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Analysis of the economic feasibility of different floating offshore renewable energies in Canary Islands

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Abstract. The aim of this paper is to study the suitability of different floating offshore energy technologies in a particular location in economic terms. In this context, their main initial investments and expenses have been taken into account in order to calculate the economic indicators of the economic feasibility study. These indicators are Internal Rate of Return, Net Present Value and Levelized Cost Of Energy. The case study has evaluated the Canary Islands (Spain) and three types of floating offshore renewable energies: offshore wind, wave energy and hybrid systems. The method created generates economic maps, which facilitates the election of the best area where install offshore renewable energy farms in the location selected. In addition, it also allows to select what is the best marine technology to be exploited in this area.

Key words. Floating offshore renewable energy, hybrid platforms, Canary Islands, offshore wind, wave energy

1. Introduction

Climate change is a proven fact [1], [2]. There are many causes that are causing this climate change and one of the main ones is the uncontrolled emission of greenhouse gases into the atmosphere [3]. The generation of energy for both domestic and industrial use through the use of fossil resources generates very significant amounts of greenhouse gases, so this type of energy source must be improved or replaced by others with less environmental impact [4]–[6]. At the environmental conference held in Glasgow (United Kingdom) on November 1, 2021 [7], [8] one of the objectives to be achieved is the so-called "objective 55" [9] that establishes the reduction of greenhouse gases by at least 55% by 2030 and achieve climate neutrality by 2050. To do this, within this objective there is talk of accelerating the implementation of renewable energies as the main sources of energy, trying to reach in 2030 that 40% of the energy produced is through renewable sources [7]. Within renewable energies we can classify them into onshore and offshore and this second medium is the least known for the development of these technologies, despite the fact that most of the planet is made up of 70% water. There are many possibilities when it comes to extracting energy from the sea, one of the most developed and most common technologies is that which obtains energy from the wind through offshore wind farms [10]–[12]. In this study, different alternatives are studied to find out what the variation is, from the point of view of economic viability, in the Canary Islands. Different devices were considered: WindFloat [13]–[15] that extracts energy of the wind, Pelamis [16], which extracts energy from the waves and Poseidon [17], which is a hybrid platform that extracts energy from both the wind and the waves together. For the analysis of economic viability, parameters such as the Levelized Cost Of Energy (LCOE), Net Present Value

(NPV), Internal Rate of Return (IRR) are analyzed [18]–[20] [21], [22].

2. Method

The method proposed calculates the main economic indicators of the main types of offshore renewable energies in a particular location. The offshore renewable energies considered are:

- Floating offshore wind.
- Floating hybrid offshore, including wind and waves.
- Floating wave energy.

The methods considered for calculating the initial investment of all these technologies have been published in different previous papers [23], [24]. In this context, the total cost of a floating offshore renewable energy farm is dependent on the cost of the several phases of the life-cycle of the farm: the concept phase (C1), the development & design phase (C2), the manufacturing phase (C3), the installation phase (C4), the operation and maintenance phase (C5) and the dismantling phase (C6).

On the other hand, the main economic parameters considered in this work are: Net Present Value (NPV), Internal Rate of Return (IRR) and Levelized Cost Of Energy (LCOE).

They are defined, one-to-one, as follows:

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

$$\boldsymbol{0 = -I_0 + \sum_{n=1}^{N_{farm}} \frac{CF_n}{(1+IRR)^n}} \quad (2)$$

$$\boldsymbol{LCOE = \frac{\sum_{n=0}^{N_{farm}} \frac{LCS_{FOREF_n}}{(1+r)^n}}{\sum_{n=0}^{N_{farm}} \frac{E_n}{(1+r)^n}}} \quad (3)$$

Being:

- $\boldsymbol{I_0}$: initial investment of the hybrid offshore renewable energy farm.
- $\boldsymbol{CF_n}$: cash flow of the project in year $\boldsymbol{n}$.
- $\boldsymbol{r}$: discount rate.
- $\boldsymbol{N_{farm}}$: number of years of the life of the project.
- $\boldsymbol{E_n}$: energy generated in each year.
- **LCS_{FOREFn}:** total life cycle cost of a floating offshores renewable energy farm in the year n

3. Case of study

The case of study will consider three different floating offshore renewable energy platforms:

- Floating offshore wind: WindFloat (scenario 1) [25].
- Wave energy: Pelamis (scenario 2) [26].
- Hybrid: Poseidon (scenario 3) [17].

It has been decided to take these platforms since they are the ones from which the most data can be obtained.

The total power of the farm is 300 MW.

On the other hand, the location selected to carry out the study are the Canary Islands (Spain), as Fig. 1 is shown.

