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Socio-economic Analysis of a Selected Multi- use Offshore Site in the Mediterranean Sea

Phoebe Koundouri
Amerissa Giannouli
Laura Airoldi
Bilge Bas
Stefanie Broszeit
Nilay Elginoz
Elias Giannakis
Fabio Zagonari
Yukiko Krontira
Aris Moussoulides
Stella Tsani
Dimitris Troianos
Petros Xepapadeas
Anastasios Xepapadeas
Barbara Zanuttigh

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Abstract The area off-shore Venice is characterized by a relatively mild climate that allows in principle a safe installation of an off-shore platform, but at the same time strongly limits the benefits of a single–purpose installation, both because of the limited available energy and because of the high distance from the shore due to the flat sea-bottom. Therefore the site appeared to be suited for multi-purpose designs with fish farming and wind energy as potential activities. An Ecosystem Services Approach (ESA) is adopted to identify possible environmental effects and conflicts with other relevant uses. We deal with these potential impacts by choosing a suitable location of the platform. Limited financial data on wind energy suggested a negative Net Present Value (NPV), whereas proper financial data on fish farming produced a slightly positive NPV. A Life Cycle Assessment applied to wind energy and fish farming estimated a significantly positive effect from reduced CO_2-eq emissions

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P. Koundouri (✉)
ICRE8: International Centre for Research on the Environment and the Economy,
Artemidos 6 & Epidavrou, Marousi, 15125 Athens, Greece

School of Economics, Athens University of Economics and Business,
76 Patission Street, Athens 104 34, Greece

London School of Economics and Political Science, Grantham Institute,
Houghton St WC2A 2AE, London, UK
e-mail: pkoundouri@aueb.gr

A. Giannouli • A. Moussoulides
School of Economics, Athens University of Economics and Business,
76 Patission Street, Athens 104 34, Greece

L. Airoldi
Dipartimento di Scienze Biologiche, Geologiche ed Ambientali (BIGEA),
University of Bologna, Ravenna, Italy

Centro Interdipartimentale di Ricerca per le Scienze Ambientali (CIRSA),
University of Bologna, UO CoNISMa, Via S. Alberto 163, Ravenna 48123, Italy

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expressed in euros. A Social Cost-Benefit Analysis (SCBA) applied only to fish farming (i.e., including financial and CO_2 results) due to lack of data and resulted on a positive NPV. However, a MUP is not recommended by SCBA, and more explicitly it is not supported by stakeholders in the short-run. Whereas, it might be suggested in the long-run, when, in a crowded sea, both economic and environmental reasons could suggest to move some activities off-shore.

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

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B. Bas
Coastal and Marine Hydrodynamics Research Group, Istanbul Technical University,
Istanbul, Turkey

S. Broszeit
Plymouth Marine Laboratory, Prospect Place, The Hoe, PL1 3DH Plymouth, UK

N. Elginoz
Civil Engineering Department, Istanbul Technical University, Istanbul 34469, Turkey

E. Giannakis
Energy, Environment and Water Research Center, The Cyprus Institute,
20 Konstantinou Kavafi, 2121, CY-1645 Nicosia, Cyprus

F. Zagonari
Dipartimento di Scienze Economiche, University of Bologna,
via Angherà 22, 47921 Rimini, Italy

Y. Krontira • D. Troianos
Kefalonia Fisheries S.A., Livadi, Lixouri, Kefalonia 28200, Greece

S. Tsani
ICRE8: International Centre for Research on the Environment and the Economy,
Artemidos 6 & Epidavrou, Marousi, 15125 Athens, Greece

P. Xepapadeas • A. Xepapadeas
ICRE8: International Centre for Research on the Environment and the Economy,
Artemidos 6 & Epidavrou, Marousi, 15125 Athens, Greece

School of Economics, Athens University of Economics and Business,
76 Patission Street, Athens 104 34, Greece

B. Zanuttigh
Department of Civil, Chemicals, Environmental and Materials Engineering, University of
Bologna, Viale Risorgimento 2, 40136 Bologna, Italy

6.1 Introduction

Within the purposes of the MERMAID a site off-shore Venice has been selected for analysis. The area is characterized by mild climate allowing in principle the safe installation of an off-shore platform. Several challenges characterize the area, including:

- mild slope of 0.35 m/km and the peculiar circulation patterns with a high seasonal variability;
- severe anthropogenic development and co-occurring impacts, which leads also to erosion and land subsidence;
- strategic area for marine fauna conservation, sheltering relevant marine ecosystems (coralligenous reefs), seabird populations and endangered marine mammals, turtles and elasmobranchs;
- vicinity of the city of Venice, with the associated high social sensitivity to the construction of new marine infrastructures.

