MERMAID

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Socio-economic Analysis of the Atlantic Site

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1 Introduction and scope of the deliverable

1.1 Goals and objectives of the deliverable

MERMAID aims at integrating and improving today's technology in an optimal way in order to enhance economic feasibility, reduce environmental impact and to increase the use of ocean space at specific sites, by means of Multi-Use Offshore Platforms (MUOPs). In MERMAID, business opportunities associated with MUOPs are investigated in four different locations in Europe through a financial assessment. In addition, MERMAID aims at identifying the impact on human welfare of MUOPs through a framework for socio-economic assessment. This framework takes into account the fact that human welfare is dependent on a wide range of social and economic aspects, including ecosystem services.

The overarching aim of this deliverable is to assess the sustainable development of the final conceptual designs of MUOPs. Sustainable development is described by a three-dimensional sustainability condition. In particular, in the framework of analysis, sustainable development is achieved when the following conditions are simultaneously satisfied:

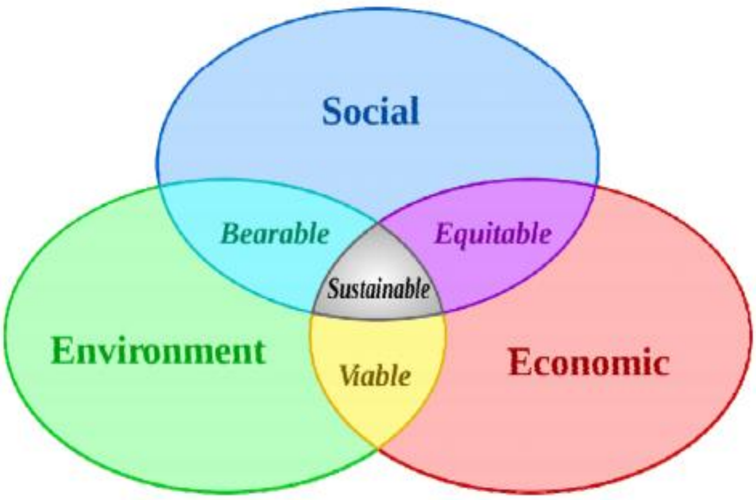

Figure 1 Spheres of Sustainable Development (W.C.O.E.A.D./Brundtland Commission, (1987); UN (2015)

a. Dynamic and Spatial Economic Efficiency and Sustainability: Economic efficiency satisfies the condition that the marginal (social) cost of each production activity under consideration equals the respective marginal (social) benefit. Hence, in this framework both private and social components of costs and benefits are considered in order to provide an integrated economic assessment in terms of efficiency. When the economic efficiency condition is satisfied over time (inter-generationally) and over space (intra-generationally) the economic sustainability of the considered production activities is achieved.

b. Dynamic and Spatial Social Equity and Sustainability: Social equity requires that the social effects of the production activities under consideration are bearable and equitable by the different social groups identified in the region under investigation. These affordability and acceptability conditions should be relevant spatially (intra-generational effects) but also dynamically (inter-generational effects).

c. Dynamic and Spatial Environmental and Ecological Sustainability: Environmental and Ecological Sustainability means that the environmental and ecological effects of the activities under consideration are sustainable over space (in the region under consideration) but also over time.

In this deliverable, we examine the possibility of sustainable development of the developed conceptual MUOP design by socio-economically assess the envisioned MUOP to be placed in the **Atlantic.**

The Atlantic site, more specifically the **Cantabria Offshore Site (COS)**, presents deep sea and harsh ocean conditions. COS 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 high energy content makes the site very attractive for developing MUOPs.

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. COS is situated 10 km Atlantic from the coast of Santander (Cantabria) and it covers up to 60 km^2 of sea. The ocean conditions are severe and challenging. The 50 year return period significant wave high and average expected wind speed will be around 9m and 27 m/s respectively.

A number of 77 units of MUOPs 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 80GWh.

The MUOP farm proposed will be integrated in a site characterized by a wide range of water depths comprehended between 40 and 200 meters where floating structures are the most suitable technology for ocean energy harvesting. The MUOP developed 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 centre of the triangle. The three outer columns are equipped with the OWC technology, and the central one supports the 5MW wind turbine.

The mooring system will be based on conventional catenary mooring lines in order to reduce technical risks and lower the costs. More detailed information about the decisions of the MUOP design can be found in the rest of MERMAID Deliverables (e.g. MERMAID D2.4, MERMAID D7.2, MERMAID D7.3).

Table 1 Atlantic Site Factsheet

Geographical location	Atlantic Ocean, Atlantic of Spain
Surface area of study site	100 km^2
Offshore distance	3-20km
Depth	50-250 m
Substrate	Mix of sandy and rocky seabed
Water temperature	10-20^{o}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

1.2 Relationship to overall project objectives

This deliverable presents the results of the application of the Methodology for Integrated Socio-Economic Assessment (MISEA) which was developed in MERMAID (MERMAID D8.1) to socio-economically assess the different proposed designs of novel Multi-Use Offshore Platforms (MUOPs). MISEA assists on identifying, not only the potential range of impacts of a proposed investment such as the construction of MUOPs, but also the likely responses of those impacted by the investment project. Since it is anticipated that these novel designs of platforms will have considerable socioeconomic and environmental impacts, MISEA provides an analytical framework that lies in agreement with the sustainability conditions. MISEA assists on designing appropriate mitigation strategies to minimize negative and maximize positive socio-economic and environmental impacts. In this context, this methodology extends the standard process of financial analysis into an assessment that incorporates socio-economic, legal, technological environmental parameters.

In particular, the methodology allows a stepwise approach of integrating information produced in the previous work packages (WPs) of the project towards the socio-economic assessment of different designs (being built by the engineers of MERMAID in previous WPs) of MUOPs. The multi-disciplinary information, allows a direct comparison between different MUOP designs, including comparison between multi-use and single-use alternatives. Under MERMAID, the information produced by the different WPs was used for the socio-economic assessment in each selected site and platform design.

- Legal and policy analysis provided the policy and legal background required for the development of the particular platform designs. Stakeholders' analysis and more specifically the stakeholders' roundtables provided inputs to for the final design and the socio-economic assessment of the selected MUOPs with regards to social acceptance and potential conflicts between stakeholders (MERMAID D2.1, MERMAID D2.4 and MERMAID Repository[1]: Regional Profiling Datasets).

- The identification of innovative platform designs formed the background required for the collection of the financial data, as well as the socio-economic analysis and monetization of environmental externalities. (MERMAID D7.1, MERMAID D7.2, MERMAID D7.3, and MERMAID Repository[2]: Regional Profiling Datasets).

- The case-study specific environmental assessments (MERMAID Repository[3]: Regional Profiling Datasets) identified the environmental effects in relation to the suggested designs. MUOPs are related to a stream of new social/environmental goods and services (e.g., increase of employment, increase food and energy security, potential interactions with

[1] http://mermaid.madgik.di.uoa.gr/
[2] http://mermaid.madgik.di.uoa.gr/
[3] http://mermaid.madgik.di.uoa.gr/

marine environment etc.) with no values readily observed in existing markets. Hence, it was required to follow non-market economic valuation methods to estimate these values (Economic Valuation Methods are explained in D8.1). Although the information was limited and based on experts' opinions and stakeholder's views, the economic values of the main environmental externalities were estimated successfully.

- The case-study specific financial feasibility assessment was crucial for the comparison between different offshore platforms. The data used in the financial assessment were the investment costs with regards to equipment, construction, labor and other costs, as well as operation data for the costs and revenues according to different functions used in the final design of each study site (e.g. energy/aquaculture production output, price, raw materials, energy used, maintenance costs, operating costs).

This methodology provided useful information on which economic activities should be implemented on the different sites, with the scope to avoid developments that would have negative socio-economic and environmental consequences, considering legal and technical aspects. This load of information assists on identifying challenges and opportunities towards the implementation of suggested MUOPs. A representation of the connections between the WPs' outputs used as inputs is given below.

