DEPARTMENT OF INTERNATIONAL AND EUROPEAN ECONOMIC STUDIES

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

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

Bilge Bas
Nilay Elginoz
Elias Giannakis
Amerissa Giannouli
Phoebe Koundouri
Flemming Møhlenberg
Aris Moussoulides
Ole Svenstrup Petersen
Stella Tsani
Petros Xepapadeas
Anastasios Xepapadeas

Working Paper Series

17-18

December 2017

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

Bilge Bas, Nilay Elginoz, Elias Giannakis, Amerissa Giannouli, Phoebe Koundouri, Flemming Møhlenberg, Aris Moussoulides, Ole Svenstrup Petersen, Stella Tsani, Petros Xepapadeas, and Anastasios Xepapadeas

Abstract Denmark has designated the area of the Kriegers Flak to install an offshore wind farm of 600 MW, which is planned to be fully operational in 2022. This chapter investigates the combination of wind turbines and offshore aquaculture. The fish farming is planned as two separate facilities located between the two groups of turbines and each fish farm section will consist of 12–14 round cages with a diameter of 45 m and a feeding barge delivering feedby means of compressed air through tubes to each cage. Although the Social Cost Benefit Analysis of the multi-use platform scenario was not completed due

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

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, Nicosia CY-1645, Cyprus

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

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

F. Møhlenberg • O.S. Petersen
DHI, Agern Allé 5 2970, Hörsholm, Denmark

to lack of information, the scenario is expected to be sustainable considering the current policy and institutional framework, as well as the environmental andsocio-economic effects.

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

3.1 Introduction

The Baltic Sea is the world's largest estuary, comprising salty North Sea water mixed with freshwater from rivers from Russia, Scandinavia, the Baltic countries, and a large part of Northern Europe. The specific location selected for the MERMAID Project is called Kriegers Flak, which is a shallow ground (25 m) within the Danish Exclusive Economic Zone (EEZ) in the estuary of the Baltic Sea, approximately 15 km from Danish and Swedish coasts. The Kriegers Flak is a large sandy shoal with a sand layer thickness of up to 8 m located in the Western Baltic Sea between Denmark, Sweden and Germany. The site is characterized by medium, but high quality, wind resource, moderate exposure to waves, and currents and salinities and temperature, being close to optimal for salmon aquaculture (Fig. 3.1, Table 3.1).

Denmark has designated the area of the Kriegers Flak to install an offshore wind farm of 600 MW, which is planned to be fully operational in 2022. Since Kriegers Flak has good conditions for fish farm activities, the ultimate objective is to combine wind turbines and offshore aquaculture. The wind farm is estimated to consist of two areas with a total of 8 MW turbines. The seabed conditions are good, thus foundations may be of gravity-base type or driven monopiles. In addition to the turbines, two 220 kV substations and necessary submarine cables to onshore connections are planned.

The fish farming is planned as two separate facilities located between the two groups of turbines to gain some physical protection from the foundations and the wind turbines. Each fish farm section will consist of 12–14 round cages with a diameter of 45 m and a feeding barge delivering feed by means of compressed air through tubes to each cage. The depth of the net cages will be 12–15 m and the