Considering the numerous maritime uses in the area, one of the key challenges to be solved is the location of the platform, depending on the potential conflict of uses deriving from the harbors with their commercial and touristic maritime routes, the fisheries, the oil and gas platforms, the natural habitats and the restricted areas (see Fig. 6.1, right). The main environmental parameters of the site are summarized in Table 6.1.

The meteo-marine climate of the site can be characterized as mild (Fig. 6.2). The maximum measured wave height is slightly higher than 4 m and the calm period is close to 40% (i.e. conditions with a wave height < 0.25 m), resulting in a mean available annual wave power around 1.1 kW/m. The wind velocity is in the range 3–4 m/s at 25 m height, and therefore its estimation at 100 m height is around 4.7 m/s.

Both wind and waves show two main incoming directions: one from the North East (Bora, between 0°N and 85°N) and a second from the South East (Scirocco, between 105°N and 175°N), being the Bora direction dominant both in intensity and frequency. The Adriatic is a semi-closed basin, and it is characterized by a low tidal excursion (< 1 m), so the tidal energy resource can be excluded from the multi-use scenario.

Existing installations of wave energy devices in Europe are located in areas with an available wave power ten times higher as compared to this site. Similarly, for the exploitation of off-shore wind energy Orecca FP7 Project established a minimum threshold value of 6 m/s at hub height, that is higher than the average wind speed at this site. Therefore the available potential renewable energy resources appear economically ineffective for single purpose installations.

Based on the existence of many near-shore aquaculture farms, the site could be suitable for aquaculture. Moreover, the increasing demand on the global market, combined with the numerous existing space conflicts in coastal areas, has stirred interest in moving aquaculture further off-shore.