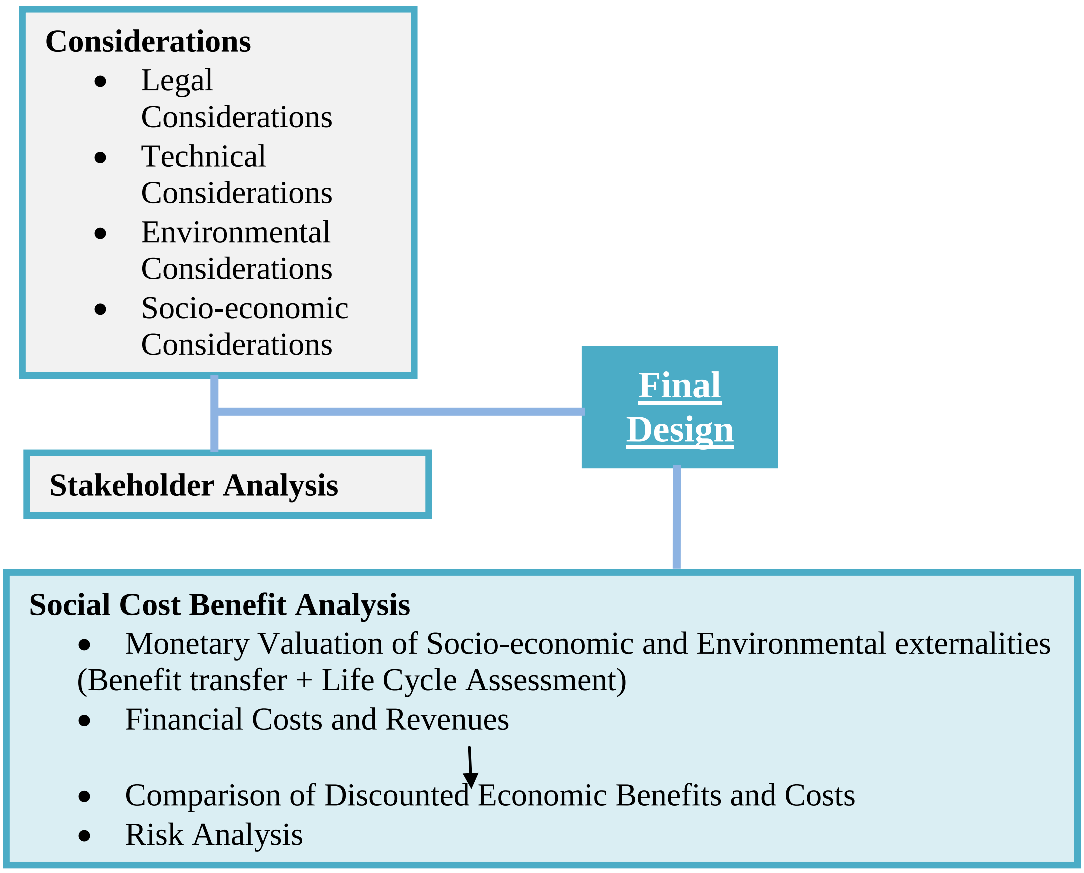

Figure 2 MERMAID Stepwise approach of integrating information

1.3 Outline for the reader

The document is divided into **6** different sections. **Section 2** describes the general methodology framework of the conducted assessment and introduces the online assessment tool as the application of this methodology. **Section 3** includes a regional description of the Atlantic Sea site. **Section 4** describes the economic valuation of environmental changes. **Section 5** includes the financial assessment for the Atlantic Sea site. **Section 6** includes the undertaken social cost benefit analysis and **Section 7** offers concluding remarks and recommendations.

2 General framework of the methodology and introduction to the Assessment Tool

2.1 The methodology for Socio-economic Assessment of MUOPs

In this section the Methodology for Integrated Socio-economic Assessment (MISEA) is described in detail. This methodology allows us to identify, valuate and assess the potential range of impacts of different feasible designs of MUOP investments, and the responses of those impacted by the investment project. This methodology aims to investigate the possible sustainable development of MUOP investments, by focusing on marine sustainable management, extending the standard process of financial analysis into an interdisciplinary assessment that incorporates socio-economic, technological, legal and environmental parameters, parameters, aiming at an estimation of the total impact on economic welfare in society.

Economic welfare includes the net benefit earned by a private company, as well as the total benefit /cost to the national economy. If we want to capture the total economic value of a project we need to consider the socio-economic and possible environmental impacts to the ecosystem.

Socio-economic impacts can be characterized as “direct” and “indirect”. This distinction is with regards to the level of effect on those who are involved in the MUOPs, meaning that particular economic sectors and people can be affected directly and/or indirectly by the use and operation on MUOPs. Direct impacts correspond to the earning capacity and costs of aquaculture, energy and maritime business, concerning for example the employees and their families, as well as the suppliers of aquaculture, energy and maritime businesses. Indirect impacts on the other hand are related to impacts on consumers and the broader economy.

Based on the analysis produced under each MUOP design for each site and the stakeholders’ views (MERMAID D2.4), MUOPs will create new employment opportunities and will have strong economic impact in the community. Enterprises will benefit by the development of new technologies and will improve the technical capacities for energy production and aquaculture. In addition, MUOPs have the potential to increase research and development regarding technological advances and to boost educational aspects.

Accordingly, implementing an MUOP would affect the environment and the ecosystem services. Ecosystem services are defined as services provided by the natural environment that benefit people (Defra, 2007). Individuals place values on the environmental resources and their ecosystem services for given changes in their quality and/or quantity, which are expressed in relative terms based on individuals' preferences. Based on the MERMAID EIA manual, experts opinions of the MERMAID project and Life Cycle Assessment (LCA), environmental effects were identified. These were linked to human welfare and their value was elicited using economic theory.

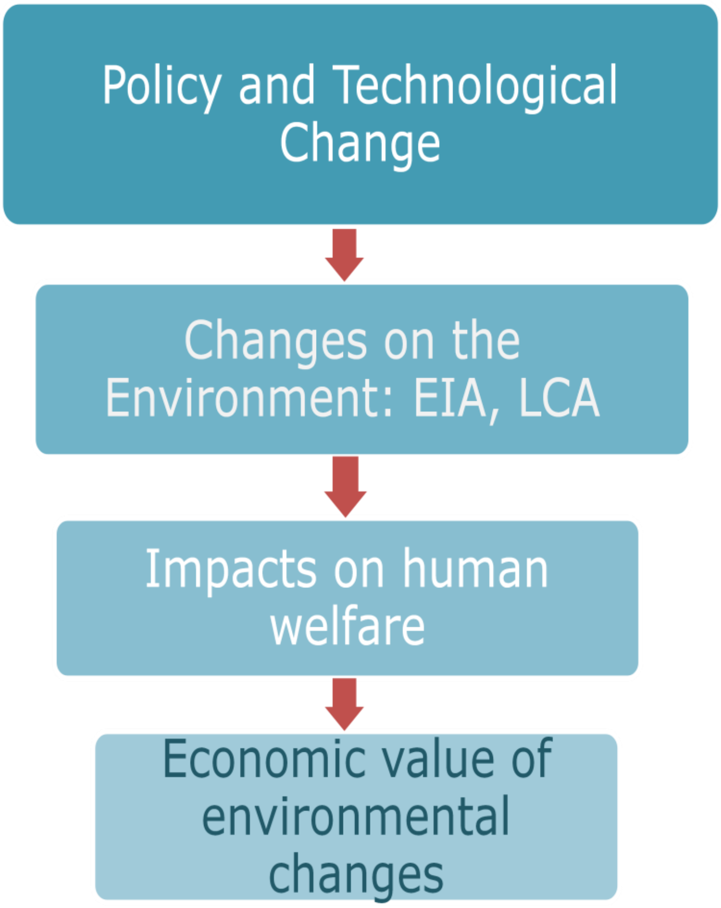

Figure 3 Overview of the impact pathway of policy and technological change

The Total Economic Value (TEV) for any given product or resource is the sum of use (direct, indirect, option value) and non-use values (altruistic, bequest, existence value). Natural resources and their ecosystem services are generally not traded in markets. As a result no market price is available to reflect the economic value of environmental changes. Hence, expressing these impacts in monetary terms using non-market methods is required (see Freeman et al., 2014). We present at the next figure the TEV framework and the economic techniques used in economic valuation of benefits derived from the ecosystem services (see D8.1 for more details).