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

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

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

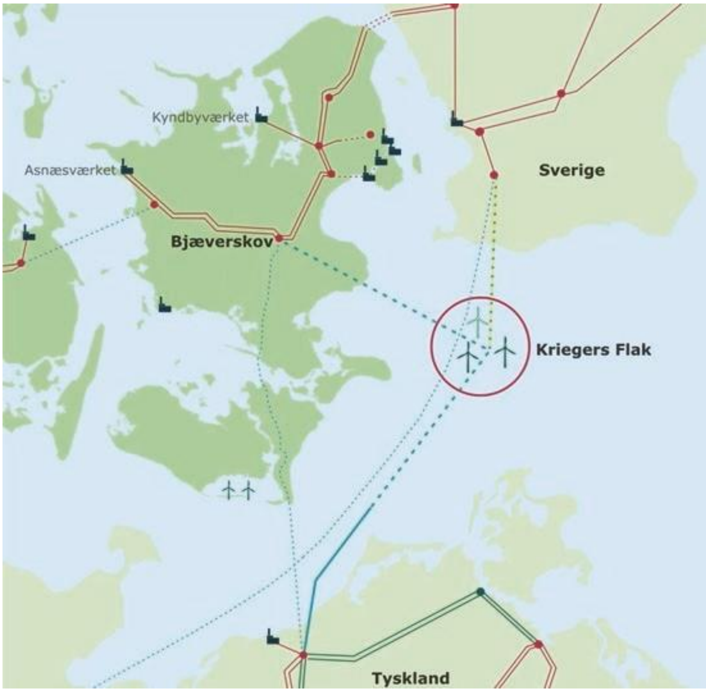

Fig. 3.1 Location of Kriegers Flak

Table 3.1 Basic facts about the Kriegers Flak

Geographical location	Kriegers Flak, Western Baltic Sea (site)
Offshore distance	15 km east of the Danish coast
Depth	18–40 m
Substrate	Sandy layer (thickness of up to 8 m)
Surface water temperature	0–20 °C
Salinity	7–9 psu (upper 15–18 m)
Currents	Variable currents driven by wind, gradients & differences in sea level
Mean tidal range	No tides present
Wave height	Mostly moderate (1–1.5 m)

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

cages might be either floating or submersible. The conditions at the site are favourable in terms of dilution of waste from the farm and optimal conditions for fish growth and quality. (MERMAID project 2015, 2016).

The socio-economic analysis of the multi-use design for the Kriegers Flak site is applied as follows: The case study is put into a socio-economic context in Sect. 3.2 through identifying and describing actors, economic sectors and institutions. In Sect. 3.3, the environmental impact of the multi-use is analysed, 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. 3.4, which is followed by an attempt to apply a social cost-benefit analysis in Sect. 3.5. 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. Section 3.6 concludes.

3.2 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.

3.2.1 Demographics and Economic Activities

The land area of the study site amounts to 7273 km^2. The population accounted for 816,172 inhabitants in 2012 with density of 112 inhabitants per km^2. The population of the study site exhibits a rather balanced distribution between male (49.6%) and female (50.4%), while the average household size is around 1.8 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 indicates a rather high share of population with elementary education (34%), and a low share of population with higher education (22%), while almost 44% of population has secondary education.

Total employment in the Baltic site amounts to 370,000 persons (2013). The employment synthesis is rather balanced since male employment amounts to 51% and female employment accounts for 49%. Unemployment rate in the region amounts to 7.4% (30,000 persons). The structure and organization of the regional economy can be studied through the analysis of the sectorial employment. The analysis of employment by branch of economic activity portrays that the major sectors offering employment in the region are the public administration, education and health sector (35%) and the trade and transport sector (21%). Overall, regional economy is highly services-oriented since the tertiary sector accounts for 77% of total employment, while the secondary sector contributes by 21%. The contribution of the primary sector to total employment has been contracted to 2%.

The total value of regional production in the study site amounts to 432,125 million DKK (2011). In terms of the sectoral shares of regional production, the tertiary sector contributes about 62% to the regional product generation, the secondary sector contributes by 36%, and the primary sector by only 2%. In particular, the manufacturing industry contributes by 30% in the regional product formation, the wholesale trade sector by 27% and the transportation sector by 12%.

The planned windmill park is expected to create 10,000 jobs during the construction phase. The operational and maintenance needs of the MUOP will secure jobs and will act as an international window for Danish know-how. Both aquaculture and wind energy extraction will benefit from sharing seabed area in terms of sharing transportation costs, housing etc.