In this context, it is important to notice that the location is a very important aspect in the design of this type of farms because it influences the distance from farm to shore, the distance from farm to shipyard, the depth, the energy resources of the places, etc.

Fig. 1. Location selected (in green). Adapted from [27].

Finally, the electric tariff considered in the case of study is 250 €/MWh.

4. Results

Considering the floating offshore wind farm, IRR goes from 3 % to 36 % (see Fig. 2), NPV goes from –204 M€ to 1,580 M€ (see Fig. 3) and the LCOE goes from 76 €/MWh to 258 €/MWh (see Fig. 4).

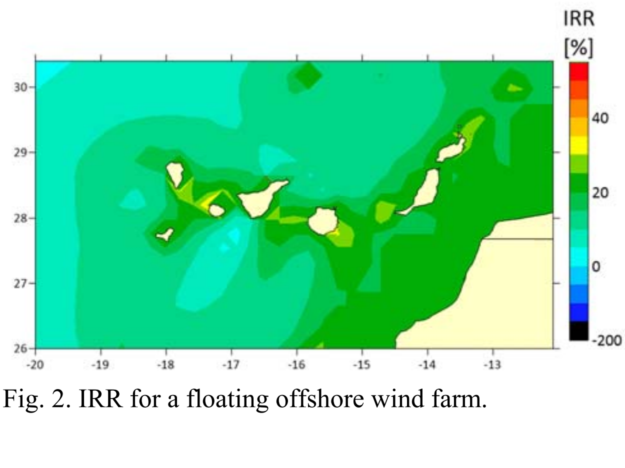

Fig. 2. IRR for a floating offshore wind farm.

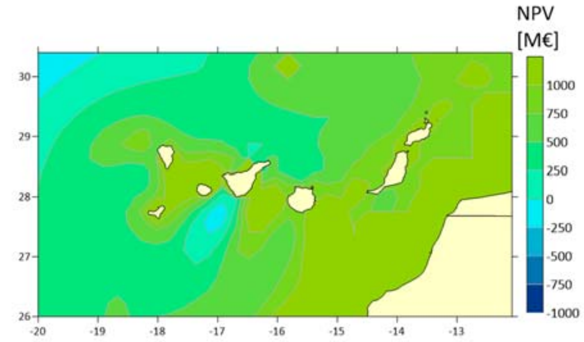

Fig. 3. NPV for a floating offshore wind farm.

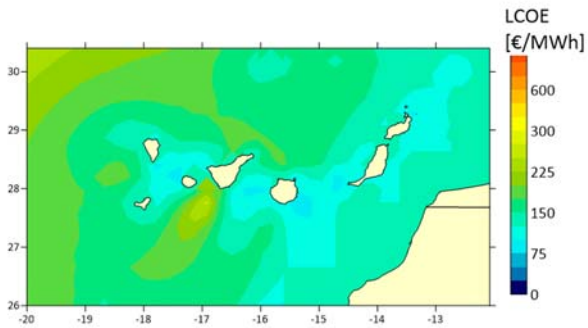

Fig. 4. LCOE for a floating offshore wind farm.

Considering the floating wave energy, IRR goes from -183 % to -176 % (see
Fig. 5), NPV goes from -2,990 M€ to -1,197 M€ (see Fig. 6) and the LCOE goes from 1,045 €/MWh to 3,093 €/MWh (see

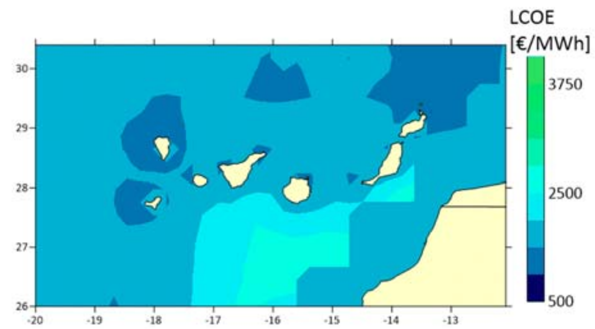

Fig. 7).

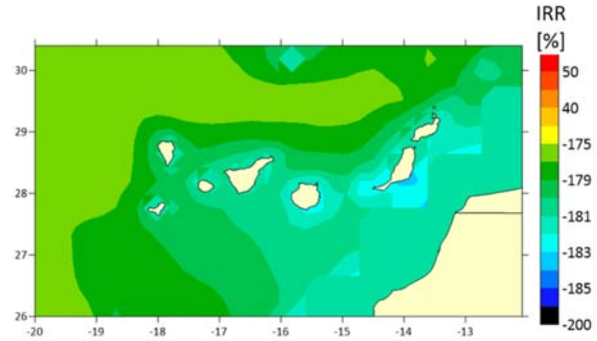

Fig. 5. IRR for a floating wave energy farm.