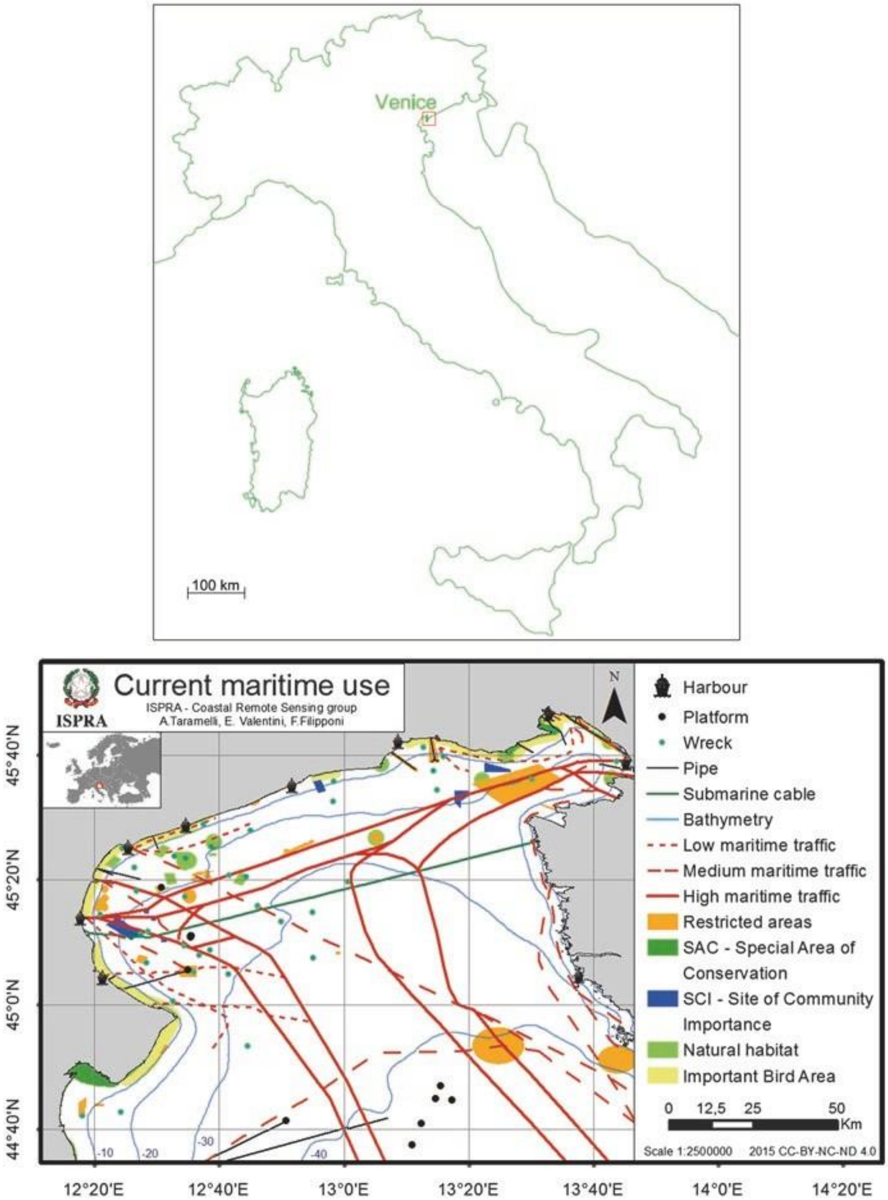

Fig. 6.1 Location of the site highlighted with a *red square*; next are shown different existing uses in the selected area

Table 6.1 Basic facts about the Mediterranean site

Geographical location	Northern Adriatic Sea, off the coast of Venice (site)
Offshore distance	16 km
Depth	16 m, gentle slope towards south east
Substrate	A mixture of sand and mud
Average water temperature (+/− 1SD)	14 °C (+/− 6 °C)
Average Salinity	27.5 psu (+/− 1.5 psu)
Mean tidal range	0.6 m (+/− 0.15 m)
Mean wave height	1.25 m
Expected annual wave power	3 kW/m
Average wind speed	4.54 m/s
Expected annual wind power	Large turbines: 12.7 GWh/y/4 Vestas V112 turbines

Source: MERMAID (2013). http://www.vliz.be/projects/mermaidproject/docmanager/public/index.php?dir=Outreach_Material%2F&download=MERMAID_Booklet.pdf

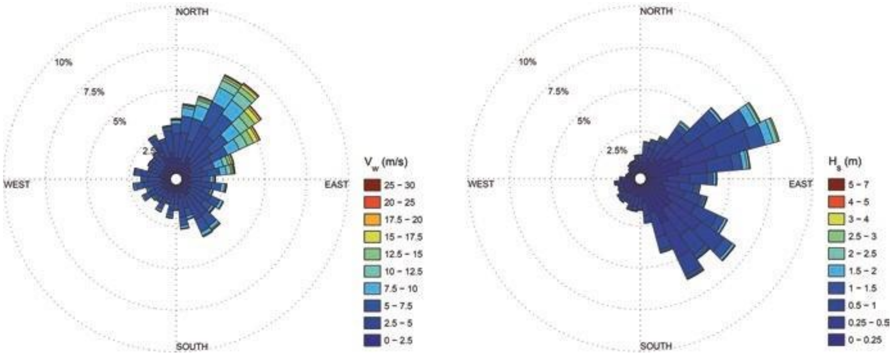

Fig. 6.2 *Rose* diagram of the mean annual wind (to the *left*) and wave (to the *right*) regime at the Med site

According to the application of an original multi-criteria procedure and to the ranking of alternatives based on expert judgment (Zanuttigh et al. 2016), the selected multi-use design consists of wind turbines and fish farming (Fig. 6.3).[1]

The fish farm is designed to support annual production capacity of 2000 tons, equally divided between the gilthead sea bream (*Sparus aurata)* and European sea bass (*Dicentrarchus labrax*) species. It is made of 56 sea cages of 32 m in diameter. To assure good fish health, the bottom depth at the installation is 25 m, i.e. around three times the depth of the nets (9 m).