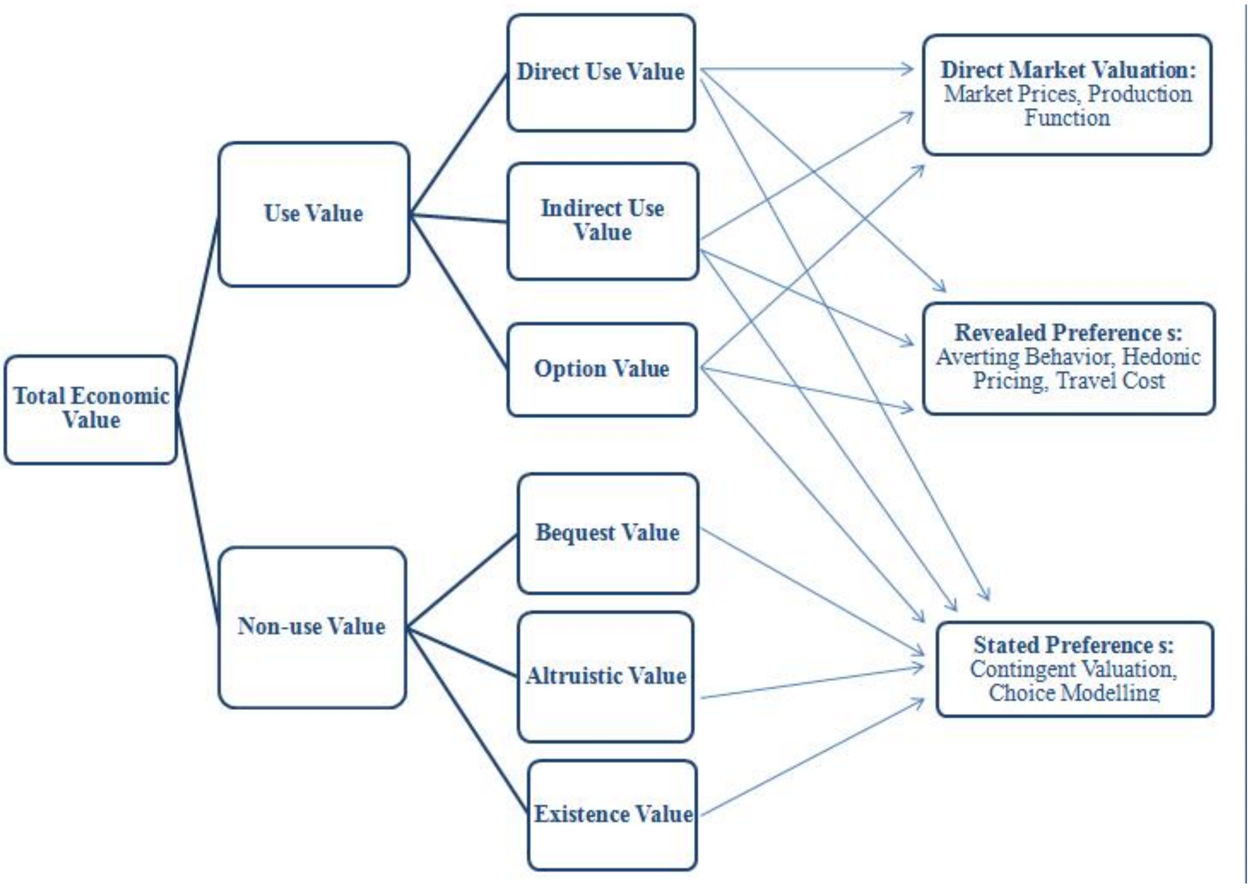

Figure 4 Techniques for monetary valuation of non-market services (Koundouri and Giannouli, 2015)

Primary valuation can be done either using stated preferences or revealed preferences techniques. However, in MERMAID, the benefit transfer method was applied for the socio-economic assessment, i.e. monetary estimates of the non-market value of impacts of MERMAID study sites were derived from earlier studies (Johnston et al., 2015). In addition, based on the Life Cycle Assessment (LCA), we compared each platform's CO_2 emissions to those that would have been produced via traditional (not renewable) energy sources as the result of producing same amount of electricity and aquaculture products. For this case, we used the social cost of carbon (SCC) to estimate the benefits produced from this comparison. After the identification and quantification of the environmental and socio-economic benefits, the financial costs and revenues from energy extraction and aquaculture production were included into the analysis.

More explicitly, MISEA consists of the following steps:

- **Scoping Phase** Defining boundaries, key impacts, key stakeholders, information availability

<u>Socio-economic characterization of the existing situation in the site with regards to wind power production, aquaculture and transport maritime services</u>: The collection of required data for the socio-economic

characterization was performed during the implementation of the regional baseline characterization questionnaire (MERMAID Repository[4]: Regional Profiling Datasets). See section 3.

- **STEP 1** Socio-economic characterization per case study: Wind power, wave power and aquaculture production

Production-Side Analysis of Multi-use Space: This analysis is based on estimated financial costs of offshore structures, and also on the costs of environmental and ecological changes due to the proposed multi-use structure, as identified by the environmental impact assessment.

Demand-Side Analysis of Multi-use Space: This analysis depends on the evaluation of socio-economic consumption benefits related to the proposed structures and also on the benefits of environmental and ecological changes due to the proposed multi-use structure, as identified by the environmental impact assessment/environmental analysis.

- **STEP 2** Translated Externalities into financial flows: Benefit transfer and Life Cycle Assessment (LCA)

Costs and benefits produced by environmental change related to wind power, wave power and aquaculture production were estimated using benefit transfer methods (transferring monetary values from earlier studies to the policy site) and relying on the Life Cycle Assessment with regards to CO_2 emissions quantity change. (See section 4)

- **STEP 3** Recommendations based on economic tools: Social Cost-Benefit Analysis (SCBA)

The last step for assessing viability is the use of Cost Benefit Analysis (i.e. Social Cost Benefit Analysis for MERMAID Project). See section 6.

It should be noted that, a sensitivity analysis was also performed in order to incorporate the socio-economic uncertainty of the environment under which each MUOP design could be developed and operate (See MERMAID D8.6). Particularly, it is assumed that uncertainty about each parameter value can be captured by a probability distribution that will be used to compute the social costs/benefits. A subsequent step in including uncertainty requires experts to provide their estimates of the most likely value of parameters of interest, together with upper and lower bounds, assessing the likelihood that actual values would lay above or below these upper and lower estimates.

Overall, the methodology is used to evaluate the trade-offs with regard to socio-economic welfare between different proposed multi-use structures. Case-study specific recommendations are offered after employing Social Cost Benefit Analysis. See section 7.

[4]http://mermaid.madgik.di.uoa.gr/

2.2 The Assessment Tool

For the purpose of MERMAID MUOPs' assessment, an online assessment tool was developed (See Annex II). This tool incorporates the information produced during the project, comparing the socio-economic aspects derived from the MUOP to the baseline of each case study under consideration. This tool has the potential to be used for future sustainability analysis of multi-use projects.

The importance of this tool lies on its outputs and its capacity to provide a guideline to support decision-making. The MUOP assessment tool was applied in all four case studies and attempts to help all the stages of the research by indicating the pathway of choosing the most appropriate MUOP design with regards to the different aspects involved (socio-economic characteristics, technological, legal, environmental, financial and economic constraints and considerations). The tool helps to identify costs and benefits emerging from the MUOP specific design and thus provides important information for the Social Cost Benefit Analysis (SCBA). The assessment tool collects and systematizes multidisciplinary information for each case study. The different sections of the tool are the following and they are closely related to the MISEA:

A) Technical and Legal Feasibility Assessment;
B) Environmental Impact Assessment;
C) Monetization of Environmental Externalities;
D) Financial and Economic Assessment;
E) Social Cost Benefit Analysis and Risk Analysis

The sections of the assessment tool related to the Atlantic Site are presented in the Annex II.

<u>A. Technical and Legal Feasibility Assessment</u>

The Technical and Legal Feasibility Assessment (TLFA) section of the assessment tool requires from the users to identify if the MUOP design is feasible by considering legal and technical considerations. Users are also required to take into account financial costs and revenues of the installation and operation of the platform, consider the project's time horizon, any existing possibilities of combined use and finally any other options for technological upgrades. Simultaneously, a set of risks needs to be identified and taken into account. The set of risks include: technical uncertainty, financial uncertainty, impact diffusion (i.e. correlated risks between functions), political uncertainty and unclear definition of property rights.

The users select the appropriate answer which is then quantified accordingly as input into the tool. The first questions represent the main aspects that need to be taken into account for the legal and technical feasibility. The tool quantifies the answers and feeds them into an algorithm that displays a message of whether the user may continue with the rest of the process, or, a message could be shown based on the unmet technical or legal constraints, i.e. if the answers to the last questions are negative.

Table 2 Technical and Legal Feasibility Assessment and Significant Risks

A. Technical and Legal Feasibility Assessment (TLFA)	
a.	Approximations to production parameters (Costs: capital, Operation and Maintenance (O&M), administration costs and revenues)
b.	Definition of project's time horizon
c.	Possibilities of combined use
d	Possibility for technological upgrades
e.	Uncertainty about reliability of the techniques used
f.	Uncertainty about estimates of costs and revenues
g.	Impact diffusion (correlated risks between functions)
h.	Political uncertainty
i.	Unclear definition of property rights
j.	Is location feasible? (Take into account legal considerations)
k.	Is location feasible? (Take into account technical considerations)

<u>B. Environmental Impact Assessment</u>

Regarding the Environmental Impact Assessment (EIA), the users are asked to identify all significantly positive and/or negative environmental impacts (at local, regional and global levels). Also, they are asked if there is an EIA available for similar project(s) in the region. The set of risks identified for this section refer to the uncertainty about climate change and other environmental parameters, the possible non-linear environmental effects, as well as the irreversible environmental effects of the operation of the platforms. The table below presents the questions posed to experts and researchers, including the set of risks to be identified. The answers of the users, which should be based on an Environmental Impact Assessment or Environmental Analysis undertaken during the design phase of the MUOP, are quantified for the tool.

