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SOCIO-ECONOMIC ASSESSMENT OF A SELECTED MULTI-USE OFFSHORE SITE IN THE ATLANTIC

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Socio-economic Assessment of a Selected Multi-use Offshore Site in the Atlantic

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Abstract This chapter presents the results obtained from the analysis of the multi-use design for the Cantabria Offshore site in the Atlantic coast. The analysis shows that the technology exists. Nevertheless at the present the profitability of potential business is still uncertain. The reliability of the activity as a self-sustained business relies on the existence of a stable regulatory framework, on the availability of financial support from the state and on the relaxation of the regulatory barriers existing in the industry. Likewise ocean energy industry is far from been socially accepted in the region. The socio-economic analysis suggests that the multi-use scenario can be profitable.

Keywords Multi-use offshore platforms • Marine infrastructure • Socio-economic analysis • Environmental analysis • Marine spatial planning • Atlantic

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5.1 Introduction

The Cantabrian sea is a small part of the Atlantic Ocean. It consists of an area between the Biscay Gulf at the East and Galicia at the Western part of the Iberian Peninsula. A narrow continental shelf combined with open sea conditions exposed to Atlantic-western storms lead to a severe ocean environment. The ocean conditions are severe and challenging. In the MERMAID project, the Cantabria Offshore Site (COS) was selected, given its deep sea and harsh ocean conditions. COS is situated 10 km Atlantic from the coast of Santander (Cantabria) and it covers up to 60 km^2 of sea. It is characterized by a moderate wave and wind energy resource. The available mean wave energy resource is 25–30 kW/m and the mean available wind power is 600 W/m^2. The 50 year return period significant wave high and average expected wind speed will be around 9 m and 27 m/s respectively (Table 5.1, Fig. 5.1).

The high energy content makes the site very attractive for developing wind and wave energy extraction. A number of 77 units of multi-use design that includes wave and wind energy are expected to be installed. Based on the wave and wind energy availability, each unit will be equipped with a 5 MW wind turbine, as well as a wave energy concept based on Oscillating Water Colum (OWC) technology. The expected average annual power production is around 80 GWh.

The multi-use farm proposed will be integrated in a site characterized by a wide range of water depths comprehended between 40 and 200 m where floating structures are the most suitable technology for ocean energy harvesting. This multi-use design is a novel concept based on a triangular concrete made semisubmersible. It is equipped with four columns, three at each vertex and one at the center of the triangle. The three outer columns are equipped with the OWC technology, and the central one supports the 5 MW wind turbine. The mooring system will be based on conventional catenary mooring lines in order to reduce technical risks and lower the

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Table 5.1 Basic facts about the Cantabria Offshore site

Geographical location	Atlantic Ocean, North of Spain
Surface area of study site	100 km^2
Offshore distance	3–20 km
Depth	50–250 m
Substrate	Mix of sandy and rocky seabed
Water temperature	10–20 °C
Max. tidal currents	1.5 cm/s
Wave heights	Mostly <6 m
Mean wave energy potential	20 kW/m on 50 m depth
Average wind speed	7.5 m/s

Source: http://www.vliz.be/projects/mermaidproject/docmanager/public/index.php?dir=Outreach_Material%2F&download=MERMAID_Booklet.pdf

