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DOI:
10.1109/ICCEP57914.2023.10247487

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Castro-Santos, L, Rubial-Yanez, P, Lamas-Galdo, I, Cordial Iglesias, D, Piegari, L, Tricoli, P & Vizoso, AF 2023, The economic feasibility of a floating offshore wind energy farm considering different steel prices: The case of study of the Canary Islands. in *2023 International Conference on Clean Electrical Power (ICCEP).*, 10247487, International Conference on Clean Electrical Power, Institute of Electrical and Electronics Engineers (IEEE), pp. 612-616, 8th International Conference on Clean Electrical Power, Italy, 27/06/23. https://doi.org/10.1109/ICCEP57914.2023.10247487

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Publisher Rights Statement:
L. Castro-Santos et al., "The economic feasibility of a floating offshore wind energy farm considering different steel prices. The case of study of the Canary Islands," 2023 International Conference on Clean Electrical Power (ICCEP), Terrasini, Italy, 2023, pp. 612-616, doi: 10.1109/ICCEP57914.2023.10247487.

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The economic feasibility of a floating offshore wind energy farm considering different steel prices. The case of study of the Canary Islands

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***Abstract*— The objective of this work is to calculate the Levelized Cost of Energy (LCOE), Net Present Value (NPV) and the Internal Rate of Return (IRR) of a 700MW floating wind farm located in the Canary Islands. For this, three possible scenarios have been analyzed taking into account the price of steel and each of the economic parameters have been calculated for each of the scenarios, showing that the highest economic variations are related to the IRR and LCOE.**

***Index Terms*-- economic parameters, offshore wind, steel.**

I. Introduction

Global energy generation is undergoing a change due to various factors, both environmental and political. As for the environmental factors that are causing this change, as is well known, for many years now cleaner energy sources have been used to avoid uncontrolled emissions of greenhouse gases [1], as was the case with emissions in the generation of electricity through the use of fossil fuels [2]. This type of resource (fossil fuels) in addition to being an unclean source of energy is also exhaustible, so the search for an alternative was and is one of the political objectives since the end of the last century [3]–[5]. Within renewable energies we can talk about onshore and offshore energies, but if we take into account that 70% of the planet is made up of water, we can deduce that we have many areas of the planet from which we can extract energy and that they are untapped [5]–[8]. One of the most developed and competitive offshore renewable energy sources is wind energy [9], and within this we can talk about two main types that would be fixed platforms [10], [11] (monopile, tripod, tripile, etc.) and floating platforms [12] (spar, TLP, etc.).

Along with this environmental problem are added political factors. The current war between Russia and Ukraine [13] is causing a shortage of energy sources in many countries, mainly in countries of the European Union, due to the dependence that this type of energy causes with respect to the countries that have the resources. This is another of the reasons why renewable energies are the most suitable alternative to solve both problems. Along with this energy dependence, in this case, the dependence on raw materials for the manufacture of the platforms is linked, which is causing the prices of steel to rise uncontrollably [14]–[16]. That is why it is necessary to analyze how these variations in steel prices affect the profitability of offshore wind farms.

II. Objectives

Due to the instability of the prices of numerous raw materials and specifically for the case study of steel in this work we intend to know how the variation in steel prices affects the profitability of offshore wind farms. This study is carried out for a 700MW floating offshore wind farm (140 turbines of 5MW each) located in the Canary Islands and three possible scenarios have been analyzed with three possible steel prices. In order to establish whether the scenarios analyzed generate a situation of economic viability, it is necessary to know the values of Levelized Cost Of Energy (LCOE), Net Present Value (NPV) and de Internal Rate o Return (IRR) [17]–[20].

