

MARINE RENEWABLE ENERGY IN PORTUGAL

IF
AND
WHEN

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The marine renewable energy (MRE) industry (including offshore wind and wave energy) is growing in Europe and in Portugal. However, MRE is currently too costly to compete with both fossil fuels and other renewable energy sources. Yet, there are important external effects at local level associated with the deployment of MRE infrastructures (e.g. carbon dioxide and local air pollutants emissions savings, reduction of visual disamenities, among others) which have been typically used as arguments to grant regulatory support to such projects (construction subsidies or feed-in-tariffs, among others).

By building an economic model taking into account the net benefits from those external effects, we find that the economic potential value of offshore wind energy at the local level, in particular floating offshore wind turbines, can be positive. Based on the evidence found, we further seek to contribute to energy policy and spatial planning regarding MRE, in the transition to a more sustainable energy system.

Marine Renewable Energy

IN PORTUGAL

WHAT IS MARINE RENEWABLE ENERGY?

Marine Renewable Energy (MRE) refers to any technology harvesting renewable energy from the sea. It encompasses wind energy, both offshore (far from the coast) and nearshore (close to the coast), wave or tidal energy, salinity gradients and ocean temperature differences. This study looks in detail at offshore wind energy, nearshore wind energy and wave energy, as evidence found for Portugal shows that these energy sources have the highest technical potential.

The ocean, and in particular marine renewable energy (MRE), is expected to play a key role in the transition to a more sustainable global energy system. The European Union (EU) and Portugal, in particular, are positioned as global players in the MRE market.

In the last decade, the European Commission has published the Blue Growth Communication¹ and the Marine Renewable Energy Action Plan,² two strategic documents that identify MRE as a focus area at European level. In 2015, the offshore wind energy capacity in Europe was 11 gigawatt (GW), three of which were installed in 2015 alone (EWEA, 2016).³

Portugal's National Strategy for the Sea 2013-2020⁴ also considered MRE as a strategic opportunity for the country. Moreover, the POEM (*Plano de Ordenamento do Espaço Marítimo*), a study that spatially identified the different uses of the sea, selected a vast area along the Portuguese coast suitable for MRE deployment.

In Portugal there are currently three MRE demonstration projects: two wave energy technology projects – the **WaveRoller** in Peniche and the **Wave Centre** in Pico Island in Azores, and one offshore wind technology – the **Windfloat** in Aguçadora.

THE 1ST OFFSHORE FLOATING WINDFARM IN PORTUGAL WILL BE OPERATIONAL BY 2018

After five years in the sea, the WindFloat prototype completed the test phase at the end of 2016. During this period, the prototype proved its technological viability under adverse weather conditions, having resisted waves with more than 17 meters and winds above 111 Km/hour.

The Windfloat project generated and injected more than **17 GWh in the national grid** during the test phases, corresponding to the **electricity consumption of more than 1400 families**.

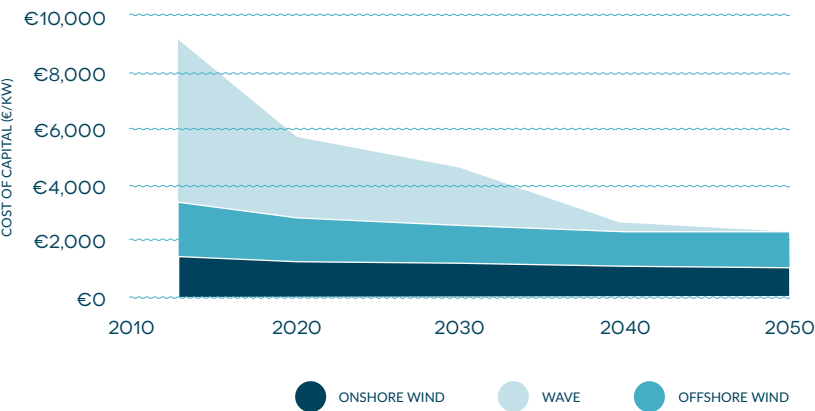
After the success of the pilot phase, the future windfarm will be operational by 2018 with an installed capacity of **25 megawatts (MW)**.⁵

Costs and Benefits

OF MARINE RENEWABLE ENERGY

The **capital costs associated with MRE** are still too high to allow for these technologies to be competitive: offshore wind energy's costs are currently 2.5 times higher than the costs of onshore wind, while wave energy costs remain 6 times higher than onshore wind (Figure 1). However, the gap between these costs is expected to decrease significantly over time, meaning there might be an opportunity to invest in this industry in the future.

Figure 1 /
Expected evolution of capital costs for MRE and onshore wind energy according to the European Commission (2014)



The gap between onshore wind and marine renewable energy costs is expected to decrease significantly over time, meaning there might be an opportunity to invest in this industry in the future.