The wind farm consists of four VESTAS V112, each of which is characterized by a 112 m rotor diameter and by a rated power of 3.3 MW. The total production is of 12.7 GWh/y, with around 1000 equivalent hours. To reduce wake effects, a spacing

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[1] For details see: MERMAID (2016) and Zanuttigh et al. (2015)

Fig. 6.3 Representation and layout of the selected multi-use platform in the Mediterranean Sea (Source: By courtesy of VLIZ)

of seven rotor diameters (distance of around 800 m) around each wind generator is assumed. The space occupied by the multi-use offshore platform (MUOP) is a square area of 0.64 km^2, where the wind turbines are placed at the corners and the fish farm in the middle. This configuration allows sufficient spacing around the cages for water circulation and allows boat traffic to move between installations (MERMAID project 2015, 2016).

One of the main challenges of this MUOP is connection to the grid, due to the costs induced by the long distance to shore (27 km from the closest harbour) and the environmental impacts of the cables on the soft bottom.

The fish and the wind farms are designed for 20 and 30 years operational time respectively. At the end of the MUP lifetime, a complete removal of cages and wind turbines is expected, while the feeding platform could be maintained for research purposes.

The proposed MUP can be considered as a module to be repeated, however:

- the fish demand is not so high to justify an extensive module reproduction;
- the fish farm may increase organic matter and nutrients and therefore a detailed EIA should be carried out;
- the conflict with other uses (such as fishery or navigation) has to be accounted for.

In the following sections a socio-economic analysis of the multi-use design for the Mediterranean Sea site is applied as follows: The case study is put into a socio-economic context in Sect. 6.2 through identifying and describing actors, economic sectors and institutions. In Sect. 6.3, the environmental impact of the multi-use farm 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 found in Sect. 6.4, which is followed by an attempt to apply a social cost-benefit analysis in Sect. 6.5. Given that data for both functions were not available; a Social Cost-Benefit Analysis (SCBA) was applied to the single use scenario aiming to support the importance of considering possible externalities, i.e. non-market economic impact, into the analysis. The chapter is concluded with a discussion and recommendations in Sect. 6.6.

6.2 The Case Study in a Socio-economic Context

This section aims at contributing to an improved understanding of the effects of the multi-use design by providing a brief description of the case study profile. Demographic and socio-economic facts are provided, stakeholders are identified, and relevant institutional and policy settings are described. Environmental uncertainties and implementation obstacles are also discussed.

6.2.1 Demographics and Economic Activities

The study site is in close proximity to the Veneto region of Italy. The land area of the study site amounts to 18,378 km^2. The population in that area accounts for 4,937,854 inhabitants with population density of 269 inhabitants per km^2 (2011). The population of the study site exhibits a rather balanced distribution between male (51%) and female (49%), while the average household size is around 2.4 persons per household. The qualitative aspects of human resources in the study site can be revealed through the educational level of the population. The population is characterized by a rather favourable educational attainment level, which constitutes an important asset for development prospects. More specifically, almost 46% of the population has completed graduate and postgraduate studies.

Total labour in the Mediterranean site amounts to 2,240,713 persons. Male employment amounts to 59%, while female employment accounts for 41%. Unemployment amounts to 128,612 persons (or 5.8%) of which 46% is male and 54% is female. Sectoral employment is often considered a crucial indicator in analysing economic structure and organization. The analysis of employment by branch of economic activity portrays that the major sectors offering employment in the region are the manufacturing sector (28%) and the trade sector (15%). The economy is service-orientated since tertiary sector (service sector) accounts for 60% of total employment, while the secondary sector (manufacturing sector) contributes by 37%. The contribution of agriculture (primary sector) to total employment is 3%. With regards to the qualitative characteristics of the employees, almost half of them hold baccalaureate, while 15% of labour force has attained graduate and postgraduate studies. The percentage of employees with primary education is only 4%.

The total value of regional production in the study site amounts to 130,634 million euros (2011). In terms of the sectoral shares of regional production, the tertiary sector contributes around 63% to the regional product generation, the secondary sector contributes by 35%, and the primary sector by only 2%. More specifically, the manufacturing industry contributes by 26% in the regional product formation, the property and business services sector by 14%, and the trade sector by 12%.