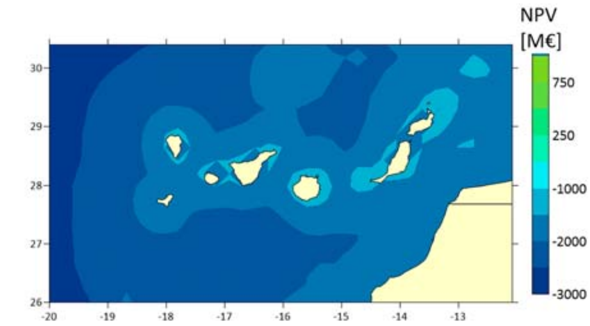

Fig. 6. NPV for a floating wave energy farm.

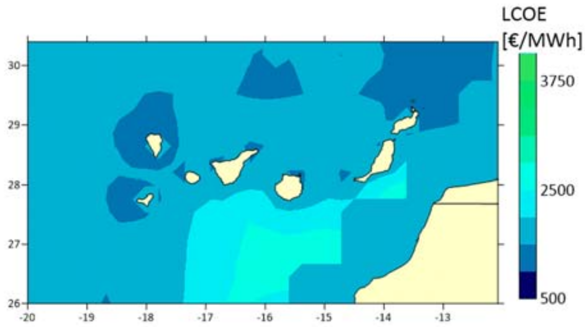

Fig. 7. LCOE for a floating wave energy farm.

Considering the floating hybrid systems, IRR goes from 7% to 30% (see Fig. 8), NPV goes from 195 M€ to 1,308 M€ (see Fig. 9) and the LCOE goes from 93 €/MWh to 202 €/MWh (see Fig. 10).

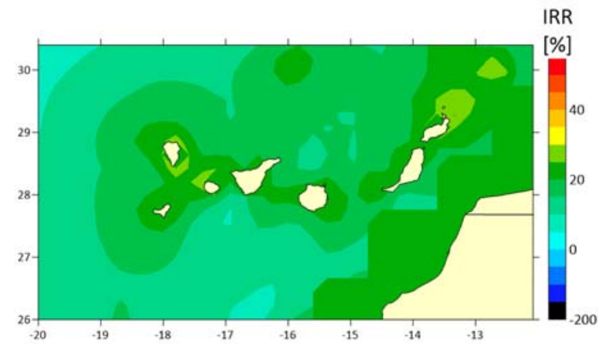

Fig. 8. IRR for a floating hybrid system.

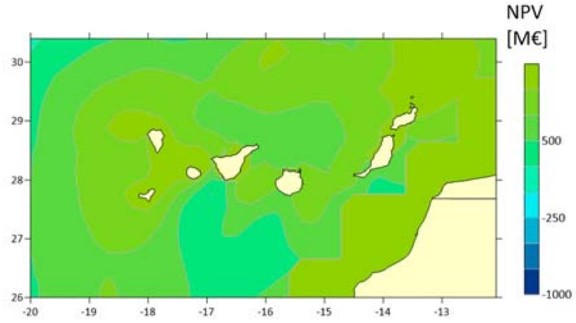

Fig. 9. NPV for a floating hybrid system.

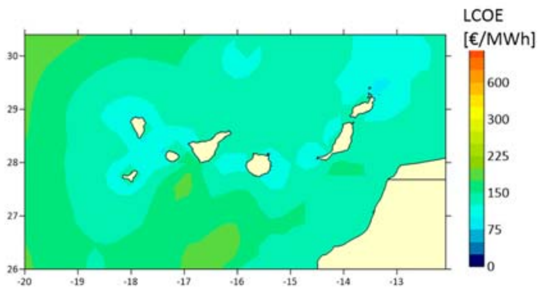

Fig. 10. LCOE for a floating hybrid system.

Therefore, the best technology to extract energy from seas in the Canary Islands is offshore wind, followed by hybrid systems and wave energy, because its LCOE is lower as can be seen in the Table 1.

	Scenario 1	Scenario 2	Scenario 3
IRR best(%)	35.95	183.35	30.34
NPV best (M€)	1,580	-1,197	1,308
LCOE best (€/MWh)	76.45	-1,197	93.38

Table 1. Summary of the main economic parameters.

5. Conclusion

This paper has studied the suitability of different floating offshore energy technologies in a particular location in economic terms. For this purpose, their main initial investments and expenses have been taken into account in order to calculate the economic indicators of the economic feasibility study. These indicators are Internal Rate of Return, Net Present Value and Levelized Cost Of Energy.
The case study has evaluated the Canary Islands (Spain) and three types of floating offshore renewable energies: offshore wind, wave energy and hybrid systems.
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