There are **several benefits from investing in clean energy sources** which can elicit society's support to MRE. Burning fossil fuels has a large impact on air pollution, which are felt at local level (non-carbon external costs) and global level (climate change related external costs). Therefore, by displacing those sources by MRE, benefits are generated not only from reduced local air pollution (e.g. SO₂, NO_x, PM_{2.5} and PM₁₀) with important health benefits to local populations, but also from avoided carbon dioxide emissions. The

external effects of MRE considered in this study are summarized in Table 1, where positive and negative external effects are considered. Other (negative) effects that were not considered due to lack of data include the noise impacts for local populations, biodiversity impacts associated with operating and deploying energy devices, bird mortality due to collision with wind turbines and/or interference with marine biodiversity due to the electromagnetic field of cables buried in the seabed.

	OFFSHORE WIND	WAVE
Carbon dioxide emissions savings	✓	✓
Local air pollution emissions savings (SO ₂ , NO _x , PM _{2.5} and PM ₁₀)	✓	✓
Visual impact	✓	Not available
Artificial reef effects	✓	✓

Table 1 /
Summary of the external effects considered in this study

If and When

TO INVEST IN MARINE RENEWABLE ENERGY?

By taking into account i) decreasing capital costs in real prices, ii) the value of the external effects, and iii) location-specific factors, we developed an analytical framework aiming at answering these two questions for each type of MRE considered - offshore wind, nearshore wind and wave energy.

We developed our model for both the **private investor** and the **social planner** for each MRE type. While the private investor receives revenues from selling electricity and has to pay for operation and maintenance, and capital costs, the social planner, besides the aforementioned costs and revenues, takes into account the net benefits associated with the investment.

There are two important outputs of the modelling exercise: the **social value** and the **starting year of the investment**. We assume that if the optimal time to start the investment is after 2050, it will be not viable, as market conditions are expected to change significantly in the long-run, reducing the reliability of the results obtained. In this context, **the goal is to understand whether there is potential economic value to deploy MRE and, hence, scope for intervention**.

Without support, the private investor will not invest

The revenues from selling electricity are not enough to compensate for the capital-intensive investment costs of the three types of MRE infrastructures. These have not yet reached a sufficient maturity level, unlike what has been observed, for instance, in the onshore wind industry. Even with capital costs decreasing over time, our results suggest that MRE (including offshore, nearshore wind energy and wave energy) will never be able to be competitive in the long-run.

Offshore wind energy may be viable from 2020-2030 onwards

From a social perspective, offshore wind energy is viable before 2050 in two cases: if landscape impacts are low enough and/or at selected higher energy density locations (with around 100 km²). In the former case, **deployment would be optimal starting in 2027** and in the latter case deployment would occur around 2037. We find that the weight of the benefits from local air pollution savings on the social value of the investment is higher than from carbon dioxide emission savings. In some cases, the **benefits from avoiding local air pollution are five times larger than the benefits from avoiding carbon dioxide emissions**.

Nearshore wind energy is not viable

The fact that nearshore wind (meaning bottom-fixed wind turbines) has to be deployed close to the coast, due to the high steepness of the Portuguese seabed near the shore, suggests that the landscape impacts for nearshore wind are considerable. Moreover, when compared to offshore wind energy, nearshore wind energy is associated with other negative impacts which were not taken into account in this study. Therefore, and though nearshore wind was found to be viable in the unlikely scenario of low landscape impacts, we may conclude that, **for Portugal, nearshore wind is not viable from a social perspective**. Our results indicate that public support for this specific technology should not be fostered.

Wave energy is still too expensive

We also find that, even accounting for external effects, capital costs for wave energy are still too high to allow for the viability of the investment. Only if the **technology improves fast enough with respect to efficiency** (increases in the capacity factor), **robustness** (longer lifetime of devices) and **cost savings** (lower capital costs than expected) **would it become viable for deployment before 2050**. If Portugal envisions becoming a player in wave energy in the long-term, supporting R&D should be considered.

Contributions to Marine Spatial Planning

The POEM identified a wide area as having the physical conditions required for offshore wind deployment (see details below). Considering the whole area is unrealistic, since there are conflicting interests with important economic activities, namely fishing and tourism. Instead, by focusing on smaller and more energetic locations, deployment of offshore wind may occur by **2037**.