III. Methodology

The calculation of the costs involved in a floating offshore wind farm is a very interesting issue in terms of their future installation [21]. In this sense, the total life-cycle cost of a floating offshore wind farm (LCS_FOWF), see equation (1), can be defined as the sum of the costs of each of its life-cycle phases (conceptualization (C1), design (C2), manufacturing (C3), installation (C4), maintenance (C5) and dismantling (C6)) and its main components (offshore wind turbine, offshore wind platform, mooring, anchoring and electric system).

$$LCS_{FOWF} = C1 + C2 + C3 + C4 + C5 + C6 \quad (1)$$

During the present year 2022, the Ukraine war, joined to the fact of the SARS-COV2 world pandemic situation, motived that the prices of some raw materials, such as steel, increased their prices considerably. Therefore, this situation can influence the economic feasibility of offshore wind farms.

In addition, it also generated that the European Union is supporting the renewable energies, which are independent on the gas price.

In this context, the cost of manufacturing (C3) and the cost of dismantling (C6) a floating offshore wind farm depend on the cost of steel.

The present paper will analyse how the steel price will have influence on the following economic factors: LCOE (Levelized Cost Of Energy) (see equation (4)), NPV (Net Present Value) (see equation (2)) and IRR (Internal Rate of Return) (see equation (3)).

$$\boldsymbol{NPV = -I_0 + \sum_{n=1}^{N_{farm}} \frac{CF_n}{(1+r)^n}} \quad (2)$$

$$\boldsymbol{0 = -I_0 + \sum_{n=1}^{N_{farm}} \frac{CF_n}{(1+IRR)^n}} \quad (3)$$

$$\boldsymbol{LCOE = \frac{\sum_{n=0}^{N_{farm}} \frac{LCS_{FOREF_n}}{(1+r)^n}}{\sum_{n=0}^{N_{farm}} \frac{E_n}{(1+r)^n}}} \quad (4)$$

Were I_0 is the initial investment of the floating offshore wind farm, CF_n is the cash flow of the project in year n, r is the capital cost, N_{farm} is the life-cycle (in years) of the project and E_n is the energy generated in each year by the floating offshore wind farm.

IV. Case of Study

The case of study will be the Canary Islands (Spain, Europe), which are located closed to the African continent. **Error! Reference source not found.** shows the Canary Islands in blue color.

Figure 1. Location of the case of study [22].

The offshore wind platform selected is the floating substructure called WindFloat, which has a 5 MW of power due to there are a lot of information about it [23]. The size of the farm taken into account is 700 MW, considering WindEurope data [24], which implies 140 floating offshore wind turbines.

The electric tariff considered will be 175 €/MWh, as a medium price during 2022 in Spain (see Figure 2) and the capital cost will be 6%.

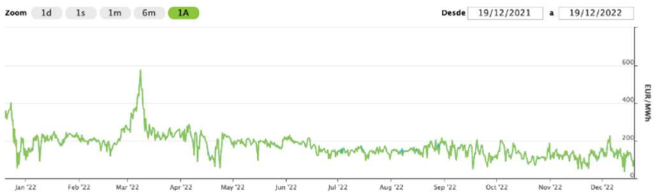

Figure 2. Value of the Spanish electric tariff during 2022 [25].

Finally, regarding the cost of steel, three different scenarios will be considered, as Table 1 is shown:

Table 1. Scenarios taken into account regarding the cost of steel.

Scenario	Cost of steel (€/ton)
1	500
2	750
3	1000

V. Results

Taking into account Scenario 1, the LCOE goes from 66.16 €/MWh to 219.41 €/MWh (see Figure 3), IRR goes from -2.32 % to 23.56 % (see Figure 6) and NPV goes from -1,119 M€ to 2,341 M€ (see Figure 7).