3.2.2 Stakeholders

The most vulnerable groups to wind power production in the study site are: (a) energy suppliers; (b) persons involved in equipment and machinery sector; (c) energy consumers; (d) persons involved in transport constructing and letting activities. The most vulnerable groups to aquaculture in the study site are: (a) fishermen; (b) persons involved in transport constructing and letting activities; (c) persons involved in tourism activities; (d) persons involved in transport and storage activities. The most vulnerable groups to transport maritime services in the study site are: (a) fishermen; (b) persons involved in tourism activities; (c) persons involved in transport and storage activities. The most vulnerable groups to wind energy production in the study site are: (a) energy suppliers; (b) persons involved in equipment and machinery sector; (c) energy consumers; (d) persons involved in transport constructing and letting activities. In all four cases the geographic location of stakeholders who may be impacted by the proposed changes is within the Danish economic zone at the Kriegers Flak in the Baltic Sea (van den Burg et al. 2016; MERMAID project 2013).

Aquaculture has great opportunities in remote areas of Denmark in terms of growth and jobs. However, NGOs are opposed to aquaculture because of the emission of nutrients and the interaction with habitats and species. NGOs primarily focus on the discharge of nutrients and the use of antifouling to the nets. In general, fish farms and aquaculture at sea are less accepted by the public compared to wind farms. However, all these public images can change. There is currently a debate that argues that aquaculture is not polluting and produces healthy food in an environmentally efficient and correct way. Furthermore, it is likely that the pylons and foundations of turbines would provide a new habitat for sessile filter-feeders, and that they would be able to sequester part of the waste lost from the fish farms, thereby reducing the environmental impact of the fish production. Finally, the development of a MUOP can create opposition for developing more intensive economic activities at sea (van den Burg et al. 2016; MERMAID project 2013).

3.2.3 Institutional and Policy Framework

3.2.3.1 Policies Related to Offshore Wind Energy

The Danish Government provides the main conditions for offshore wind parks in the Promotion of Renewable Energy Act (Act no 1392 27th December 2008), and the Danish Electricity Act (Danish Energy Policy 2012). Chapter 3 is mainly relevant for off-shore wind parks. This chapter regulates the access to exploiting energy from water and wind offshore. Most important condition is that the right to exploit energy from water and wind within the territorial waters and the exclusive economic zone (up to 200 nautical miles) around Denmark belongs to the Danish State. The act also lays down the procedures for the approval of electricity production from water and wind and pre-investigation.

Some of the most important sections of the Renewable Energy act (2008) are: (a) approval for preliminary investigations shall be granted either after an invitation for applications in a tendering procedure or after receipt of an application; (b) approval for preliminary investigations shall be granted for areas in which the Minister for Climate and Energy considers energy exploitation may be relevant; (c) the Minister for Climate and Energy may stipulate terms for the approval, including on the conditions to be investigated, on reporting, on the performance and results of the preliminary investigation, on the access of the Minister to utilise the results of the preliminary investigation, cf. and on compliance with environmental and safety requirements and similar.

In general, the establishment of offshore wind turbines can follow two different procedures: a government tender procedure run by the Danish Energy Agency; or an open-door procedure. For both procedures, the project developer requires all three licenses. All licenses are granted by the Danish Energy Agency: (a) license to carry out preliminary investigations; (b) license to establish the offshore wind turbines; (c) license to exploit wind power for a given number of years, and – in the case of wind farms of more than 25 MW – an approval for electricity production.

In the open-door procedure, the project developer takes the initiative to establish an offshore wind farm of a chosen size in a specific area. In an open-door project, the developer pays for the transmission of the produced electricity to land. An open-door project cannot expect to obtain approval in the areas that are designated for offshore wind farms in the report Future Offshore Wind Power Sites - 2025 from April 2007 and the follow-up to this from September 2008. There are three examples of the open-door procedure. It was followed for the DONG Energy off-shore wind farm at Avedøre and Frederikshavn – and for the Sund & Bælt project at Sprogø.