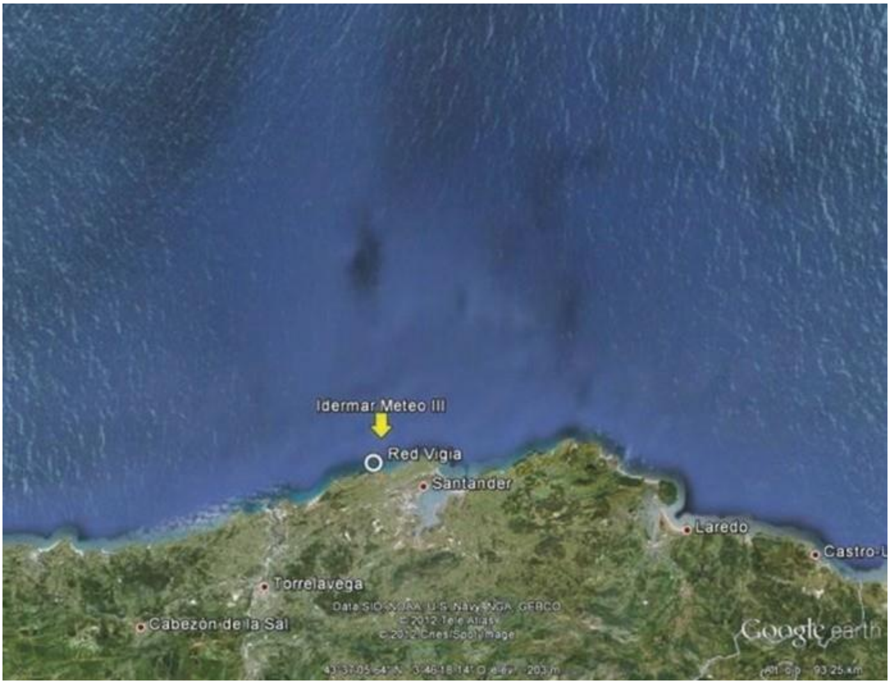

Fig. 5.1 Location of the Cantabria Offshore site

costs (MERMAID Project 2015, 2016). The availability of natural port facilities constitutes an additional advantage for the deployment of the selected activities.

In this chapter we perform a socio-economic analysis of the multi-use design for the Cantabria Offshore site. For this the following steps are applied. The case study is put into a socio-economic context in the following section. For this are identified and described the actors, the economic sectors and the institutions of interest. Next the multi-use environmental impact is analyzed, and the potential of valuing these impacts in monetary terms is assessed. An initial financial and economic assessment of the multi-use design is also performed. This is followed by a social cost-benefit analysis.

5.2 The Case Study in a Socio-economic Context

5.2.1 Demographics and Economic Activities

The land area of the study site accounts 5321 km^2. The population of the region amounts to 577,995 inhabitants with density of 109 inhabitants per km. The regional population synthesis is rather balanced between male (51%) and female (49%), while the average household size is around 3.1 persons per household. The qualitative aspects of human resources in the study site can be revealed through the educational level of the population. The educational attainment is rather balanced between primary, secondary and higher level. In particular, almost 32% of the population has elementary education that can be considered quite high and could impede the goal of economic development. Almost 36% of population has secondary education and 32% of population has higher education.

Total labor in the Atlantic site amounts to 277,100 persons. Male employment amounts to 55%, while female employment accounts for 45%. The unemployment rate in the region is around 20.5%. Sectoral employment is often considered an important indicator in analyzing the economic structure and organization. The analysis of sectoral employment indicates that the economy is more services-oriented, as the tertiary sector accounts for 73% of total employment. The contribution of agriculture to total employment has been contracted to 3%, while manufacturing and construction sectors contribute by 16% and 8%, respectively. With regards to the qualitative characteristics of the employees, 56% of the labor force has higher education (26% of the population holds baccalaureate and 30% has attained graduate studies), while 34% of the labor force has education.

The total value of regional production in the study site amounts to 12.8 million Euro. In terms of the sectoral shares of regional production, the tertiary sector contributes by 60% to the regional production generation, the secondary sector contributes by 37%, and the primary sector by only 3%. In particular, manufacturing industry contributes by 17% in the regional product formation, construction sector by 12%, and the trade sector by 10%.

The MUOP selected design is expected to have an increase in temporary employment. It is also expected to accrue benefits for the industry and benefits for existing businesses. In particular, it has been estimated that during the construction phase of the proposed platform 1000 persons can be employed over a three-year period, while 500 persons can be employed for O&M activities during the operation phase. This will enrich the available expertise for the companies and other stakeholders involved in the Industrial Cluster organized around local University and Regional Government.

5.2.2 Stakeholders, and Implementation Barriers

A group of stakeholders was interviewed in November 2012 in order to understand their views and perceptions about MUOPs in Cantabria. Three alternative MUOP designs were presented to local stakeholders, namely, the wave energy generation in combination with aquaculture, the wind energy generation in combination with aquaculture, and the wind and wave energy generation in combination with aquaculture. With regards the technical feasibility of the proposed schemes, the stakeholders referred that in general there is a high risk on geotechnical failure and failure with land connections. These risks are expected to be highest on the third alternative, i.e. wind and wave energy generation combined with aquaculture.

