Project Evaluation

EWEA projections (http://www.ewea.org/offshore/) indicate already a projected offshore wind power plant for the North of Portugal in 2017, with 301 MW of total installed capacity and using 3.5 MW turbines. Also, REN [4] pointed to the possibility of reaching 550 MW of installed offshore wind power in Portuguese coast by 2019. The geographical characteristics of the country along with the estimated wind resource and the environmental restrictions somehow limit non explored onshore wind power potential. It becomes then relevant to analyze the viability of offshore wind projects in Portugal. This work addresses the strategic, environmental and economic interest of these projects taking into account the technical restrictions and the support policies.

A. Technical analysis

The commercial value of an offshore project is highly dependent of the energy production, which in turn directly depends on the wind speed. A small difference on the wind speed represents a very significant change on the obtained profits of the project, as the electricity generation is proportional to the cube of the wind speed. Picking the best location is then fundamental. Although the offshore wind characterization process is costly, as underlined by [6], a reliable financial report must be based on these previous technical studies.

The wind power resource potential is then a fundamental parameter for the computation of the viability of the investment. To the authors' knowledge, the studies characterizing the wind regime on the Portuguese coast are still few. According to some international studies, an average wind speed of about 6.5 to 7.5 m/s may be expected for a bathymetry level of 25 m, reaching 8.5 m in a few more favorable spots (http://www.windatlas.dk/Europe/Index.htm). Much of the potential sites are located in deep waters as described by [16], with preliminary values showing an expected wind potential of about 3400 to 3700 h/year in the most favorable wind spots. Locations at the Northern coast present a good compromise between electric grid connections and resource assessment, with wind potential reaching 2600 to 3000 h/year at a bathymetry depth of 20 to 30 m. It should be noted that the average full capacity equivalent operating hours for onshore wind power plants ranged between 1640 and 2090 h/year in Portugal in the last three years (own calculations from [17]). This demonstrates the expected more favorable wind conditions at sea and may partly compensate the higher project costs.

B. Strategic analysis

The SWOT analysis is frequently used to describe the Strengths, Weaknesses, Opportunities and Threats for a business project or company. However, it is been also used on the analysis of energy sectors, technologies and policies [18]-[20]. Fig. 1 presents a SWOT analysis for the offshore wind power sector in Portugal, taken into account the external characteristics of the Portuguese energy system and the internal characteristics of companies presently operating in the market and of the potential offshore wind power projects.

The unpredictability of wind speed and the consequent variability of the electricity generation represents an important weakness of the wind power sector in general. This should be a major issue of concern both form the private investor and from the energy planner/regulator points of view. In fact, the generation company profits are directly linked to the electricity generated and the security of supply of the National electricity system is a key priority of the energy decision makers. To tackle this problem, and due to the difficulties on electricity storing, companies and energy planners strongly rely on the diversification of their portfolio of electricity power plants. In Portugal, the wind and hydro power combination is particularly important for the operations management and planning of the electricity system, as discussed in [21].

The existence of regulated feed-in tariffs reflects the need to ensure the interest from private investors, representing an opportunity to reduce the risk of the project. This way, the liberalization trend of the market becomes a threat and even if different protection mechanism are to be considered (for example green certificates), the competition from other RES must not be taken lightly. For the particular case of Portugal, the high concentration of the electricity market may create additional difficulties to the entrance of new operators, reducing the incentive to the implementation of new technologies that may imply additional changes to the existing grid, as discussed by [22].

	Strengths	**Weaknesses**
Internal	Offshore wind speed higher than onshore wind speed. No population density. Experience of the national companies on the wind power sector and motivation of the private companies. National cluster for the wind industry. Independence from fossil fuel markets.	High installation costs. External impacts. Unpredictability of the wind speed. Technology still under development. Reduced experience with offshore wind technology. Economic viability dependent of regulated tariffs.
	Opportunities	**Threats**
External	Still no offshore wind farms in Portugal. Market growth perspectives. Revenues still protected by feed -in tariffs and by ensured access to the grid. Energy and climate change priority on policy agendas.	Competition from other RES. High concentration of the electricity market. Liberalization trend of the market and of the tariffs. Increasing demand for turbines across the world.

SWOT Analysis

Offshore wind power sector in Portugal

Fig. 1 SWOT analysis for the offshore wind power sector in Portugal

From the positive side of the project, the more favorable wind regimes at sea must also be underlined. The higher distance from populations represents another important advantage that may help and abbreviate the licensing procedure. Wind is an endogenous energy resource and, as so, the increasing use of wind power contributes to the security of supply of the country, to the reduction of the external energy dependency and protects the energy system from the fossil fuels price increase. The concerns with security of supply and the recognized energy relationship with climate change are on the top of European countries priorities creating an opportunity to the wind power sector.