Table 3 Environmental Impacts Assessment and Significant Risks

B. Environmental Impacts Assessment (EIA)	
a.	Significant negative environmental impact (local, regional, global)
b.	Significant positive environmental impact (local, regional, global)
c.	EIA available for similar project in the region
d.	Uncertainty about climate change and other environmental parameters
e.	Non linear environmental effects & threshold identification
f.	Irreversible environmental effects
g.	Environmental considerations: is the location feasible?

C. Monetization of Environmental Externalities

The user is asked to choose the location of the MUOP. According to this choice, pre-estimated monetary values of the identified environmental change related to the specific location are incorporated into the final section of the assessment tool (see Section 4).

D. Financial and Economic Assessment

The Financial and Economic Assessment (FEA) section of the tool attempts to extract the estimated financial costs (capital, operations & management, administrative) of the MUOPs. This section also requires the estimation of potential financial revenues as well as the efficiency gains from combined use of the platform.

The user can upload a csv (comma separated value) formatted file, a format that can easily be exported from all common spreadsheet software such as Microsoft Excel. Alternatively, the user can input manually the requested values at the appropriate input boxes. It should be noted that, the user will be asked to include the number of kWh and kg related to yearly energy production and aquaculture production, respectively. By this way, the corresponding change in CO_2 emissions due to MUOP operation is monetized through the social cost of carbon as an input to the SCBA (see Section 4).

E. Social Cost Benefit Analysis and Risk Analysis

This final section of the tool uses the financial and economic data, including monetized externalities, produced by the previous sections and run a Social Cost Benefit Analysis (SCBA) by comparing discounted flows of costs and benefits. The results indicate if the proposed design is socio-economically sustainable or not. The risks that may influence the results of this assessment concerns the uncertainty and missing information in estimation of external effects and in perception formation as well.

The tool concludes with a risk analysis, simulating different scenarios to define sensitive values and the overall risk of the selected infrastructure.

- First scenario: Deterministic model

The tool uses a number of potentially sensitive variables according to user selection over a predefined list, and calculates net present value for the user specified time horizon. The user chooses the minimum and maximum values for each of the variables. The tool performs sensitivity analysis based on these inputs and produced visualizations so that the user is able to observe the behavior of these variables.

- Second scenario: Stochastic models with one variable fixed.

While one of the potentially sensitive variables of the model (e.g. interest or growth rate) is fixed at the user input value, the tool models the others as randomly distributed according to a predefined distribution. With these parameters the tool runs a Monte Carlo simulation so as to obtain a distribution for the total cost. The results are presented as a summary table with basic statistical values for the distribution of the total cost, and graphic visualizations.

3 The Atlantic Site Regional Profiling

MERMAID project experts have decided that the multi-use offshore platform (MUOP) in the Atlantic site will be consisted from infrastructures of wind and wave energy. The site location (Open Ocean) is suitable for these uses and with great potential, especially for the wave energy production. Wind power production is currently expanded in Spain. In 2013, wind farms became the first source of electricity, while also at the same year the first offshore wind turbine was installed in Spain, in a Canary Islands area. On the contrary, aquaculture activities are not possible. Although, marine aquaculture is being practicing in Spain since 1973 and inland aquaculture expands significantly year by year, the water conditions are not appropriate for aquaculture since the site is exposed to energetic seas and swells and located in a cold water area. Located on the Atlantic coast of Spain, Cantabria offers a good opportunity for offshore technology deployment with a reasonable combination of depth and distance. The availability of natural port facilities constitutes an additional advantage for the deployment of the selected activities.

The description of the study site profile contributes to a better understanding of the effects of the selected multi-use activities on the local socio-economic environment. This section outlines the socio-economic context of the study site, describes the institutional framework, and identifies actors, i.e. economic sectors, individuals that may be impacted by the MUOP.

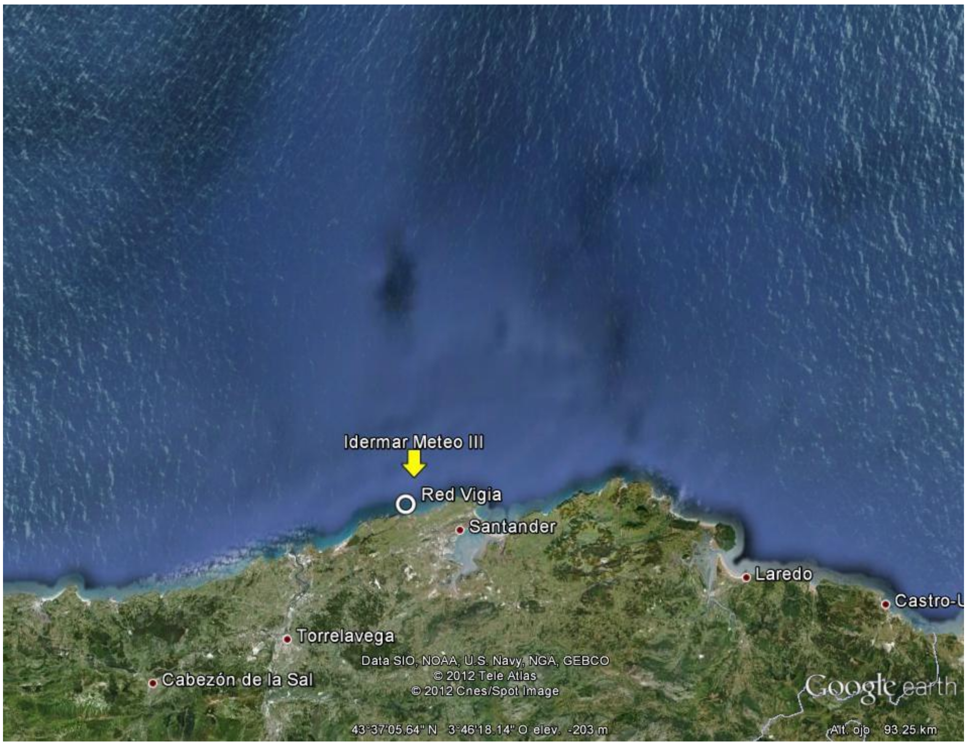

Figure 5 Location of the site (MERMAID D2.1)

3.1 Demographics and Economic Activities

The Cantabrian offshore site is located in the Atlantic coast of Spain in the region of Cantabria. It is a medium size site with a surface around 100km$_2$, while is well suited to explore floating wind turbines and wave energy concepts. In particular, this specific site is rather challenging because of the very rough wave and wind conditions, while its location is close to large port facilities, as well as shipyards and other industries.

The land area of the study site accounts for 5,321 km2. The population of the region amounts to 577,995 inhabitants with density of 109 inhabitants per km2. 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 labour 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 analysing the economic structure and organisation. The analysis of sectoral employment indicates that the economy is more services oriented since 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 labour force had higher education (26% hold baccalaureate and 30% has attained graduate studies), while 34% of the labour force had secondary education.

The total value of regional production in the study site amounts to 12,829,911 euro. In terms of the sectoral shares of regional production, the tertiary sector contributes by 60% to the regional product 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%.

3.2 Socio-economic Impacts of MUOP

A detailed analysis of the current political and social conditions in the Atlantic site revealed that in terms of wave energy production and transport maritime services the most vulnerable groups and those impacted more are fishermen and persons involved on activities related to tourism and maritime transport. With regards to wind energy production, the most vulnerable groups are farmers, cattle breeders and persons involved on activities related to tourism and maritime transport, while for aquaculture the sectors of tourism and cattle breeding seem to be the most vulnerable.

The financial feasibility of the alternative MUOPs identified high costs for equipment, decommissioning and operation & maintenance for all platforms. The combination of wave energy with aquaculture is expected to have the lowest costs on both equipment and power extraction systems compared to the other alternatives, while the wind and wave energy generation with aquaculture is expected to have the highest costs under almost all criteria. Finally, all alternative MUOPs are expected to have an increase in temporary employment**,** benefits for industry and benefits for existing businesses. In particular, it has been estimated that during the construction phase of the proposed platform 1,000 persons can be employed over a three-year period, while 500 persons can be employed for M&O activities during the operation phase.

The involved stakeholders who will be affected by the proposed MUOPs include for the wind power production the 20% of property owners in the coast, the 50% of fishermen in the port and the 50% of maritime companies. The same stakeholders are affected by the wave power production with the only differentiation made on the percent of the property owners in the coast which is a bit lower (10%). For the aquaculture it was estimated that 20% of residents wouldn’t have access to the coastal area or to bath due to pollution. Finally, for the transport maritime services it was estimated that all industries around port facilities and all municipalities around port would have been affected.

3.3 Institutional and Policy Framework

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 approved on 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 PER promotes the production of renewable energies according to the Royal Decree 661/207 and the Sustainable Economy Law 2/2011. Furthermore, the PER establishes the available power of each marine energy. By 2020, the offshore wind energy goal is 750MW, while the wave energy power goal is 100MW.