While there is a lot of research on offshore wind energy, local businesses and academia focus on developing wave energy and mooring systems. Consequently, the expected local benefits of wind energy are considered low, whereas wave energy development is believed to strengthen local businesses. Wave energy production is an emerging technology that can provide access to new markets, while wind power production can generate employment in affected activities, e.g. electrical maintenance and maritime services at local level.

The sensitivity of local society towards the aesthetic and functional impact of the proposed facilities is rather high and negative. Locals perceive coastal sea areas as free access areas and hence any restriction, actual or presumed, is traditionally considered as a private appropriation of public areas receiving thus heavy public opposition. This attitude is applied to coastal facilities on both ground and sea. Previous proposals developed in the area involving ground facilities have been abandoned or restricted due to this attitude (e.g. fracking, oil drilling and land windmills). The lack of local energy availability and the strong energy dependence of the country do not guarantee public interest and support of the activity. Furthermore, uncertainty over future impacts is also an important source of rejection of private settlements on public areas.

There is also great uncertainty on the regulatory conditions for the affected sectors. The majority of proposals made for the Atlantic site are oriented to energy production. Thus, costs cannot be shared among sectors, while the financial conditions of the business operation depend critically on policy regulations determined by the public sector. There is also uncertainty on spatial planning regulations. Past experience has shown that the needed guarantees for long term investments are never provided and initial approvals can easily be rejected. There is also uncertainty in the availability of funding that may have a great impact on the potential development of the infrastructure. Furthermore, the uncertain character of the proposed activities represents a significant restriction for financial agents that want financial guarantees to assume their participation in the funding scheme.

The local society is nowadays concerned about different emerging new technologies. The government of Cantabria between 2008 and 2011 promoted the onshore wind development in the region. Several social initiatives led by political parties and other civil associations revealed a negative perception of the initiative that was deeply reflected on the Cantabrian society. Due to the negative social perception the government of Cantabria decided to reduce the onshore wind development by 2012. In 2012 a new emerging technology associated to shale gas extraction, emerged as a very promising source of income. Nevertheless social perception in this case as well has been highly negative. Social and political initiatives led by different organizations are highlighting the negative impacts of these technologies and as a result significant social barriers to this technology have been set. These examples show how social perception in Cantabria can setup barriers that can impede different kind of initiatives.

The potential barriers in the implementation of the project can be identified at international, national and regional level. These barriers include:

(a) Lack of social consensus
(b) Need for consistent time scheduling for decisions and intermediate steps
(c) Regulatory risks connected with energy policy in Spain and Europe
(d) Current controversies on external energy dependence may promote marine energy production in future.

Past experiences in energy production industries have showed that strategic options have been the subject of never ending discussions. The complex bureaucratic procedure to obtain permissions is one of the major institutional and administrative obstacles. There is also insufficient coordination between ministries that further impede the offshore grid development. With regards to environmental legislation, the existing one does not explicitly exclude offshore renewable energy installations and infrastructure. However, it may slow down or hamper in some specific cases the deployment of offshore renewable energy installations/infrastructure.

5.2.3 Institutional and Policy Framework

5.2.3.1 Policies Related to Offshore Renewable Energy

The regulatory framework for the development of marine energy in Spain includes:

(a) the Renewable Energies Plan 2011–2020 (PER)
(b) the Royal Decree No. 661/2007
(c) the Royal Decree No. 1028/2007
(d) Administrative procedures

The Renewable Energies Plan (PER) of Spain was approved in November 2011. The main objective of this plan is to establish a set of guidelines and policies to meet European objectives by 2020 given by the EU Directive 2009/28/CE. The plan promotes the production of renewable energies according to the Royal Decree 661/207 and the Sustainable Economy Law 2/2011. Furthermore, it establishes the available power of each marine energy. By 2020, the offshore wind energy goal is 750 MW, while the wave energy power goal is 100 MW.