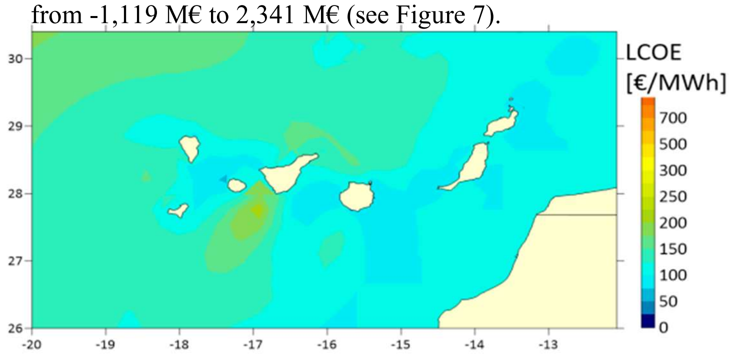

Figure 3. LCOE (in €/MWh) for Scenario 1.

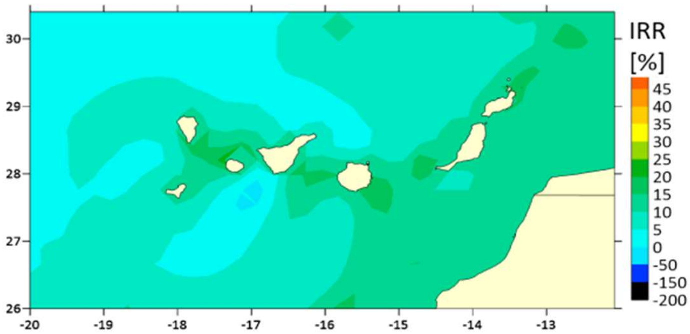

Figure 4. IRR (in %) for Scenario 1.

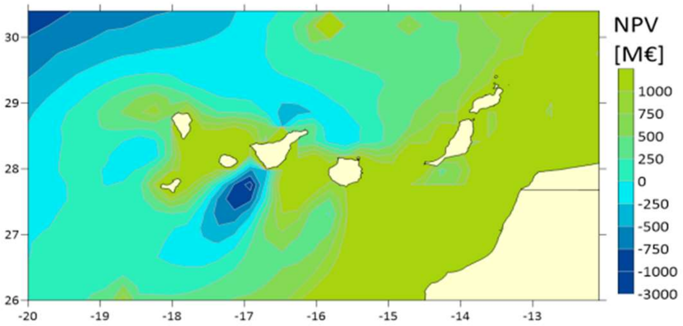

Figure 5. NPV (in M€) for Scenario 1.

Taking into account Scenario 2, the LCOE goes from 67.94 €/MWh to 223.28 €/MWh (see Figure *6*), IRR goes from -2.56% to 22.64 % (see Figure 9) and NPV goes from -1,174 M€ to 2,286 M€ (see Figure 10)).

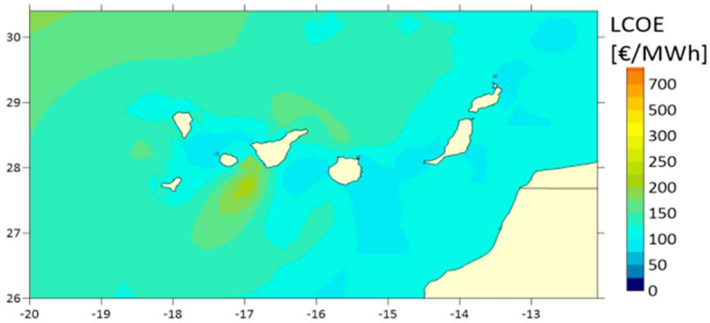

Figure 6. LCOE (in €/MWh) for Scenario 2.

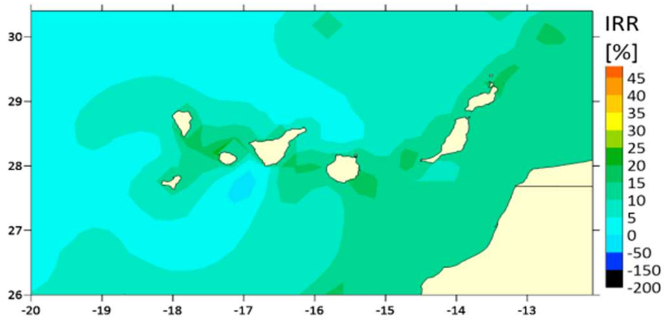

Figure 7. IRR (in %) for Scenario 2.