6.2.2 Stakeholders

The stakeholders who may be affected by the multi-use designs are located in the coastal areas in Venetian Region. It should be noted that in the final design, no wave energy converters are considered. Nevertheless, information with regards to wave energy production is included in regional profiling for reference to future projects.

A thorough examination of the current political and social conditions in the Mediterranean site revealed that in terms of the aquaculture the most vulnerable groups and those impacted more are fishermen, persons involved in activities related to tourism and transport constructing and storage. With regards to wave energy production, the most vulnerable groups are mainly energy suppliers, the sector of equipment and machinery, the transport constructing activities and the consumers (van den Burg et al. 2016; MERMAID project 2013).

6.2.3 Institutional and Policy Framework

6.2.3.1 Policies Related to Offshore Energy

Currently, no regional or national legislation regulating renewable offshore energy projects exists in the region. The Ministry of the Environment is responsible for safeguarding the environment. The Ministry of Infrastructures and Transport regulates issues of production of energy. The authorizations for the construction and operation of wind plants are issued by the Ministry of Infrastructures and Transport. The Ministry of Economic Development and the Ministry of the Environment are also consulted, while the peripheral offices of Genio Civile provide concessions of the maritime State property use. With regards to incentives for energy from marine renewable sources, the government ensures 0.34 € per kWh for all plants smaller than 5 MW. No national or regional legislation exists to regulate subsidies for such a project. Unlike other energy sectors, wind energy generation is at an early stage of development and there is no established industry consensus on codes and standards.

6.2.3.2 Policies Related to Aquaculture

The Regional Government which is in charge of authorizing aquaculture activities can reimburse up to 50% of investment expenditures. The state refunds up to 80% of the insurance premium to create incentives for insurance that cover structural risks linked to natural events, climatic conditions and price fluctuations. Furthermore, the Region has set up local commissions to modernize the aquaculture sector.

It has to be stressed that aquaculture in the European Union (EU) is regulated by strict laws. A fish farm needs to fulfill an extensive list of requirements to get a permit of operation. This ensures that the operation will not have adverse impacts on the environment and that there is no clash with other activities. Once a permit is issued, which means an Environmental Impact Assessment (EIA) has been conducted in the area and all other requirements are met, then the company is obliged to conduct regular checks, which ensure the proper operation of the farm.

6.2.4 Environmental Uncertainty and Implementation Obstacles

Controversies about aquaculture have arisen when clam producers imported a Philippine species (*Ruditapes philippinarum*) which is larger and grows faster than the native clam (*Ruditapes decussatus*). It was intentionally introduced in Northern Adriatic Sea coastal lagoons in 1983 to support a clam fishery suffering a crisis due to overexploitation of native clam *Ruditapes decussatus*. The Japanese kelp *Sargassum muticum*, the Asian kelp *Undaria pinnatifida* and the pacific oyster *Crassostrea gigas* have also been introduced by aquaculture and have rapidly spread in the Venice and Po Delta coastal lagoons. Overall the north Adriatic sea is a hotspot of species invasions (Occhipinti et al. 2011) As a result, concerns about the impacts of aquaculture on biodiversity and the current fishery sector were expressed.

Additionally to invasive species, eutrophication (related to both point-source discharges and non-point loadings of limiting nutrients, such as nitrogen and phosphorus), is another adverse impact of concern when aquaculture is considered. Karakassis et al. (2005) estimated that the overall N and P waste from fish farms in the Mediterranean represents less than 5% of the total annual anthropogenic discharge, while the overall annual increase in P and N pools in the Mediterranean, under a production rate of 150,000 tons, is less than 0.01%. In other words, Karakassis et al. (2005) results imply that “there is little risk of a noticeable increase in the nutrient concentration in the entire Mediterranean or even in the Eastern Basin as a result of fish farming”. Moreover, Pitta et al. (2009) found that grazing plays a key role in regulating phytoplankton biomass, keeping chlorophyll *a* at low levels and effectively transferring nutrients up the food web. Nonetheless, it is essential to tackle water eutrophication from fish production, also to allow current and future diving activities in this area.