The Royal Decree 661/2007 establishes a regular and legal framework in order to give stability and certainty and a sufficient return to the society. It aims at promoting an efficient operation of the electrical system, while it integrates and maximizes renewable energies in the electrical system. Finally, it establishes some mechanisms and incentives for market participation.

The renewable installations are classified in the following groups:

- Category A: cogeneration and residual energy installations
- Category B: renewables (solar; wind; geothermal, hot rock, wave, tide, ocean-thermal; mini-hydro, power < 10 MW; hydro, power > 10 MW; biomass; biogas and others; industrial biomass);
- Category C: energy recovery from waste (SUW; waste not previously considered; waste accounting for at least 50% of primary energy used; plants pursuant to Royal Decree No. 2366/1994 of waste from mining operations).

Marine energies, including wind and waves, are included in the second category and they are considered special regime energy resources. The Directorate-General of Energy Policy and Mines is the competent authority for the inclusion in the special regime when the installation is located in territorial waters. The mechanisms for remunerating the energy produced in the special regime includes a single regulated list of charges for all programming periods and a market sale through the system of bids managed by the market operator, the bilateral contracting system or by installment, or a combination of all these.

5.2.3.2 Administrative Procedures Related to Offshore Renewable Energy

The administrative procedures include the following processes: (a) administrative authorization which is set by the Royal Decree No. 1955/2000; (b) environmental impact assessment of the project; (c) environmental impact study (available Environmental Impact Assessment (EIA) for similar project in the region: Plan Eólico de Cantabria); (d) identification and justification of the sea-land public domain to be occupied; (e) approval of the construction project; (f) start-up certificate.

The administrative authorization body of installations is the Directorate-General of Energy Policy and Mines of the Ministry of Industry, Energy and Tourism. The grants authorizations and concessions to occupy the sea-land public domain are provided by the Ministry of Agriculture, Food, and the Environment (Directorate-General of Coast and Sea Sustainability). The Directorate- General of Environmental Quality and Assessment and Natural Affairs of the Ministry of Agriculture, Food, and the Environment is the competent environmental body, while the Secretariat-General for the Sea passes measures to protect and regenerate fishery resources. The Ministry of Development (Directorate-General of the Merchant Marine) is responsible for passing measures for maritime security, navigation and human life at sea, while port authorities are responsible for grants authorizations and concessions to occupy the port public domain.

5.2.3.3 Policy Obstacles and Regulatory Uncertainty

The majority of proposals made for the Spanish Coast site are oriented to energy production. Thus, costs cannot be shared among sectors, while the financial conditions of the business operation depend critically on policy regulations determined by the public sector. However, there is uncertainty on spatial planning regulations. Past experience has shown that the needed guarantees for long term investments are never provided and initial approvals can easily be rejected. There is also uncertainty in the availability of funding that may have a great impact on the potential development of the infrastructure. Furthermore, the uncertain character of the proposed activities represents a significant restriction for financial agents that want financial guarantees to assume their participation in the funding scheme.

The complex bureaucratic procedure to obtain permissions is one of the major institutional and administrative obstacles. There is also insufficient coordination between ministries that further impede the offshore grid development. With regards to environmental legislation, the existing one does not explicitly exclude offshore renewable energy installations/infrastructure. However, it may slow down or hamper in some specific cases the deployment of offshore renewable energy installations/infrastructure.

Other legislative obstacles include the following:

(a) the international marine spatial planning (MSP) instruments set up provisions influencing the legislative and procedural requirements for offshore renewable energy and the related grid infrastructure
(b) the maritime spatial planning is closely related to a legal framework
(c) the priority principle for navigation has been firmly anchored in the United Nations Convention on the Law of the Sea (UNCLOS) and is reflected in the dominant position of the shipping sector
(d) the fundamental right to lay submarine cables is firmly anchored in the UNCLOS
(e) lack of clarity of information, specific uncertainty related to grid capacity reinforcements.

5.3 Monetization of Environmental Impact

5.3.1 Impact on Ecosystem Services

The selected multi-use design for the Cantabria Offshore site might influence a number of the marine ecosystem services supplied by the Atlantic Coast. These include provision of food and raw materials, supporting services, cultural and habitat services (Table 5.2).