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 to promote 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.

As it was discussed above, 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 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 (APS).

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.

3.4 Controversies, Uncertainty and Implementation Obstacles

A group of stakeholders was interviewed on 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 on 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 of the region. Several social initiatives led by political parties and other civil associations showed up 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. On 2012 a new emerging technology, the shale gas, raised as a very promising source of income. However and in this case the social perception for this new technology was 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. Unfortunately, past experiences in energy production industries have showed that strategic options have been the subject of never ending discussions with cyclical options been adopted. The dependence of this site on energy production activities makes this issue critical; (d) current controversies on external energy dependence may promote marine energy production in future.

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; (f) lack of clarity of information, specific uncertainty related to grid capacity reinforcements.

4 Monetization of Environmental Externalities

From the previous section it is concluded that due to the multidimensional character of the impacts (socio-economic and environmental of direct and indirect outcomes, i.e. at stakeholder, industry and community scale), a range of different information was needed in order to assess them. As a result, market data, secondary data for the performance of simulations, surveybased primary data, data provided from literature review, consultation with experts and stakeholders and information coming from environmental impact assessments were important in the framework of integrated assessment.

The negative environmental impact of the proposed Atlantic MUOP include the following: (a) degradation of the aesthetic value of the landscape since the visual impact up to 10km offshore; (b) impact on birdlife (flight paths for migratory birds will be affected); (c) impact on animal life through the sound of wind turbines; (d) impact on marine life through radiation pollution; (e) exploitation of mineral resources. With regards water quality issues no signs of eutrophication or potential for eutrophication have been observed in the proximity of the outfall discharge. Due to the vertical mixing of the plume and horizontal dispersion, no significant increases in nutrients and/or phytoplanktonic biomass have been observed.

Table 4 Ecosystem Services Possibly Affected by the MUOP

Atlantic Site				
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
Comments	Construction and Operation Phase	Not Relevant	Construction and Operation Phase	Operation Phase

Source: Communication with Site Managers and Biologists

4.1 Life Cycle Assessment

For evaluating the potential environmental burdens of the Atlantic MUOP, a study of Life Cycle Assessment (LCA) was executed by ITU. LCA is a method that targets the whole environmental impacts of a product/service from its raw material production to its disposal, in other words 'from its cradle to grave'. Prepared case-specific Life Cycle Inventory (LCI) includes of all of the used resources, material & energy flows, wastes and emissions through product/service life time with their quantities. This data is then classified according to the contribution of the components to different environmental impact categories such as climate change, eutrophication, ecotoxicity, etc. Categorized parameters are then weighted to measure their contribution potential to the environmental impacts which makes possible to evaluate the whole system quantitatively in terms of environmental burdens (Baumann & Tillman, 2004). Procedures related to application of LCA studies are regulated with ISO 14040 series standards (ISO, 2006a, b). According to this, an LCA study comprises mainly four stages as Goal & Scope Definition, Inventory Analysis, Impact Assessment and Interpretation. Whole of these stages are iterative which may be developed continuously and have interaction with each other.

In the context of the LCA study made for Atlantic site, an LCA in line with ISO 14040 and 14044 standards is carried out using Ecoinvent integrated GaBi software and the CML 2001 method is used to calculate the results. MUOP designed by University of Cantabria comprises oscillating column type wave energy devices and 5MW NREL wind turbine that are installed on a triangular semisubmersible concrete platform. In the energy farm, totally 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 goal of the study is to analyse potential environmental burdens of MUOP through its lifetime. The systems studied in LCA study included production and 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. The main data for LCI was provided by University of Cantabria design team via filling out the LCI questionnaire prepared. Provided information consists of dimensions of the platform and material types and amounts that are used to manufacture the platform. Data gaps were filled by using the literature by the LCA team. LCI tables are available on request.

CML 2001 method evaluates the potential environmental impacts in 11 different impact categories: Global Warming Potential (GWP), acidification, eutrophication, ozone layer depletion, abiotic depletion, abiotic depletion fossil, freshwater aquatic ecotoxicity, marine aquatic toxicity, human toxicity, terresticecotoxicity and photochemical ozone creation.

In the context of this study, only GWP impact category was concentrated on as to be related to as an input for the estimation of the economic benefit of changes in CO_2 emissions. According to the characterisation results, obtained GWP impact category result is 20.4g CO_2-eq for Atlantic site MUOP study.

It is well known that when energy is produced from renewable energy sources, greenhouse gas emissions are lower in comparison with the same amount of energy produced from conventional energy sources. 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 20.4g 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 799.6g 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 441.6g CO_2-eq.

Table 5 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 6 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*25years = 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*25years = 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*25years =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*25years =23988 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*25years =13248 ton CO_2

Based on the Life Cycle Assessment the economic benefit of changes in CO_2 emissions due to MUOP construction and operation was estimated. For this purpose, the social cost of carbon was used, which refers to the monetary value, the shadow price of world-wide damage done by anthropogenic CO_2 emissions (Pearce 2003). According to Arrow et al (2014) social cost of carbon is $19.50 per ton of carbon 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 value used was the one produced using the state-space model **(22.5€ per ton[5], 2013)**.

4.2 Benefit Transfer

Gathering primary site-specific data is costly and time-consuming, which has made Benefit Transfer (BT) a popular alternative for the valuation of ecosystem goods and services. BT uses existing economic value estimates from one location to another similar site in another location. In particular, it concerns an "application of values and other information from a 'study' site where data are collected to a 'policy' site with little or no data" (Rosenberger and Loomis, 2000, p.1097). That is the result of previous environmental valuation studies are applied to new policy or decision-making contexts. However, there are a number of criteria that have been identified in the literature for benefits transfer to result in reliable estimates as summarised in Brouwer (2000):

- sufficient good quality data
- similar populations of beneficiaries
- similar environmental goods and services
- similar sites where these goods and services are found
- similar market constructs - similar market size (number of beneficiaries)
- similar number and quality of substitute sites where the environmental goods and services are found.

Bergland et al. (1995) discussed three main approaches to BT: (i) the transfer of the mean household WTP, (ii) the transfer of an adjusted mean household WTP and, (iii) the transfer of the demand function. The first approach assumes similarity in good and socio-economic characteristics between the study and target site and the other two approaches attempt to adjust the mean WTP and re-calculate it respectively, in order to account for differences between the two sites in terms of environmental characteristics and/or socio-economic characteristics. See also recent BT reviews such as Navrud (2010), Johnston and Rosenberger (2010), and Johnston et al. (2015).

It was decided under MERMAID to apply an adjusted BT to account for potential environmental and socio-economic impacts. In order to choose the relevant studies, common socio-economic and geographical characteristics are considered between the policy site and the study sites

[5] Exchange rate 0.83 $/ €

of each examined paper. Since it is hard to find studies related to offshore multi-use platforms, research has to be expanded on case studies that include similar environmental and social effects in the marine area without explicitly referred to offshore platforms. The aim is 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 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 €per person per year (2013)**. Assuming that the affected population is **577,995** based on the regional profiling, the economic revenues will be **695,727.13 (2013) euros per year.** Pugh, D., & Skinner, L. (2002) paper was used for the purpose of benefit transfer. More details on the calculations are given in the Annex I.

Benefit Transfer Adjustments

- Income Changes: Assuming the demand for ecosystem services changes with income, we used the income elasticity (e) of willingness to pay (WTP) to adjust the value on the study site:

$$WTP_p = WTP_S \left(\frac{Y_p}{Y_s}\right)^e$$

WTP_p: the value from the policy site
WTP_s: the value from the study site
Y_p: income per capita from the policy site
Y_s: income per capita from the study site

The income elasticity of WTP is expressed as the % change in WTP for 1% point change in income and shows how much the WTP for an ecosystem service changes with income. According to Desaigues et al. (2007), the income elasticity for the European Union countries ranges from 0.2 to 0.5. For the study, the central value 0.3 for the elasticity and the GDP per capita as a proxy for income due to lack of data for the income per capita were used.

- Price Changes over time: Inflation causes the general price levels in a country to rise over time and any given amount of money is worth less. So, we adjusted the values to account for inflation in order to represent the general price level of the same year between the policy and study site by using the GDP deflators.

- Purchasing Power Differences: General prices for goods and services vary across different countries and within the countries, which reflects differences in the costs of production and demand. We used the purchasing power parity (PPP) adjusted exchange rates taken from the World Bank World Development indicators database. PPPs reflect how much 1$ costs in another country.

The process was based on UNEPs manual on valuing transferred values of ecosystem services (2013). Additionally, the Environmental Valuation Reference Inventory (EVRI), which is a comprehensive benefits transfer database that consists of over 1900 valuation studies and was used for the BT application. Values are expressed in 2013 prices, using data from the World Bank.