In addition, the selected study site minimizes the controversies about energy production with regards to potential conflicts with other relevant environmental characteristics or uses of the marine environments, e.g., off-shore ports, naturalistic areas, fishery activities, tourism activities, and with the general conservation of the ecologically relevant species and habitats (see MERMAID Location Selection Tool).

Furthermore, fishery is a main income source in the region in both commercial and recreational terms. Significantly valuable biological seabed concretions (coralligenous type), which are called tegnue, exist in the region; these are protected areas and attract lots of divers. Thus, the selection of the location of the multi-use design was done specifically excluding those areas. However, the local stakeholders are very skeptical about the economic feasibility and success of aquaculture, while on the contrary are very optimistic for the economic potential of the wave energy production.

6.3 Monetization of Environmental Impact

6.3.1 Impact on Ecosystem Services

The selected multi-use design for the Northern Adriatic Sea site might influence a number of the marine ecosystem services supplied by the Mediterranean. Aquaculture would increase the provisioning services through production of edible fish biomass. If the site is not carefully managed, the increase in fish biomass and resulting fish feces as well as fish feed may increase nutrient loading in the surrounding waters and sediments (Wu 1995; Pitta et al. 2005; Price et al. 2015). Such platforms could also be used to further cognitive development of visitors to the site if access is allowed for teaching purposes (Table 6.2).

Artificial structures favour non-indigenous species (NIS) as they have several advantages at colonising these compared to natives, leading to regional scale changes in their relative abundances (Airoldi et al. 2015). Artificial structures can also harbour polyps of cnidarians and dinoflagellates. When this happens, they may lead to increased numbers of, for example jellyfish (Duarte et al. 2013) or harmful algal blooms or damage fish if the polyps are attached to fish cages (Baxter et al. 2012). However, efforts have been made to identify solutions to reduce some of these risks. For example, the settlement and growth of NIS on artificial structures can be limited by using materials or coatings that prevent colonisation of any species including NIS. Ecologically informed repair schedules can limit the spread of NIS by favouring a quicker recovery of the native ones (Airoldi and Bulleri 2011). In the Adriatic sea, work within MERMAID has also shown that actively gardening ecologically relevant habitat-forming species could be a promising tool to contemporaneously enhance native species and deter NIS (Perkol-Finkel et al. 2012, Ferrario et al. 2016).

Based on the site characteristics and the information provided by the site manager and biologists, it was decided to estimate the economic value of the negative

Table 6.2 Examples of ecosystem services potentially affected by the multi-use design and examples of these effects

Category of ecosystem services	Provisioning services	Supporting/regulating services	Cultural services	Habitat services
Ecosystem services	Food and raw materials	Nutrient cycling	Cognitive development	Diversity
Effect	Positive due to increase in farmed fish biomass	Negative due to increased fish feces and fish feed from farm entering the water column leading to increased nutrient loads in the water column	Positive if site is used for education purposes (for example school trips)	Negative during construction, negative during operation unless ecological engineering is used to reduce chance of invasive species and support native species, particularly habitat forming species
Period of the effect	Operation Phase	Construction and operation phase	Not relevant	Construction and operation phase

Source: Communication with Site Managers and Biologists

effects of the presence of Harmful Algal Blooms in Italian waters during operation of multi-use designs using the Benefit Transfer Method. Although such effects are currently rather small, they could be further enhanced by water quality issues related to aquaculture and by the introductions of additional artificial habitats related to the multi-use design’s construction and operation. However, since these effects will not be crucial in the 30 years of expected operation duration and the location of the MUOP was chosen with the scope to minimize such negative environmental effects, it was chosen not to consider this value to the social cost benefit analysis.

6.3.2 *Impact on CO_2 Emissions*

Another environmental effect associated with the Northern Adriatic Sea site are carbon dioxide (CO_2) emissions. Those emissions were estimated through a Life Cycle Assessment (LCA) for evaluating the Global Warming Potential (GWP) associated with the multi-use for the Northern Adriatic Sea site.[2] Resulting quantity of

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[2] An LCA consists of four stages; (a) objective and scope definition, (b) inventory analysis, (c) impact assessment and (d) interpretation. LCA is a standardized method which follows ISO 1040 series (ISO 2006a, b) and covers life cycle stages of a product or function. During the life cycle inventory stage, after constructing the flow chart of the product/function, for each process or activity inputs and outputs are listed with their quantities. The next step is converting emissions to the related impact categories using several methods like TRACI, CML 2001, etc.