Table 5.2 Ecosystem services probably affected by the multi-use design

Category of ecosystem services	Provisioning services	Supporting/regulating services	Cultural services	Habitat services
Ecosystem services	Food and raw materials	Nutrient cycling	Cognitive development: research and education	Diversity
Period of the effect	Constrution and operation phase	Not relevant	Construction and operation phase	Operation phase

Source: Communication with Site Managers and Biologists

Under MERMAID Project it was decided to apply an adjusted Benefit Transfer method to account for potential environmental and socio-economic impacts. The referred adjustments considered income changes, price changes over time and purchasing power differences. The adjustments were based on UNEPs manual on valuing transferred values of ecosystem services (2013).

In order to choose the relevant studies, common socio-economic and geographical characteristics are considered between the policy site and the study sites of each examined paper. Since it was hard to find studies related to offshore multi-use platforms, research had to be expanded on case studies that include similar environmental and social effects in the marine area without explicitly referring to offshore platforms. The aim was to estimate the effects produced – moving from the baseline to the final platform design - on the ecosystem services defined under the environmental assessment.

Based on the policy site characteristics and the information provided by the MERMAID site managers and biologists, cultural services with regards to cognitive development were given monetary values. However, economic values for all the possible effects on ecosystem services were not given due to lack of data. The positive benefit during the construction and operation period produced from R&D and education was estimated to be 1.2 euros per person per year (2013). Assuming that the affected population is 577,995 based on the regional profiling, the economic revenues amounts to 695,727.13 (2013) euros per year (Table 5.3).[1]

5.3.2 Impact on CO_2 Emissions

Energy Farm MUOP designed by University of Cantabria comprises oscillating column type wave energy devices and 5 MW NREL wind turbine that are installed on a triangular semisubmersible concrete platform. In the energy farm, 77 energy platforms are planned to produce energy. Transmission of produced electricity is realized through submarine cables which are gathered at one offshore substation. After this, electricity is transmitted to an onshore substation where it is connected to main transmission lines. The systems studied in LCA study included production and

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[1] Pugh and Skinner (2002) paper was used for the purpose of benefit transfer.

Table 5.3 Benefit Transfer Application for the Cantabria Offshore Site.

Description	Research and Education			
Pugh and Skinner (2002)	Total Value (£)/year (2004)	UK Population (2004)	Value (£)/ person (2004)	Benefit transfer value (Euro) (2013)
This study estimated the value added for research and development in the marine sector, including education and training during the period of 1994–2000.	292,000,000/6 = 48,666,667(£)	59,990,000	0.81(£)	1.20 (Euro)

Exchange rate 2004, £/$ used: 1.77

installation of MUOP components (wind turbine, wave energy converter, floating platform) and electricity transmission system (offshore substation and submarine cables), operation and maintenance activities, disposal of MUOP farm as well as transportation of materials during the life cycles of the MUOPs. Electricity distribution that is located onshore was excluded from the system studied. Functional unit was selected as 2 kWh electricity produced by the system.

Wind and wave according to the characterization results, obtained GWP impact category result is 20.4 g CO_2-eq for the site. To give the decrease in the amount of greenhouse gases due to renewable energy sources, the comparison is made with conventional electricity production techniques and European electricity mixes, respectively. If this comparison is made for Atlantic Case design, the result is the difference between 820 and 20.4 g CO_2 equivalents by taking the average value for electricity production via coal burners for 1 kWh electricity produced (Schlömer et al., 2014). Therefore, it is claimed that if 1kWh energy is produced by the designed MUOP, GHG emissions are decreased for 799.6 g CO_2-eq compared to electricity production by coal usage. In the case of considering European electricity mix (ENTSO-E network) which corresponds to 462 g CO_2-eq/kWh (Itten et al. 2014), the difference is 441.6 g CO_2-eq (Tables 5.4 and 5.5).