There are many factors at the local level that are crucial to ensure the viability of MRE. For example, **water depth at the place of installation**, **energy resource** (either wind speed or wave power), **distance from the electricity grid**, among others. We studied the viability of several locations along the Portuguese coast (Figure 2) to understand how different local characteristics impact on the viability of the investment from a social perspective. In the case of wave energy, we found that none of the selected locations is viable due to high capital costs, as the industry is still in its infancy. In the case of nearshore wind, landscape impacts can be pivotal. As for offshore wind installation, while the capacity factor (i.e. the percentage of time during which the wind turbine is operating, given the wind regimes) is especially important for the installation of this type of energy, the distance to the grid also plays an important role.



Figure 2/
Map of examined locations for potential MRE deployment

Important Results

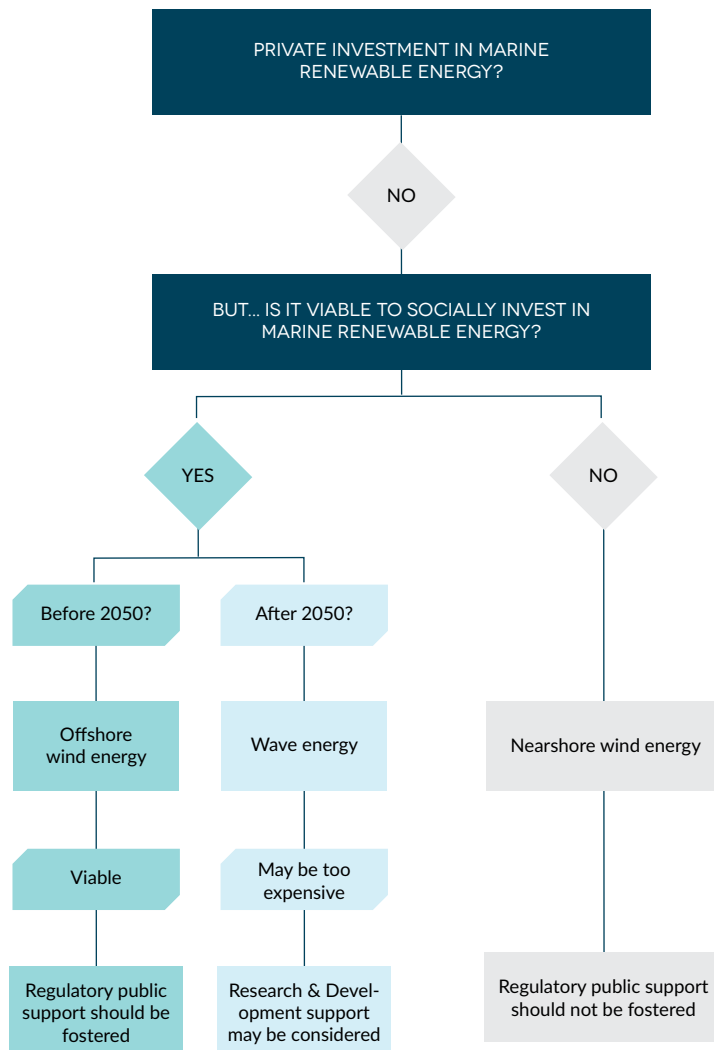


Figure 3/
Summary of outcomes and recommended courses of action

Final Remarks

Based on the results obtained, and to fulfil the vision laid down in the National Strategy for the Sea, a few remarks regarding marine spatial planning and energy policy that aim to contribute to creating value in the MRE industry are identified:

Should offshore wind energy be subsidized?

The MRE industry is a long-term investment with a typical lifetime ranging from 15 to 30 years. We find evidence that offshore wind seems to be viable from the point of view of society. Historically, in Portugal, Feed-in Tariffs (FiTs) have been introduced to support renewable energy projects. **Our findings suggest that a FiT of €85 per MWh for offshore wind (i.e. floating offshore platforms) would be enough to make offshore wind viable in 2020-2030.** Though, a full answer to the question raised requires a general equilibrium approach to evaluate how the relative competitiveness between the different renewable energy sources (RES) will evolve along the transition path toward a less carbon intensive economy, which is beyond the scope of this research work.

More information is needed on the landscape impact of infrastructures in the sea

We found that there is no information available in Portugal on the landscape cost associated with infrastructures at sea. According to our study, the decision on whether to invest or not in nearshore wind is highly dependent on landscape costs. However, there are currently no non-market valuation studies at national level that estimate the visual costs of infrastructures at sea, or, in particular, the visual impact of wind turbines close to the coast. For our modelling exercise, we used studies from other countries to create different ranges of values for the visual disamenities scenarios, adjusted for Portugal. To properly assess the landscape impacts of these projects, **scientific studies of the economic impact of infrastructures at sea in the landscape values should be promoted.** With this additional information, the areas with low landscape impacts where deployment of MRE would be feasible could be identified, helping policy design.