The experience of national companies operating on the wind power sector is also a fundamental advantage for the investors. The national cluster for the sector, demonstrates the interest and motivation of private companies. The offshore segment may add additional importance to this cluster with important social and economic gains both at regional and local levels. As potential weaknesses, the reduced experience with the offshore technology, along with the lack of studies characterizing in detail the wind regimes in the Portuguese coast must be recognized. It should be noted however, that the pointed weaknesses are at the same time contributing for the creation of new business opportunities. This is a sector that is far from being fully explored at international level, it presets high growth perspectives both for the electricity generation sector and for the technology development, industrialization and all kind of associated services.

C. Financial evaluation

For the financial evaluation the installation of a wind farm in the North of Portugal was considered, aiming to analyze the viability of project from the private investor point of view. This project was used as an example, based on average costs published on the literature for offshore wind power plants and on the estimated characteristics of the wind resource near the Portuguese coast. Table I and Table II summarize the cost and financial information used on the analysis along with obtained financial indicators of the project.

TABLE I
DATA CONSIDERED FOR THE FINANCIAL EVALUATION OF THE PROJECT

Number of turbines	30
Turbine power	3500 kW
Total installed power	105 000 kW
Investment cost	2 514 €/kW (based on [9])
Total	263 970 k€
O&M cost	16 €/MWh (based on [7])
Total	5 040 k€/ano
Full capacity equivalent operating hours	3000 h (based on [16])
Electricity generation	315 000 MWh/ano
Electricity tariff	74 €/MWh feed in tariff for wind power in Portugal
Income	23 310 k€/year
Life time	25 years
Discount rate	10%

TABLE II
RESULTS OF THE FINANCIAL EVALUATION OF THE PROJECT

Cost/Income	Present value (k€)
Investment cost	263 970
O&M cost	45 748
Income	211 586
Net Present Value (NPV)	-98 132
Internal Rate of Return (IRR)	5%

The results demonstrate how ensuring the financial viability of wind power projects in the Portuguese coast may be difficult, taking into account the present feed in tariff for the wind sector. Even if more favorable wind conditions were to be considered, reaching for example 4000 full capacity equivalent operating hours, the IRR would still only be 8%. However, the private investor and energy policy decision makers must take into consideration that this is an innovative project, with strategic and environmental gains that hardly may be addressed by a pure financial analysis. The issue of non financial project evaluation is longer debated in [23]. The presented analysis assumed that the feed-in tariff for the offshore wind power technology would be equal to the one presently used for the onshore projects in Portugal. However, the potential National interest of the offshore wind power technology may give rise for a differentiation of these feed in tariffs in order to increase the private investors' interest on these projects.

D. Environmental evaluation

The energy production and consumption represent the largest sources of greenhouse gas (GHG) emissions in the EU. In Portugal, about 90% of the CO_2 emissions are due to the activities related to energy consumption, being the electricity and heat generation particularly relevant. In fact, about 1/3 of the CO_2 emissions come from fossil used for electricity generation [21]. The average emission factor for the public electricity and heat production sector was 311 g CO_2 $_{equivalent}/kW_{hconsumed}$ (own calculations based on [17] and [24]) in 2008. Assuming the direct substitution and that the electricity generation from wind power releases zero emissions, the avoided emissions from the investment under analysis may be computed.

Avoided emissions = 0,311 × 315 000 = 97 981 ton CO_2 equivalent/year.

It should be noted that this information only allows for a rough estimation of the avoided emissions. As [21], [25] showed, the increase of the installed wind power in the Portuguese system will have an impact on the efficiency of the thermal power plants and consequently on the average emission factor of the electricity sector. The same way, an electricity system highly dependent on coal will have avoided emissions much higher than the ones obtained for systems with high RES share or even based on natural gas power plants.

Nevertheless, besides the avoided emissions other external impacts associated with the offshore wind power projects must always be taken into consideration. These impacts, although not being easy to quantify or even identify during the initial studies, should not be overlooked. The full assessment of environmental and social impacts along with the identification of the relevant stakeholders is fundamental for the public acceptance of the project and for the effective concretization. Reference [6] report puts in evidence aspects such as the visual impact of the offshore power plants, the noise during the plant construction with significant impacts on the sea life, the impact on fish and birds communities among many others. Studies like [13], [11] or [26] underline the need to properly assess the environmental aspects and public acceptance of the offshore wind power projects as well as it is recommended for onshore projects. A more detailed description of the subject may be found in [21] (Chap. III.4.5).