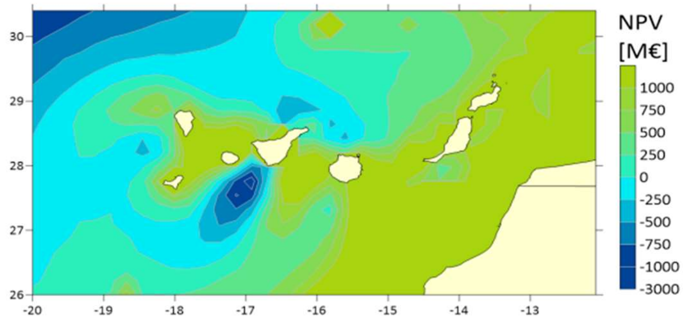

Figure 8. NPV (in M€) for Scenario 2.

Taking into account Scenario 3, the LCOE goes from 69.73 €/MWh to 227.16 €/MWh (see Figure 9), IRR goes from -2.80% to 21.77 % (see Figure 10) and NPV goes from -1,228 M€ to 2,232 M€ (see Figure 11).

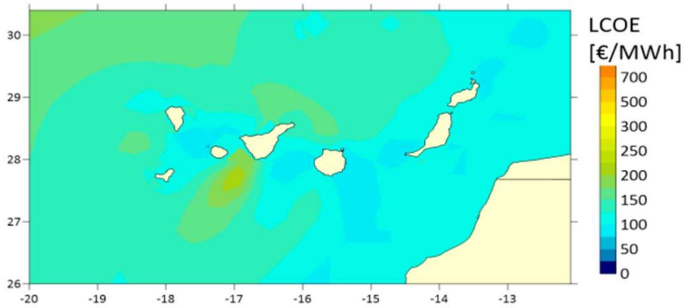

Figure 9. LCOE (in €/MWh) for Scenario 3.

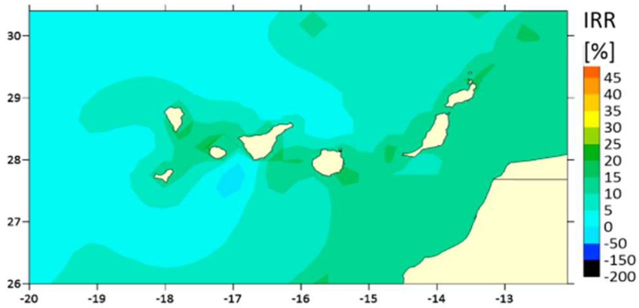

Figure 10. IRR (in %) for Scenario 3.

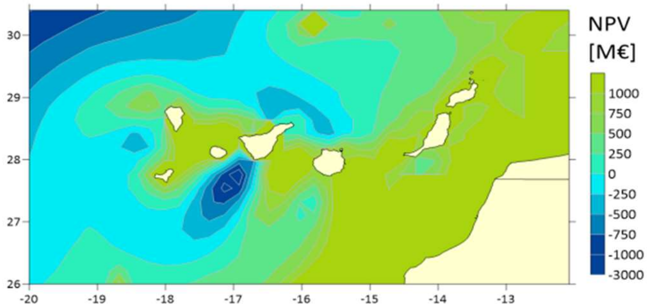

Figure 11. NPV (in M€) for Scenario 3.

Considering the comparison between the three Scenarios, Figure 12 shows that the highest economic variations are related to the IRR and LCOE, with values of -7.6% and 5.4% respectively.