3.2.3.2 Policies Related to Fish Farming

The management, control and development of fisheries and aquatic resources, like aquaculture, in Denmark are regulated by the Fisheries Act (2004) under the Ministry of Food, Agriculture and Fisheries. In particular, Chap. 13 of this act addresses offshore ocean farming and establishes licensing system governing mariculture facilities. Besides the fisheries Act, the regulation on the establishment and operation of ocean farms contains more detailed rules on the licensing system of mariculture facilities. There is no general definition of aquaculture in the Fisheries Act (2004). The Regulation relative to the establishment and operation of ocean farms (1991), adopted under the Act, has, however, the following definition of ocean farming: “With ocean farming is understood fish farms consisting of cages and the like, placed in marine waters which requires the use of feed for its operation”.

According to the Danish Aquaculture Organisation, the environmental legislation on aquaculture exists on two levels: (a) general legal acts that all types of economic activity have to comply with, and (b) legal acts for various forms of aquaculture. However, there is no specific law on aquaculture in Denmark. All Danish fish farms have to be officially approved in accordance with the Danish Environmental Protection Act Ord. No. 122 of March 1st 1991. A fixed feed quota is assigned to each individual farm in addition to specific requirements including feed conversion ratios, water use and treatment, effluents, removal of waste, etc.

The overarching legal framework for marine farming is the environmental frame directive, implemented in Danish legislation as consolidated Act. No.932. Marine farming is only partly covered by this directive. The ecological status applies for coastal waters up to 1 nautical mile whereas the chemical status applies for coastal waters up to 12 nautical miles. The most critical issue in this directive is the discharge of nitrogen. In the programme of measures for marine farming stands that there must be no overall reduction in the current discharge of nitrogen approved marine farms, but also that new permits must not lead to increased discharge. It is impossible for farms to increase the production without an increase of nitrogen load. On the longer term farms could possibly compensate for such increase. If marine farms want to increase their production it can apply for a part of the total nitrogen quota. But the permit is only granted under the condition that the increase in the discharge of nitrogen is eliminated by compensatory farming.

For aquaculture facilities that are placed on land taking in marine water and for farming of mussels, oysters etc. no regulations have been issued pursuant to the Fisheries Act (2004). For fish farming that requires feed an approval according to the Environmental Act is required. All marine farms must have an environmental permit no later than 2014. The Environmental Protection Act (No. 1757 issued December 22th 2006) sets the overall framework for issuing such permits. At this time most marine farms have obtained permits under this act. Marine farms also have to comply with the requirements for discharge of residues of medicines (Order No. 1022 issues August 25th 2010) and protected habitats (Protection of Nature Act No. 933 issued September 24th 2009).

3.2.3.3 Policies Related to Environmental Concerns

When the project can be expected to have an environmental impact, an Environmental Impact Assessment (EIA) must be carried out. The specific procedure for the EIA regarding offshore electricity producing installations is described in Executive Order No. 684 of 23rd June 2011 on EIA. That also includes sections that implement the EU EIA directive (PM).

Any party applying to establish an offshore wind farm must prepare an environmental report in order to ensure: (a) that the environmental conditions within the defined installation are described; (b) that impact and reference areas are studied and described; (c) that all known environmental impacts in connection with the establishment and operation of the wind turbine installation have been previously considered and assessed; (d) that the authorities and the general public have a basis for assessing and making a decision regarding the project.

An EIA is necessary for developing aquaculture activities. This can be found in the Planning act (order No 1510 issued December 15th 2010). For marine farms situated up to one nautical mile for the coast will require a full EIA. This is a general rule. To some extent it is decided by the local government in the area and they can administer this rule in different ways. For existing farms outside the nautical mile zone only a screening is required. This has been done as a result of a political compromise between government, farmers and environmental organizations. The regulation on supplementary rules contains requirements regarding the contents of the EIA. The regulation provide that when establishing a new marine water fish farm outside a zone designated for aquaculture in the Regional Plan, or when changing such a facility considerably, an EIA shall be worked out. If the aquaculture facility in question is designated for intensive fish farming or has an intake of fresh water, an EIA shall be worked out as far as the facility it is likely to have a considerable impact on the environment, even when it is to be established in an aquaculture zone.