IV. Sensitivity Analysis

Due to the innovative character of the project and the little information available, a sensitivity analysis is presented focusing in particular on three main variables: the feed in tariff, the discount rate and the investment cost, assumed on the base case scenario.

There are several incentives and support schemes designed to promote the development of electricity generation from RES. These incentives may be based on market prices with additional premium values, on the imposition of minimum shares to electricity generators and suppliers, on the existence of green certificates or more frequently on feed-in tariffs set for a fixed period. A description of these mechanisms for the EU member states may be found in [7]. This study points already to the existence of different feed-in tariffs for the offshore and onshore wind power projects in countries like Germany, Greece or France. In Germany for example, the feed-in value for offshore projects is set at 91 €/MWh for at least 12 years. As for France, this value is 130 €/MWh for 10 years.

In Portugal, the present fixed feed-in tariff is about 74 €/MWh for wind projects guaranteed for 15 years (2010 value, according to Decree Law 225/2007). However, the Portuguese feed-in tariffs have been suffering adjustments over the years, in order to create conditions to attract investors to a sector that is expected to contribute to emissions reduction, to the regional and national development and to the reduction of the external energy dependency. The feed-in tariffs in Portugal is longer debated in [27].

As for the discount rate, theoretically, high discount rates favor technologies with low investment values and higher variable costs. As seen in Table II, wind power technology has a high capital costs that must be compensated by the returns over the long run. This means that the financial results of the project will be highly favored by a reduction of the considered discount rate. Reference [10] results also illustrated the importance of this variable and demonstrated how the economics of wind power is strongly affected by the use of higher discount rates.

The reduced number of offshore projects along with the lack of information for the Portuguese coast turns the process of cost estimation very difficult. As seen in Section II, the average investment values are not straightforward and depend much on the coast characteristics. Although, some studies point to the possibility of the reduction of the investment values (see for example [7]) the estimations are uncertain and the Portuguese coast characteristics may create additional difficulties to the project implementation.

Table III presents the results of a simulation procedure for different conditions. The main objective is to estimate the fee-in tariff that would be required to make the project financially interesting from the point of view of a private investor.

TABLE III
Results of the Sensitivity Analysis of the Project.

Investment cost (k€)	263970	315000	263970	315000
Discount rate (%)	10%	10%	6%	6%
Feed-in tariff (€/MWh)	108	126	82	94

V. Conclusions

Over the last years we have been witnessing the development of the RES for the electricity generation and this trend is expected to hold for the next years. In Portugal, the strategic combination of wind and hydro power growth aims to reduce the energy dependency of the country, increasing the security of supply and reducing the vulnerability of electricity prices to international fossil fuel markets. The same way, it is expected to contribute to the mitigation of GHG emissions and to promote the emergence of new industrial clusters.

The offshore wind power sector is giving the first steps at the international level. However, it is already a promising technology with proved results in North European countries. This paper aimed to contribute to this theme by focusing on the evaluation of the economic, strategic and environmental interest of these projects in Portugal. The strategic analysis demonstrated that being this sector innovative, the investment on it may bring considerable advantages to investor companies and at same time may have a relevant economic and social contribution. However, the Portuguese coast has a limited wind potential comparatively with the North European countries and requires depth water foundations. This represents an important weakness that may turn the economic return of the project difficult, under the present price conditions. The results suggest that additional support schemes are required to promote the necessary attractiveness of private investors for offshore power wind projects. In particular, and according to the present Portuguese RES policies, a more favorable and guaranteed feed in tariff is required.

Based on recent studies, the importance of the environmental impact assessment is underlined. Assuming a simplistic approach of direct substitution of energy sources for electricity generation, the avoided CO_2 equivalent emissions were quantified. A deeper analysis of the environmental impacts is required focusing not only on emissions but also on other social relevant impacts and envisaging always the public participation on the process. Future work is suggested to address both the social dimension of offshore wind power projects and the impacts of wind power on the operation and management of electricity systems (see for example [21] or [28]). This theme is now also being developed under project “Sustainable Electricity Power Planning” (http://sepp.dps.uminho.pt/)).

References

[1] European Commission “European energy and transport. Trends to2030-update 2005”, 2008 (http://ec.europa.eu/energy/index_en.html).