5 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 reanalysis 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 Atlantic site MUOP's was composed of 77 units of 8Mw floating devices with mixed technology: windmills and oscillating water column farm, total power 616Mw. Total manufacturing cost is estimated to be 2.7 Mill €/Mw, whereas total capital expenses reach 3.66 €/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 mill €/Kw and the average cost of energy reaches 0.167 €/kwh.

The energy price starts with 0.15 euros/kwh and jumps into 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 7 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/m2	5 Mw	0.2304	10.09 Gwh	59%
Wave	28 kw/m	3 Mw	0.0544	1.43 Gwh	55%

It should be noted that the device is still under a redefining process to refine and improve the capacity factor (ratio of energy captured over nominal capacity of the device). The final figures are expected to improve in the near future. With these figures we have obtained the expected business revenues, and costs for the project that can be seen in the next results.

In ***Figure 6*** and ***Figure 7***, the EPCI budget, CAPEX, OPEX and Project budget are summarized. As it can be seen, the total project budget is up to 3,739,899,031€. Almost the 60% is related to the CAPEX. It is important to notice the 23% of financing project cost considered due to the total investment required to develop the MUP 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.)

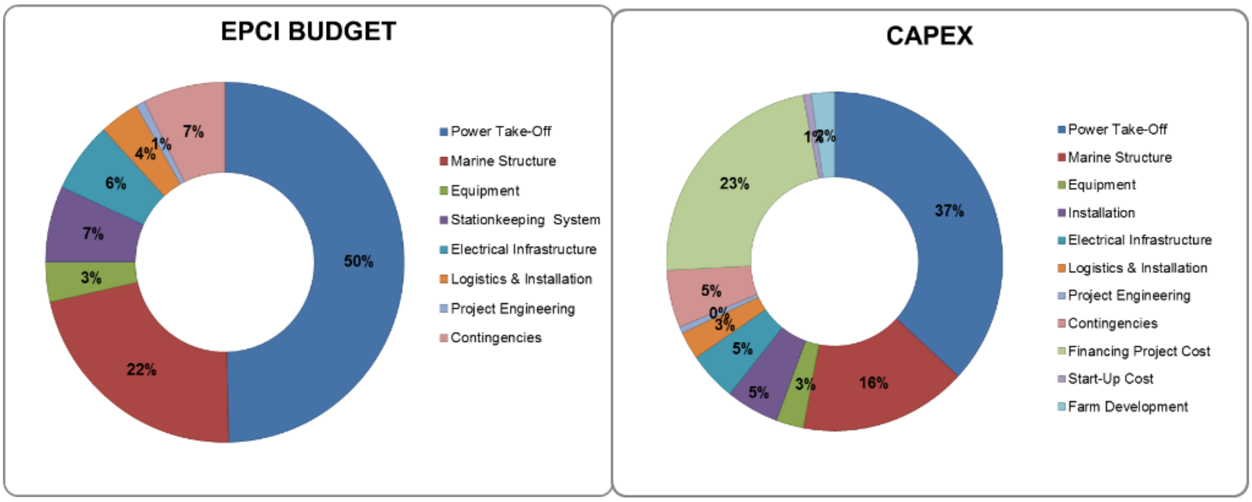

Figure 6 EPCI budget and CAPEX

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%).

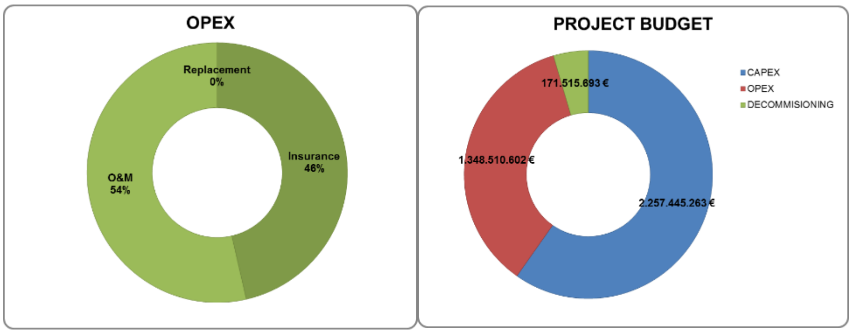

Figure 7 OPEX and Project Budget

In table 8, the main parameters related to the investment costs are summarized. As it can be seen, the cost of energy of the MUP farm is almost 167€/MWh.

Table 8 Costs per Kw

CAPEX	3,665	€/KW
OPEX	2,189	€/KW
PROJECT COST	6,071	€/KW
COST OF ENERGY	0.167	€/KWh

6 Social Cost Benefit Analysis

The Social Cost Benefit Analysis (SCBA) assesses the monetary social costs and benefits of an investment project over a time period in comparison to a well-defined baseline (reference) alternative. In this way the costs and benefits of MUOPs are evaluated and compared to estimate the economic efficiency of implementing the project. As a rule, a project is deemed to be socially profitable if total discounted benefits exceed total discounted costs (positive net present value (NPV)). The NPV results reveal whether the net benefit generated by the investment project of Multi-Use platforms is positive and significant well into the future, conditional on the utilized discount rate scheme. A general calculation of the NPV is the following:

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

Where Kt is the construction cost, Bt is the stream of benefits, Ct is the stream of operation and maintenance costs and r is the discount rate. Monetized values of externalities are also included in the benefits or costs terms.

Furthermore, the Internal Rate of Return (IRR) has been estimated. IRR is the discount rate that makes the NPV equal to zero. The higher a projects IRR, the more desirable is to undertake the project. Any project with an IRR greater than the discount rate used for the project is a profitable one.

For the Atlantic site 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, with central value the given investment cost and boundaries at $\pm$ 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 ± two standard deviation from the mean has boundaries at a distance of $\pm\gamma$ % of the mean (μ) the choice of γ was consistent with the data of the specific case. That is $\mu \pm 2\sigma = \mu \pm \gamma\mu$.

Two alternative values of 3% and 4% were used for the discount rate. These values are consistent with values obtained from the Ramsey formula for the long lived projects: $r = \rho + \eta \cdot g$

- where $\rho = L + \delta$, is the rate at which individuals discount future consumption over present consumption
- Catastrophe risk (L): catastrophe risk is 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.
- Pure time preference (δ): pure time preference, reflects individuals' preference for consumption now, rather than later, with an unchanging level of consumption per capita over time.
- Annual growth in per capita consumption (g)
- Elasticity of marginal utility of consumption (η)

Finally, the Monte Carlo simulations involved 1000 repetitions. Risk analysis results are presented in deliverable 8.6. The results of the SCBA are summarized in the table below.

Table 9 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

All values in euros.

Table 10 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.

Table 11 Internal Rate of Return estimations for Single and Multi-use Platform

	Mean IRR	St.dev IRR
Single-use: Wind function operation compared to coal energy production	13.63%	0.86%
Single-use: Wind function operation compared to ENTSO-E energy production	12.54%	0.80%
Single-use: Wave function operation compared to coal energy production	-	-
Single-use: Wave function operation compared to ENTSO-E energy production	-	-
Multi-use: Wind & Wave scenario operation compared to coal energy production	6.92%	0.62%
Multi-use: Wind & Wave scenario operation compared to ENTSO-E energy production	6.17%	0.56%

The estimates of mean NPV and its standard deviation suggest that the multi-use scenario (Wind & Wave) passes the SCBA test both in terms of NPV (positive NPV) and IRR (IRR greater than the discount rate) 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.

7 Discussion and Recommendations

The results of the financial assessment show heavy dependence on public subsidies on energy and on the network connection cost. The main external effects for this MUOP derive from interference to navigation routes, and the main drivers of risk are the resource spatio-temporal variability and the institutional risk derived from feed-In tariffs and project administrative delays. Uncertainty on the institutional framework and spatio-temporal viability of the resource are the main concerns with regards to the analysis.

Based on the 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 apart from the reduction of CO_2 emissions.

The interpretation and the level of generalization of the results are based on specific assumptions that are affected from the lack of data, especially in the case of monetization of environmental and socio-economic externalities. This means that in case of having more information, it is possible to have different results that suggest implementing or not the MUOP under examination. Similarly to the other MERMAID sites, the outcomes could differ if the comparison for implementing the MUOPs has been conducted between offshore and onshore or near-shore activities. Furthermore, longer time horizon in the SCBA than 25 years could change the outcomes based on the possible differences in energy prices and negative environmental effects, for example on biodiversity

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Annexes

Annex I Benefit Transfer Application for the Atlantic Site

Authors	Description	Research and Education			
Pugh, D., & Skinner, L. (2002).	This study estimated the value added for research and development in the marine sector, including education and training during the period of 1994-2000.	Total Value (£)/ year (2004)	UK Population (2004)	Value (£)/ person (2004)	**Benefit Transfer Value (€) (2013)**
		292,000,000/6= 48,666,667(£)	59990000	0.81(£)	**1.20 (€)**

Exchange Rate (2004, £/$) used: 1.77

Annex II The Assessment Tool

Mermaid MUOP Assessment Tool | About | Technical & Legal | ENV Impact | ECO Assessment | Financial & Economic | Social Cost Benefit Analysis

MUOP Assessment Tool

Version 3.4

Designed by: Phoebe Koundouri, AUEB

Developed by: E. Mailli, UoA, Madgik Group

This **Assessment Tool** was developed for the purposes of **MERMAID** MUOPs assessment.