The emission estimates were monetized by applying the social cost of carbon. This refers to the shadow price of world-wide damage caused by anthropogenic CO_2 emissions (Pearce 2003). According to Arrow et al. (2014), the social cost of carbon is $19.50 per ton of CO_2 using the random walk model in Newell and Pizer (2003), $27.00 per ton using the state-space model in Groom et al. (2007), and $26.10 per ton using the preferred model in Freeman et al. (2013). The monetization was based on the estimate from the state-space model, which correspond to 22.50 Euro per ton (Exchange rate 0.83 $/Euro).

Table 5.4 Unit amount of CO_2 emissions per function of MUOP and the compared production technologies

Function	Parameter	Amount	Unit
MUOP Electricity Production	Amount of CO_2-eq production per 1 kWh	20.4	g CO_2-eq
Coal Based Electricity Production	Amount of CO_2-eq saved through MUOP electricity production per 1 kWh	799.6	g CO_2-eq
ENTSO-E Electricity Production	Amount of CO_2-eq saved through MUOP electricity production per 1 kWh	441.6	g CO_2-eq

Table 5.5 Total amount of CO_2 emissions per function of MUOP and the compared production technologies

Function	Parameter	Amount
MUOP Electricity Production (WIND + WAVE)	Amount of CO_2-eq production (assuming 778.53GWh/year)	20.4 gCO_2-eq/kWh *778.53GWh/year*25 years = 397050.3ton CO_2-eq
WIND: Coal Based Electricity Production	Amount of CO_2-eq saved (assuming 777.25 GWh/year)	799.6 gCO_2/kWh *777.25GWh/year*25 years = 15537227.5ton CO_2
WIND: ENTSO-E Electricity Production	Amount of CO_2-eq saved (assuming 777.25 GWh/year)	441.6 gCO_2/kWh *777.25 GWh/year*25 years =8580840tonCO_2
WAVE: Coal Based Electricity Production	Amount of CO_2-eq saved (assuming 1.2 GWh/year)	799.6 gCO_2/kWh *1.2GWh/year*25 years =23,988 ton CO_2
WAVE: ENTSO-E Electricity Production	Amount of CO_2-eq saved (assuming 1.2 GWh/year)	441.6gCO_2/kWh *1.2GWh/year*25 years =13,248 ton CO_2

5.4 Financial and Economic Assessment

The financial data for the Atlantic MUOP derived from the final design after considering stakeholders feedback and tests. They are based on the design itself, the construction procedure estimates, the expected location and size of the project and the best available estimates for unit construction costs. First, the resource availability from the re-analysis of spatial database was estimated. From this, the resource availability from wind and wave was obtained. Then the efficiency factor was estimated for the device based on laboratory tests in the tank. Combining both sources, we got the energy produced, which was related to the energy price. Furthermore, the final series of the tests obtained for available resource showed a typical deviation from the mean for wind energy production equal to 0.59 and 0.55 for wave energy production.

The Cantabrian Offshore site MUOP's was composed of 77 units of 8Mw floating devices with mixed technology: windmills and oscillating water column farm,

Table 5.6 Estimates on annual energy production per function of the platform on the Atlantic site

	Resource	Power	Capacity factor	Energy	Sigma(Resource)/ Mean(Resource)
Wind	450 w/m^2	5 Mw	0.2304	10.09 Gwh	59%
Wave	28 kw/m	3 Mw	0.0544	1.43 Gwh	55%

total power 616Mw. Total manufacturing cost is estimated to be 2.7 million Euro/ Mw, whereas total capital expenses reach 3.66 Euro/KW. The capacity factor for the installation reaches 0.20 for windmills and 0.05 for waves consistent with other experiences. An estimate for operational cost reaches 2.189 million Euro/kw and the average cost of energy reaches 0.167 Euro/kwh. The energy price starts with 0.15 euros/kwh and jumps to 0.17 in 8 years from the operation of the platform. The energy operation costs, were estimated based on a 20% of revenues as standard in the literature. Working on a high scale simulation project initially did not show contradiction with this standard (Table 5.6).[2]

By making use of these figures, we have obtained the expected business revenues and costs of the project. In joint graphs the EPCI budget, CAPEX, OPEX and Project budget are summarized next. The total project budget is up to 3,739,899,031 Euro with 60% of it being is related to CAPEX. It is important to notice the 23% of financing project cost considered are due to the total investment required to develop the MUOP farm. The main part of the budget is allocated to the power take-off (wind turbine and OWC) and the marine structure (72% of the EPCI budget and 53% of the CAPEX) (Fig. 5.2).