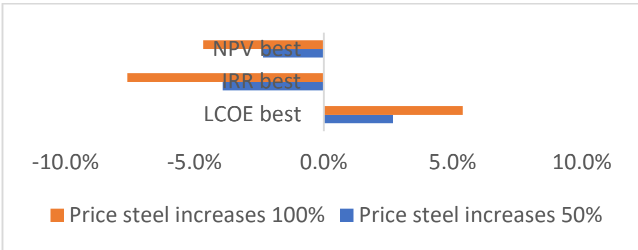

Figure 12. Variation of the main economic parameters considering variations in price steel of 50% and 100%.

VI. Conclusions

This paper has analyzed the influence of the cost of steel on the economic viability of an offshore wind farm with floating structures.

The case study has been in the Canary Islands, with 140 WindFloat-type platforms of 5 MW each and made of steel. For this, three possible Scenarios have been studied (€500/ton, €750/ton and €1000/ton).

The results show the influence of the cost of steel on the main economic parameters: Internal Rate of Return (IRR), Net Present Value (NPV) and Levelized Cost Of Energy (LCOE) respectively.

Considering Scenario 1, the LCOE goes from 66.16 €/MWh to 219.41 €/MWh, IRR goes from -2.32 % to 23.56 % and NPV goes from -1,119 M€ to 2,341 M€

Taking into account Scenario 2, the LCOE goes from 67.94 €/MWh to 223.28 €/MWh, IRR goes from -2.56% to 22.64 % and NPV goes from -1,174 M€ to 2,286 M€.

Finally, Scenario 3 shows, the LCOE goes from 69.73 €/MWh to 227.16 €/MWh, IRR goes from -2.80% to 21.77 % and NPV goes from -1,228 M€ to 2,232 M€.

Considering the comparison between the three Scenarios the highest economic variations are related to the IRR and LCOE, with values of -7.6% and 5.4% respectively.

Acknowledgement

This research was partially funded by Project PID2019-105386RA-I00 "Design of a tool for the selection of offshore renewable energy locations and technologies: application to Spanish territorial waters (SEARENEW)", financed by Ministerio de Ciencia e Innovación – Agencia Estatal de Investigación/10.13039/501100011033.

This research is part of the Project TED2021-132534B-I00 "Characterization of a software to determine the roadmap of the offshore solar energy in the Spanish shore (SEASUN)", financed by MCIN/AEI/10.13039/501100011033 and by the European Union "NextGenerationEU"/PRTR.

References

[1] B. Reimers, B. Özdirik, and M. Kaltschmitt, "Greenhouse gas emissions from electricity generated by offshore wind farms," *Renew. Energy*, vol. 72, pp. 428–438, Dec. 2014.

[2] A. P. Aizebeokhai, "Global warming and climate change: Realities, uncertainties and measures," *Int. J. Phys. Sci.*, vol. 4, no. 13, pp. 868–879, 2009.

[3] United Nations Framework Convention on Climate Change, "Paris Agreement," Paris (France), 2015.

[4] "Kyoto Protocol - an overview | ScienceDirect Topics," *Chemical Fate and Transport in the Environment*, 2015. [Online]. Available: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/kyoto-protocol. [Accessed: 07-Dec-2022].

[5] International Energy Agency, "World Energy Outlook 2018," 2018.

[6] IEA, "Energy and Climate Change," 2015.

[7] N. Rousseau, "Oceans of energy - European Ocean Energy Roadmap 2010-2050," in *International Conference in Ocean Energy*, p. 36.

[8] F. B. (Executive Director), "International Energy Agency." [Online]. Available: https://www.iea.org.

[9] B. Á. G. and L. C.-S. Almudena Filgueira-Vizoso, Joaquín Enríquez-Díaz, Isabel Lamas-Galdo, Félix Puime Guillén, David Cordal-Iglesias, "Offshore Wind as a Base for a New Sustainable Business," in *Financial Management and Risk Analysis Strategies for Business Sustainability*, S. José-Pablo Abeal-Vázquez, University of A Coruña, SpainBegoña Álvarez-García, University of A Coruña, SpainLucía Boedo Vilabella, University of A Coruña, SpainPilar Cibrán Ferráz, University of Vigo, SpainPatricia Cupeiro-López, EASD Ramón Falcon, SpainCe, Ed. Spain: IGI Global, 2021, p. 320.