The tool incorporates the information produced during the project, comparing the socio-economic aspects derived from the MUOP to the baseline of each case study under consideration.

This tool has the potential to be used for future sustainability analysis of multi-use projects. The importance of this tool lies on its outputs and its capacity to provide a guideline to support decision-making. The MUOP **Assessment Tool** was applied in all four case studies and attempts to help all the stages of the research by indicating the pathway of choosing the most appropriate MUOP design with regards to the different aspects involved (socio-economic characteristics, technological, legal, environmental, financial and economic constraints and considerations). The tool helps to identify costs and benefits emerging from the MUOP specific design and thus provides important information for the **Social Cost Benefit Analysis (SCBA)**. The Assessment Tool collects and systematizes multidisciplinary information for each case study. The different sections of the tool are the following and they are closely related to the MISEA:

A) Technical and Legal Feasibility Assessment

B) Environmental Impact Assessment

C) Monetization of Externalities

D) Financial and Economic Assessment

E) Social Cost Benefit Analysis and Risk Analysis

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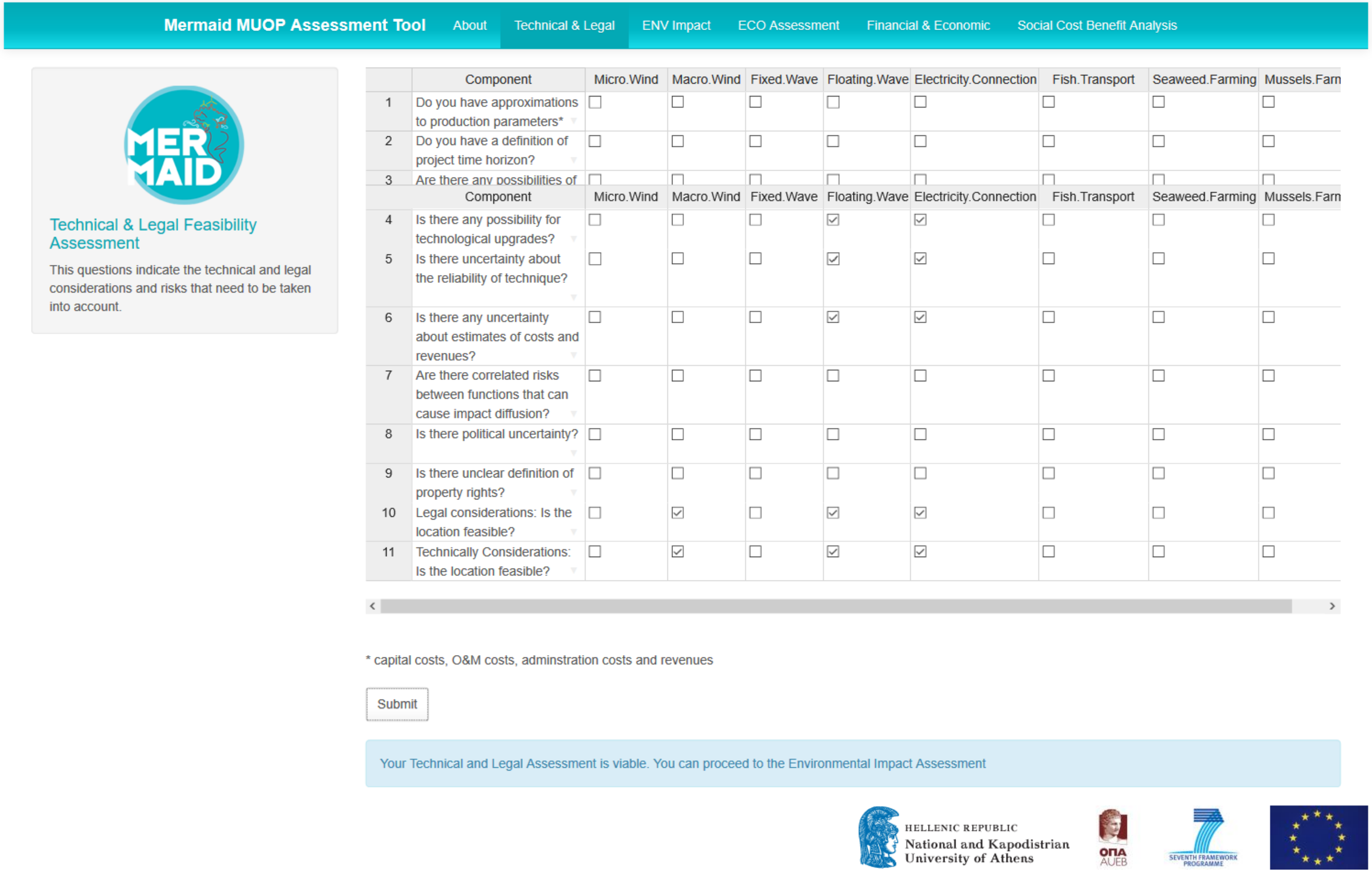
SEVENTH FRAMEWORK PROGRAMME

Techinal and Legal Feasibility Assessment



Mermaid MUOP Assessment Tool | About | Technical & Legal | ENV Impact | ECO Assessment | Financial & Economic | Social Cost Benefit Analysis

MERMAID

Technical & Legal Feasibility Assessment

This questions indicate the technical and legal considerations and risks that need to be taken into account.

	Component	Micro.Wind	Macro.Wind	Fixed.Wave	Floating.Wave	Electricity.Connection	Fish.Transport	Seaweed.Farming	Mussels.Farn
1	Do you have approximations to production parameters*	☐	☐	☐	☐	☐	☐	☐	☐
2	Do you have a definition of project time horizon?	☐	☐	☐	☐	☐	☐	☐	☐
3	Are there any possibilities of	☐	☐	☐	☐	☐	☐	☐	☐
4	Is there any possibility for technological upgrades?	☐	☐	☐	☑	☑	☐	☐	☐
5	Is there uncertainty about the reliability of technique?	☐	☐	☐	☑	☑	☐	☐	☐
6	Is there any uncertainty about estimates of costs and revenues?	☐	☐	☐	☑	☑	☐	☐	☐
7	Are there correlated risks between functions that can cause impact diffusion?	☐	☐	☐	☐	☐	☐	☐	☐
8	Is there political uncertainty?	☐	☐	☐	☐	☐	☐	☐	☐
9	Is there unclear definition of property rights?	☐	☐	☐	☐	☐	☐	☐	☐
10	Legal considerations: Is the location feasible?	☐	☑	☐	☑	☑	☐	☐	☐
11	Technically Considerations: Is the location feasible?	☐	☑	☐	☑	☑	☐	☐	☐

* capital costs, O&M costs, adminstration costs and revenues

Submit

Your Technical and Legal Assessment is viable. You can proceed to the Environmental Impact Assessment