In this case, the power take-off devices as well as, the marine structures are not replaced. Consequently, the OPEX budget is spread into operation and maintenance costs and insurance cost. They are almost equal (54%–46%) (Fig. 5.3).

5.5 Social Cost-Benefit Analysis

The Social Cost-Benefit Analysis (SCBA) applied in this case study revealed whether the net benefit generated by the multi-use investment project is positive in a temporal perspective, conditional on the utilized discount rate scheme. The Net Present Value (NPV) criterion was applied. For this the general expression for NPV is employed as follows:

$$NPV = -\sum_{t=0}^{N} \frac{K_t}{\left(1+r\right)^t} + \sum_{t=0}^{N} \frac{B_t - C_t}{\left(1+r\right)^t}$$

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[2] It should be noted that the device is still under a process of refining and improving the capacity factor (ratio of energy captured over nominal capacity of the device). The final figures are expected to improve in the near future.

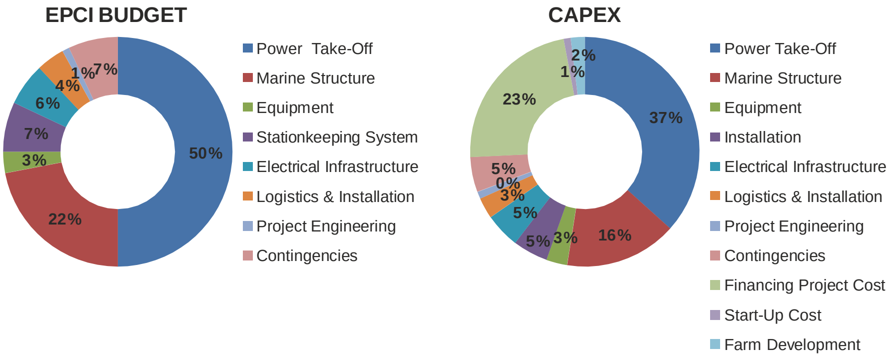

Fig. 5.2 EPCI budget and CAPEX

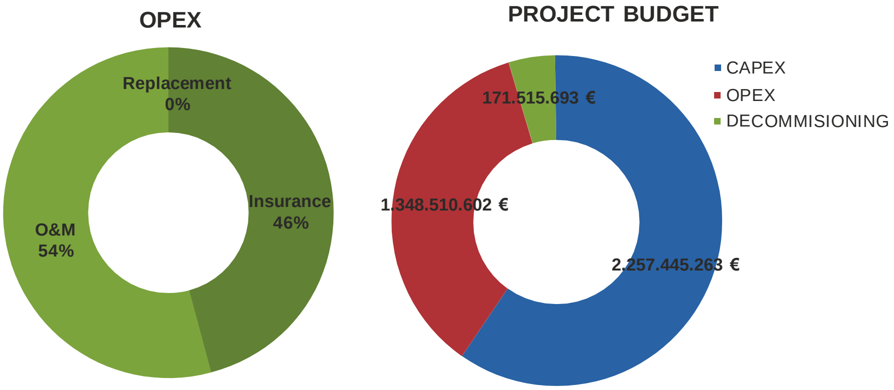

Fig. 5.3 OPEX and project budget

where K_t is investment costs, B_t is the stream of benefits, C_t is the stream of costs and r is the discount rate. Monetized values of externalities, i.e. the benefits derived by the CO_2 emissions reduction and research and education effect due to wind and wave energy production, were also included in the benefits or costs terms, which is one major feature that distinguishes a SCBA from a typical financial assessment. For this case the financial costs and revenues, together with the benefits derived by the reduction of CO_2 emissions and research and education were included in the SCBA. For the case of CO_2 emissions both comparisons were used in the analysis, i.e. reduction of CO_2 emissions compared to coal energy production and ENTSO-E production.