[10] A. J. Goupee, B. J. Koo, R. W. Kimball, K. F. Lambrakos, and H. J. Dagher, "Experimental comparison of three floating wind turbine concepts," *J. Offshore Mech. Arct. Eng.*, vol. 136, no. 2, 2014.

[11] L. Cradden, C. Kalogeri, I. M. Barrios, G. Galanis, D. Ingram, and G. Kallos, "Multi-criteria site selection for offshore renewable energy platforms," *Renew. Energy*, vol. 87, 2016.

[12] L. Castro-Santos, A. Filgueira-Vizoso, C. Álvarez-Feal, and L. Carral, "Influence of Size on the Economic Feasibility of Floating Offshore Wind Farms," *Sustainability*, vol. 10, no. 12, p. 4484, Nov. 2018.

[13] "Russia's War on Ukraine – Topics - IEA." [Online]. Available: https://www.iea.org/topics/russia-s-war-on-ukraine. [Accessed: 07-Dec-2022].

[14] "Electricity price statistics - Statistics Explained." [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics. [Accessed: 10-Mar-2022].

[15] "Histórico del precio de 62% mineral de hierro - Investing.com." [Online]. Available: https://es.investing.com/commodities/iron-ore-62-cfr-futures-historical-data. [Accessed: 10-Mar-2022].

[16] V. Nechifor, A. Calzadilla, R. Bleischwitz, M. Winning, X. Tian, and A. Usubiaga, "Steel in a circular economy: Global implications of a green shift in China," *World Dev.*, vol. 127, p. 104775, Mar. 2020.

[17] L. Castro-Santos, A. Filgueira, E. Muñoz, L. Piegiari, A. Filgueira Vizoso, and E. Muñoz Caamacho, "A general economic analysis about the wind farms repowering in Spain," *J. Energy*

Power Eng., 2012.
[18] L. Castro-Santos, A. Filgueira-Vizoso, and L. Piegari, “Calculation of the Levelized Cost of Energy and the Internal Rate of Return using GIS: The case study of a floating wave energy farm,” in *ICCEP 2019 - 7th International Conference on Clean Electrical Power: Renewable Energy Resources Impact*, 2019.
[19] L. Castro-Santos *et al.*, “Economic Feasibility of Floating Offshore Wind Farms Considering Near Future Wind Resources: Case Study of Iberian Coast and Bay of Biscay,” *Int. J. Environ. Res. Public Health*, vol. 18, no. 5, p. 2553, Mar. 2021.
[20] E. Baita-Saavedra *et al.*, “An Economic Analysis of An Innovative Floating Offshore Wind Platform Built with Concrete: The SATH® Platform,” *Appl. Sci.*, vol. 10, no. 11, p. 3678, May 2020.
[21] L. Castro-Santos and V. Diaz-Casas, “Life-cycle cost analysis of floating offshore wind farms,” *Renew. Energy*, vol. 66, pp. 41–48, Jun. 2014.
[22] Google Earth, “Web Google Earth,” 2021. .
[23] A. Aubault, C. Cermelli, and D. Roddier, “Windfloat: a floating foundation for offshore wind turbines. Part III: Structural analysis,” in *ASME 28th International Conference on Ocean, offshore and Arctic Engineering OMAE2009*, 2009, pp. 1–8.
[24] WindEurope, “Offshore wind in Europe - Key trends and statistics 2020,” *WindEurope*, vol. 3, no. 2, pp. 14–17, 2021.
[25] OMIE, “Web Operador Mercado Eléctrico de la Electricidad (OMIE),” 2022. .