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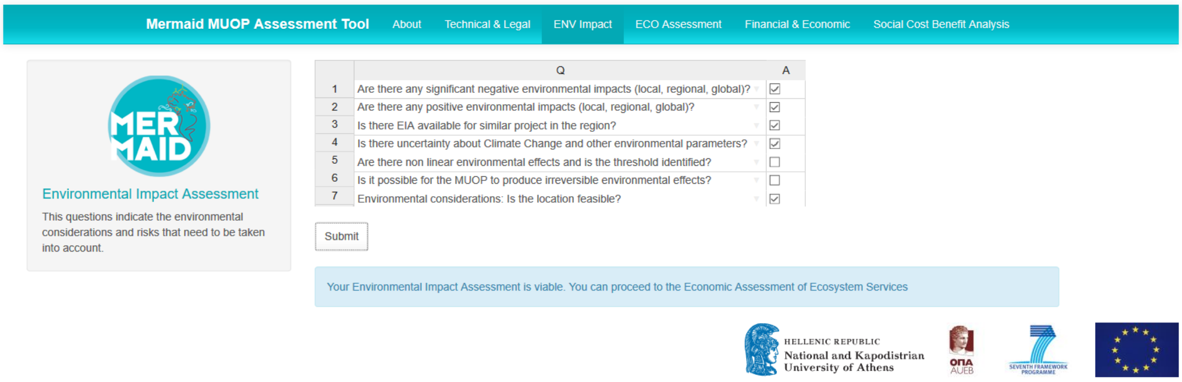
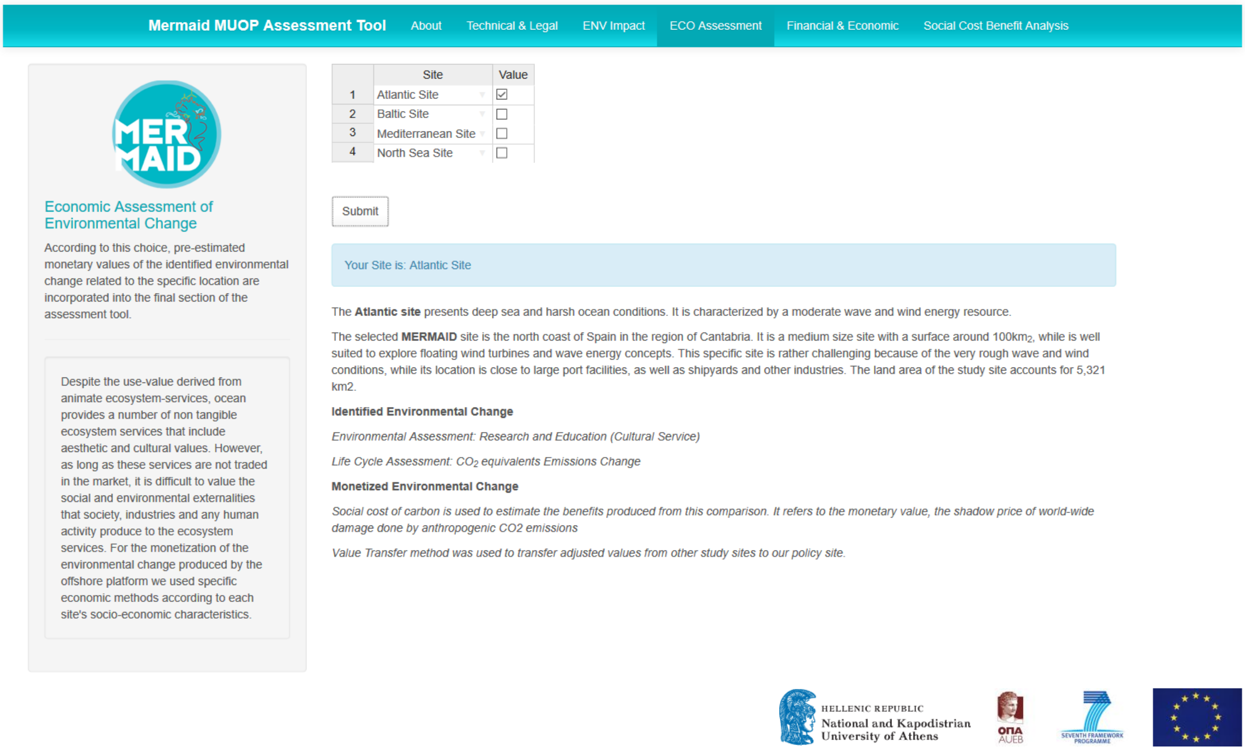
SEVENTH FRAMEWORK PROGRAMME

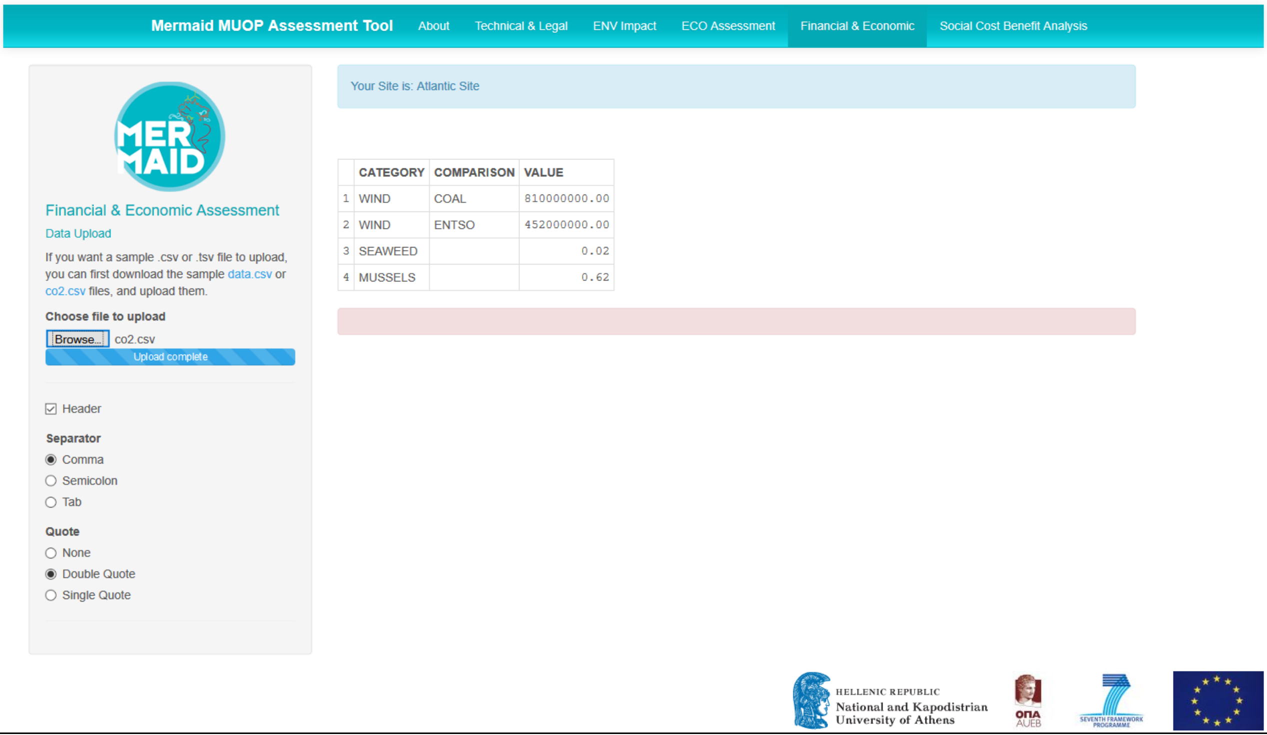
Environmental Impact Assessment



Monetization of Environmental Externalities

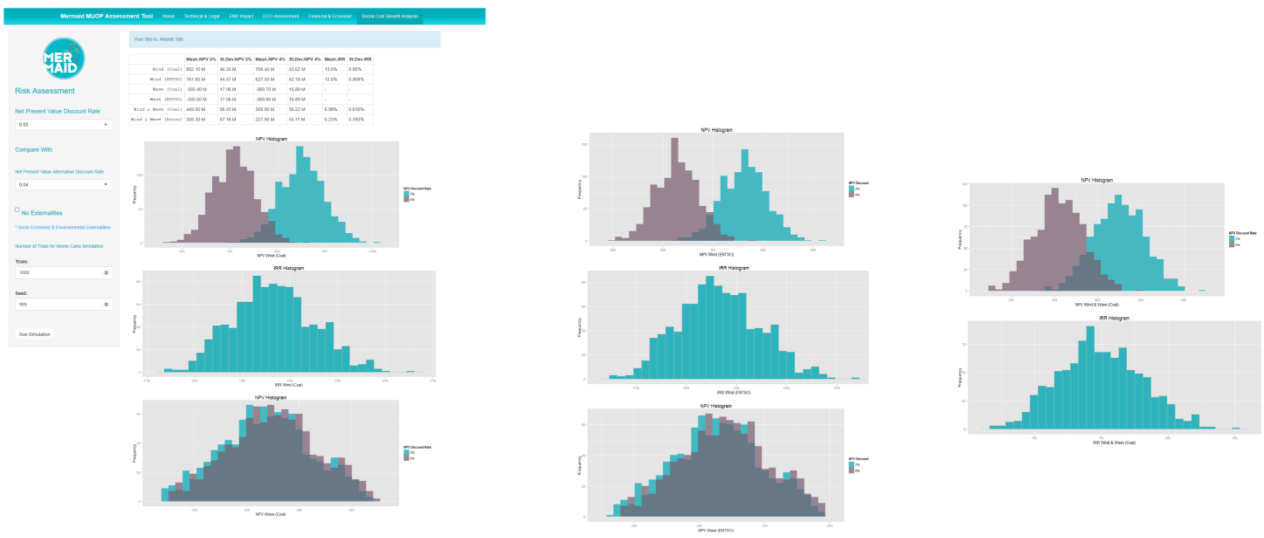


Financial and Economic Assessment



The user inserts specific requested data for the estimation of economic and financial benefits and costs.

Social Cost Benefit Analysis and Risk Analysis



It should be noted that the tool is able to compare at the same time the estimated net present value under different discount rates.

Furthermore, the tool calculates and compares the net present value for the case of including the monetized externalities and for the case where these are not included.

The detailed description of the tool and the user guide will be published in future publications.