For the wind energy production, the triangular distribution was considered. Since, there was no information regarding the stochastic factors affecting wind investment, the triangular distribution was considered as a reasonable assumption,

Table 5.7 Net present value estimations for single and multi-use platform (discount rate: 4%)

	Mean NPV (4%)	St. dev. NPV (4%)
Single-use: Wind function operation compared to coal energy production	706,564,380.13	41,298,125.64
Single-use: Wind function operation compared to ENTSO-E energy production	623,877,389.65	40,965,292.18
Single-use: Wave function operation compared to coal energy production	−389,440,742.43	16,787,778.68
Single-use: Wave function operation compared to ENTSO-E energy production	−390,505,552.28	16,750,771.88
Multi-use: Wind & Wave scenario operation compared to coal energy production	305,730,883.29	55,184,066.20
Multi-use: Wind & Wave scenario operation compared to ENTSO-E energy production	225,915,262.55	54,937,265.13

All values in euros

with central value the given investment cost and boundaries at 15% of the central value.

In the case of wind energy production and wave energy output production, normal distribution was used. Since no information about the specific distributions was available and there was only a central value for each of the items, a normal distribution was assumed with mean the given central value. The structure of the normal distribution was determined such that the mass included in the interval of ±2 standard deviation from the mean (μ) has boundaries at a distance of γ % of the mean (μ) the choice of γ was consistent with the data of the specific case.

Two alternative values were used for the social discount rate: 3% and 4%. These values are consistent with values obtained from the Ramsey formula for long-lived projects (see Dasgupta, 2008) $r = \rho + \eta g$, where $\rho = L + \delta$ is the rate at which individuals discount future utilities, L is catastrophe risk, i.e. the likelihood that there will be some event so devastating that all returns from policies, programs or projects are eliminated, or at least radically and unpredictably altered, δ is the rate of pure time preference, which reflects individuals' impatience and preference for utility now, rather than later, g is annual growth in per capita consumption, and η is the elasticity of the marginal utility of consumption. These numerical values are within the limits of typical values for the discount rate 3–4% appearing in the literature (Tables 5.7 and 5.8).

The estimates of mean NPV and its standard deviation suggest that the multi-use scenario (Wind & Wave) passes the SCBA test in terms of NPV (positive NPV) under all alternative assumptions regarding the discount rate and savings related to the reduction of CO_2 emissions. The wave scenario by itself is highly unprofitable due to high investment cost and low revenues. Since the Wind & Wave scenario is highly profitable, the inclusion of the wave function might be desirable to capture benefits related to technological progress which are quantifiable at the current stage.

Table 5.8 Net present value estimations for single and multi-use platform (discount rate: 3%)

	Mean NPV (3%)	St. dev. NPV (3%)
Single-use: Wind function operation compared to coal energy production	849,470,474.47	44,430,442.61
Single-use: Wind function operation compared to ENTSO-E energy production	760,080,006.68	43,250,317.42
Single-use: Wave function operation compared to coal energy production	−392,995,362.89	16,240,898.77
Single-use: Wave function operation compared to ENTSO-E energy production	−392,762,115.79	16,668,616.53
Multi-use: Wind & Wave scenario operation compared to coal energy production	442,343,771.94	58,288,143.94
Multi-use: Wind & Wave scenario operation compared to ENTSO-E energy production	355,399,160.92	56,008,811.17

5.6 Concluding Remarks

The assessment of the Atlantic coast site reveals that the implementation might be subject to several barriers. These are associated to lack of social consensus, to the need for consistent time scheduling decisions and actions, to the regulatory risks with regards to energy policy in Spain and Europe. On the external effects, these are identified with regards to interference of the MUOP with the navigation routes. On the identified drivers of risk the analysis indicates looking at the resource spatial-temporal variability and the institutional risk derived from feed-in tariffs and project administrative delays. Uncertainty on the institutional framework and spatial-temporal viability of the resource are the main concerns with regards to the analysis.

In financial terms, the analysis indicates the importance but also the magnitude of the required capital investments. Significant upfront payments when combined with risk and uncertainty indicate the need for support means to such initiatives. In terms of SCBA results, although the wave function alone seems not to be economically viable, synergies between wind and wave energy could result in technological progress that produces further economic benefits, that may extend well beyond the reduction of CO_2 emissions.

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