Table 6.3 Unit amount of CO_2 emissions per function and the compared production technologies

Function	Parameter	Amount	Unit
Electricity production	Amount of CO_2-eq production per 1 kWh	5.23	g CO_2-eq
Coal based electricity production	Amount of CO_2-eq saved through electricity production per 1 kWh	794.37	g CO_2-eq
ENTSO-E electricity production	Amount of CO_2-eq saved through electricity production per 1 kWh	456.77	g CO_2-eq
Fish production	Total amount of CO_2-eq production per 1 t	2.41	t CO_2-eq

Table 6.4 Total amount of CO_2 emissions per function and the compared production technologies

Function	Parameter	Amount
Electricity production	Amount of CO_2-eq production (assuming 20 GWh/year)	5.23 gCO_2-eq/kWh *20 GWh/year*20 years = 2092 ton CO_2-eq
Coal based electricity production	Amount of CO_2-eq saved (assuming 20 GWh/year)	794.37 gCO_2-eq/kWh *20 GWh/year*20 years = 317,748 ton CO_2-eq
ENTSO-E electricity production	Amount of CO_2-eq saved (assuming 20 GWh/year)	456.77 gCO_2-eq/kWh *20 GWh/year*20 years = 182,708 ton CO_2-eq
Fish production	Total amount of CO_2-eq production (assuming 2000 t/year)	2.41 tCO_2-eq*2000 t/year*30 = 144,000 ton CO_2-eq

emitted CO_2 equivalents (CO_2-eq) for each of the uses, and total amounts of emissions are presented in Tables 6.3 and 6.4; details about the estimations are found in the paragraphs below.

Wind Farm

The wind farm consists of four wind turbines. Wind turbines are 3.3 MW Vestas turbines and the total electricity generation is expected to be 20 GWh per year. In 2006, Vestas published a Life Cycle Assessment of offshore and onshore wind farms for 3.0 MW wind turbines. According to this report "1 kWh electricity generated by a V90-3.0 MW offshore turbine has an impact of 5.23 grams of CO_2 during the life cycle" (Vestas 2006). In absence of data for a 3.3 MW turbine this result can be used for the planned wind farm. When this value is compared to usage of coal for electricity production (799.6 g CO_2-eq, Schlömer et al. 2014), amount of produced CO_2eq gases is lower with a difference of 794.37 gCO_2-eq for 1 kWh electricity production. If the comparison is made according to European electricity mix (ENTSO-E network), which corresponds to 462 g CO_2-eq/kWh (Itten et al. 2014), the gain of environmental burden in the terms of CO_2-eq is 456.77 g/kWh.

Fish Farm

In the system studied, production and installation of structures, operation and maintenance activities, and disposal of structures as well as transportation of materials during the life cycles were considered. In this study, fry production is excluded. One ton of harvested fish was selected as functional unit. In the fish farm, it is planned to farm European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata)* and the capacity of the farm is 2000 tons per year. The results show that for each ton of harvested fish, 2.41 tons of CO_2-eq will be emitted during the life cycle stages of the fish farm.

The emission changes were expressed in monetary terms 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 € per ton[3] in 2013 year values.

6.4 Financial and Economic Assessment

The Northern Adriatic Sea site's wind-fish farm requires 44 million euros for the establishment of the wind farm and it is expected to produce 1 million euros per year for 20 GWh per year in energy extraction. However, no more information is available. Hence, it was not possible to run the social cost benefit analysis for this function.