[2] E. Gibson and P. Howsam, "The legal framework for offshore wind farms: A critical analysis of the consents process", *Energy Policy*, vol. 38, pp. 4692–4702, 2010.
[3] J. Markard and R. Petersen, "The offshore trend: Structural changes in the wind power sector", *Energy Policy*, vol. 37, no. 9, pp. 3545-3556, 2009.
[4] REN "Plano de investimentos da rede nacional de transporte 2009-2014 (2019)", 2008, www.ren.pt.
[5] EuroObserv'ER "Wind energy barometer", March 2010, pp. 42-73.
[6] EWEA "Wind Energy - The Facts", March 2009.
[7] EWEA "The Economics of Wind Energy" , March 2009.
[8] B. Snyder and M. Kaiser, "Ecological and economic cost-benefit analysis of offshore wind energy", *Renewable Energy*, vol. 34, pp. 1567–1578, 2009.
[9] EEA "Europe's onshore and offshore wind energy potential: An assessment of environmental and economic constraints", EEA Technical report No 6/2009.
[10] P. Söderholm and M. Pettersson, "Offshore wind power policy and planning in Sweden", *Energy Policy*, to be published.
[11] J. Ladenburg, "Attitudes towards on-land and offshore wind power development in Denmark; choice of development strategy", *Renewable Energy*, vol. 33, no. 1, pp. 111-118, 2008.
[12] J. Wilson, M. Elliott, N. Cutts, L. Mander, V. Mendão, R. Perez-Dominguez and A. Phelps, "Coastal and Offshore Wind Energy Generation: Is It Environmentally Benign?", *Energies*, vol. 3, pp. 1383-1422, 2009.
[13] J. Firestone and W. Kempton, "Public opinion about large offshore wind power: Underlying factors", *Energy Policy*, vol. 35, no. 3, pp. 1584-1598, 2007.
[14] J. Ladenburg, "Attitudes towards offshore wind farms—The role of beach visits on attitude and demographic and attitude relations", *Energy Policy*, vol. 38, pp.1297–1304, 2010.
[15] K. Gee, "Offshore wind power development as affected by seascape values on the German North Sea coast", *Land Use Policy*, vol. 27, pp. 185–194, 2010.
[16] P. Costa, T. Simões and A. Estanqueiro, "Assessment of the sustainable offshore wind potential in Portugal", in EWEC European Wind Energy Conference and Exhibition 2006, Athens.
[17] DGGE "Renováveis. Estatísticas rápidas", May 2010. www.dgge.pt (in Portuguese).
[18] N. Markovska, V. Taseska and J. Pop-Jordanov, "SWOT analyses of the national energy sector for sustainable energy development", *Energy*, vol. 34, pp. 752–756, 2009.
[19] S. Ozcira, Y. Oner and N. Bekiroglu, "An economical aspect for energy focused SWOT analysis of Ukraine", in 2009 International Conference on Clean Electrical Power, 9-11 June 2009, Capri.
[20] European Commission "Strengths, Weaknesses, Opportunities and Threats in Energy Research", Brussels, 2005.
[21] P. Ferreira, "Electricity power planning in Portugal: The role of wind energy", PhD Thesis, UM, 2008. http://repositorium.sdum.uminho.pt/handle/1822/7816).
[22] J. Markard and B. Truffer, "Innovation processes in large technical systems: Market liberalization as a driver for radical change?", *Research Policy*, vol. 35, no. 5, pp. 609-625, 2006.
[23] P. Ferreira, M. Araújo and E. O'Kelly, "Including non-financial aspects in project evaluation – a survey", in 15th Mini-EURO Conference Managing Uncertainty in Decision Support Models, Coimbra, Portugal, 22-24 September 2004.
[24] EEA "Annual European Union greenhouse gas inventory 1990–2008 and inventory report 2010", 27 May 2010.
[25] P. Ferreira, M. Araújo and E. O'Kelly, "The impacts of wind power on power systems operation", in 3rd IASME/WSEAS International Conference on Energy, Environment and Sustainable Development, 24-26 July, 2007.
[26] M. Portman, "Involving the public in the impact assessment of offshore renewable energy facilities", *Marine Policy*, vol. 33, no. 2, pp 332-338, 2009.
[27] P. Ferreira, M Araújo and E. O'Kelly, "An overview of the Portuguese wind power sector", *International Transactions on Operational Research*, vol. 14, no.1, pp 39-54, 2007.
[28] P. Luickx, E. Delarue and W. D'haeseleer, "Impact of large amounts of wind power on the operation of an electricity generation system: Belgian case study", *Renewable and Sustainable Energy Reviews*, vol. 14, pp. 2019-2028, 2010.

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