Public support of MRE needs to be consistent over time

The results of our research call for a more integrated long-run vision for the MRE industry. For example, support to MRE, through feed-in-tariffs, or the national targets associated

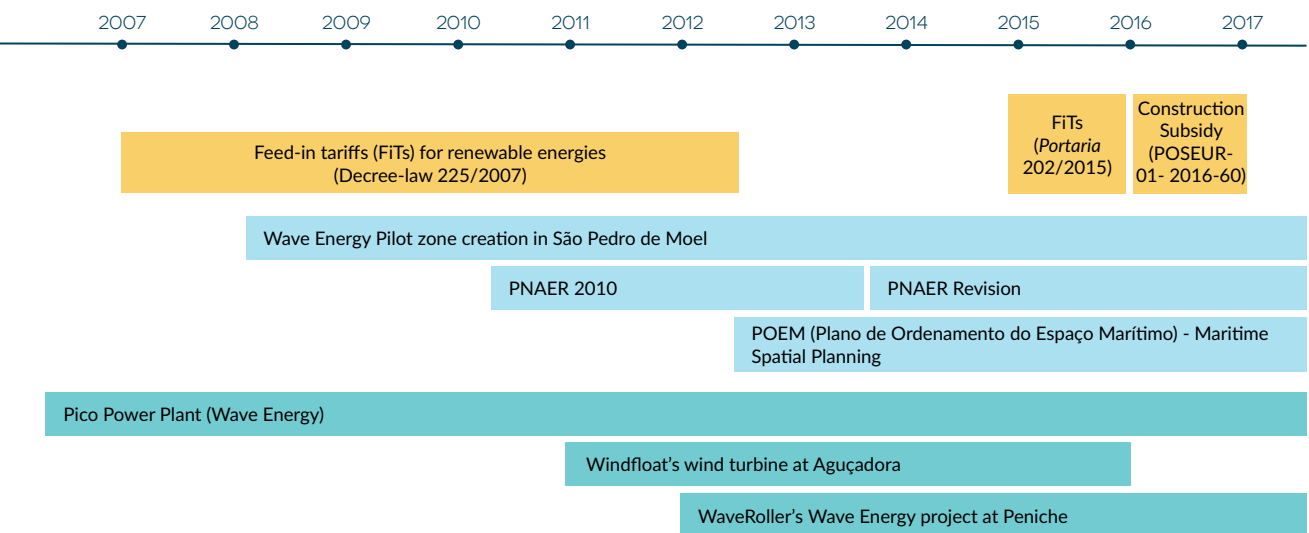


Figure 4/
Timeline of relevant policy instruments, legislation and
deployed MRE projects in Portugal in the last decade

POLICY INSTRUMENTS LEGISLATION MRE PROJECTS DEPLOYED IN PORTUGAL

with MRE, as set in the PNAER (*Plano de Ação para as Energias Renováveis*) ⁶, have not been consistent over time (Figure 4), which hinders the attractiveness of Portugal as a location to deploy these devices. **A long-term vision for the MRE industry should reduce regulatory uncertainty**, thus helping to fulfil the goals set in the National Strategy for the Sea and the national targets set in the PNAER, which should reflect this commitment.

Socio-economic tools can improve the design of spatial planning instruments

This exercise illustrates the potential of economic tools to help designing and improving spatial planning instruments, such as POEM. Models like the one used in this research can be used to derive the value of specific areas, which were previously identified as having technical potential, as well as the timing and sequence in which investments should be undertaken. We examined a few locations along the Portuguese coast, representative of the region in which they are located. Other locations could also be analysed using this framework and spatial planning instruments could be updated accordingly. **The socio-economic dimension of where to deploy MRE, including the impact of local characteristics on the investment and the value of the positive external effects, is very important when studying the viability of MRE and should be taken into account in marine spatial planning studies.**

The area within 5 km from the shore should be excluded from the POEM

We also find that nearshore and offshore wind are likely to have considerable landscape impacts within 5 km from the shore. Consequently, the Portuguese Directorate General for Maritime Policy – **DGPM** (*Direção Nacional de Política do Mar*) or **other appropriate regulatory body should exclude nearshore and offshore wind from that area in spatial planning instruments** (e.g. POEM). Moreover, as we only accounted for a few negative impacts, the quantification of all the negative impacts of nearshore and offshore wind is likely to strengthen this recommendation.

The Calouste Gulbenkian Foundation is a Portuguese private institution of public utility, which was created in 1956 in accordance with the last will and testament of Calouste Sarkis Gulbenkian. It actively pursues its statutory aims in the fields of the arts, charity, education and science in Portugal and abroad, including through its UK Branch and Paris Delegation. The Foundation promotes a wide range of direct activity and grants supporting projects and programs.

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