On the other hand, the capital expenditure for the establishment of the fish farm, over the first 22 years that data could be modelled, is estimated to be 3.7 million euros, of which 3.5 million euros is required over the first 7 years, during which time the fish farm reaches its optimum operational capacity. At year seven revenues from the sales of the fish produced are expected to be at 14.7 million euros (at an operating expenditure of 12.5 million euros). Given the current market status (prices, days payable/receivable etc) the total fish farming investment is estimated at 18.8 million euros and is expected to break even at year 13. At year 22, revenues from sales reach 19.9 million euros, yielding Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) of 4.1 million euros and Earnings After Taxes (EAT) of 3.3 million euros. The Net Present Value (NPV) of the fish farm investment is estimated at 7.2 million euros (over the 22 year period, at a discount rate of 6%). Data for fish production (production rates, production costs etc) are produced using a production model developed in Kefalonia Fisheries. Other assumptions used for calculating prices and revenues (discount rates etc) are based on mean values that are currently true for the market.

6.5 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.

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[3] Exchange rate 0.83 $/ €.

A general expression for NPV is the following:

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

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, were also included in the benefits or costs terms, which is one major feature that distinguishes a SCBA from a typical financial assessment.

However, only the single-use scenario of energy production was examined since there was incomplete information about the costs and benefits of fish production. A Monte Carlo was applied (1000 simulations) and a 22-year time horizon was selected for this SCBA.

For the Monte Carlo, a triangular distribution was used in fish investment and fish revenue. In the absence of any 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 ±15% of the central value.

Normal distribution was used in: fish labor, raw material, other, maintenance, operating costs and energy output. Since there was no information about the specific distributions and only a central value for each of the items was available, a normal distribution with mean the given central value was considered. 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 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 were used for the social discount rate instead of 6%: 3% and 4%. These values are consistent with values obtained from the Ramsey formula for long-lived projects (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 (Table 6.5).

The estimates of mean NPV and its standard deviation suggest that the fish production scenario passes the CBA test in terms of NPV (positive NPV) under all alternative assumptions regarding the discount rate.

Table 6.5 Net Present Value (in euros) estimations for fish production

	Mean NPV(3%)	St. dev. NPV(3%)	Mean NPV(4%)	St. dev. NPV(4%)
Single-use: Fish production	16,052,583	6,179,906	12,140,351	5,589,853

6.6 Discussion and Recommendations

There is no detailed data on financial costs and returns or on environmental, social and economic impacts for each single activity or all activities combined as suggested by the final design for the Mediterranean case study. Our preliminary, although tentative, analysis suggests that in the short term using a multi-use design with wind energy and fish production would be financially not sustainable, due to both low energy and fish production, and would bear high environmental risks. However, in the long-run, coastal and marine spaces might become more limited, and then going offshore will become more important to avoid unplanned and crowded uses in the future. More explicitly, for the case of aquaculture, going offshore provides better health of farmed fish, since it is supposed to provide better water quality to the farmed fish, lessen the possibility of infectious agents being transferred to them and provide a water current regime that will promote better water renewal and waste dispersal. Hence, considering and socio-economically analyzing the changes in the ecosystems and the value of ocean space could prove the sustainability of the multi-use design.

Indeed, in the Mediterranean case study, the economic internal rate of return for *all activities combined* is likely to be negative, if based on monetary analysis, and it is likely to be positive but very small, if some of the social and environmental benefits related to moving aquaculture offshore compared to inshore are taken into account. Even if currently there could be little arguments to develop multi-use farms in this area, long-term future benefits related to moving some fish and energy activities offshore would deserve careful consideration.

This decision is likely to be opposed by current stakeholders for two main reasons: (a) they might expect to bear costs today (e.g. larger fuel costs to reach an activity offshore or the risks of implementing an activity offshore) for benefits arising (for others) tomorrow; (b) they might not perceive the benefits of reduced environmental impacts from moving aquaculture offshore and increasing green energy production. A similar context was observed in urban land use planning in Italy in the 1950s, where many activities such as carpenters or smiths shops were inside villages, with benefits in terms of time saved on travelling and security for these shops, but costs in terms of noise and pollution. They were then moved to dedicated areas in the 1970–1980s.

A subsidization of offshore activities could solve the first concern (i.e. current private costs are turned into current public costs), whereas information campaign on environmental benefits could solve the second concern (i.e. current private benefits are highlighted). In other words, while private decision-makers are unlikely to perceive future benefits from moving offshore, by emphasizing current costs only, public decision makers could impose an inter-generational distribution of costs and benefits, provided that the estimated future benefits are large enough.

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