The Regulation lists the different criteria that shall be used when considering whether a facility is likely to have such an impact, i.e. the size of the facility, waste production, the vulnerability of the surrounding environment etc. When it comes to the contents of the EIA, the Regulation states that the EIA shall include a description of the planned facility, a summary of the most important alternative sites that have been examined, the reasons for the choice of alternatives, a description of the environment that can be considerably influenced by facility, as well as an account of the short term and long term influence on the environment. As to ocean farms outside the County Council planning area, the Coastal Directorate decides whether an EIA shall be carried out in relation with an application for the setting up of a facility.

3.3 Monetization of Environmental Impact

3.3.1 Impact on Ecosystem Services

The selected multi-use design for the Kriegers Flak site might influence a number of the marine ecosystem services supplied by the Baltic Sea. These are summarized in Table 3.2.

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

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

Based on the policy site characteristics and the information provided by the MERMAID site managers and biologists, habitat services with regards to increased diversity caused by the reef effect were given monetary values. However, economic values for all the possible effects on ecosystem services were not given due to lack of data. In order to do so, we approximated the positive effect on biodiversity and increase of marine biomass by the effect on algae and invertebrates (31.44 € per person, one-time payment). Hence, based on the regional profiling,[1] we estimated economic benefit due to environmental effect to be 25,750,259 Euro (2013). Ressurreição et al. (2012) paper was used for the purpose of benefit transfer (Table 3.3).

Table 3.2 Ecosystem services probably affected by the multi-use design

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

Source: Communication with Site Managers and Biologists

[1]We estimated the average population growth rate between Sweden, Denmark, Germany and Poland to be 0.35%. These are the countries possibly affected by the platform.

Table 3.3 Benefit transfer application for the Kriegers Flak Site

Description	Algae and Marine Invertebrates (Biomass)							
	Country	*Value of Algae* **(€) (2007)**		*Value of Inverts* **(€) (2007)**		*Average*	Weights	**Benefit Transfer Value (€) (2013)**
		Visitors	*Residents*	*Visitors*	*Residents*			
Ressurreição, A. et al. (2012) This study uses a contingent valuation method to estimate the public's willingness to pay (WTP) to avoid loss in the number of marine species. One-time payment.	Gulf of Gdansk, Poland	14	20	14	21	17.25	0.75	17.36
	Isles of Scilly, UK	66	75	52	59	63	0.25	14.08
Weighted Average Value to avoid Algae and Marine Invertebrates Loss (€)								**31.44**

Notes: *Mean WTP is more appropriate for cost benefit analysis* (Loomis and White 1996)
Values were expressed as one-time payment per individual

Table 3.4 Unit amount of CO_2 emissions per function and the compared production technologies

Function	Parameter	Amount	Unit
Electricity production	Amount of CO_2eq production per 1 kWh	9.32	g CO_2eq
Coal based electricity production	Amount of CO_2eq saved through electricity production per 1 kWh	810.68	g CO_2eq
ENTSO-E electricity production	Amount of CO_2eq saved through electricity production per 1 kWh	452.6	g CO_2eq
Fish production	Total amount of CO_2eq production per 1 t fish produced	3.6	t CO_2eq

Table 3.5 Total amount of CO_2 emissions per function and the compared production technologies

Function	Parameter	Amount
Electricity production	Amount of CO_2eq production (assuming 1317.6 GWh/year)	9.32gCO_2eq/kWh*1317.6 GWh/year*25 years=307,000.8ton CO_2-eq
Coal based electricity production	Amount of CO_2eq saved (assuming 1317.6 GWh/year)	810.68gCO_2eq /kWh*1317.6 GWh/year *25 years=26,703,799.2ton CO_2-eq
ENTSO-E electricity production	Amount of CO_2eq saved (assuming 2196 GWh/year)	452.6gCO_2eq /kWh *2196 GWh/year*25 years=24,847,740 ton CO_2-eq
Salmon production	Total amount of CO_2eq production (assuming 6000 t/year)	3.6tCO_2-eq *6000 t/year*15 years=324,000 ton CO_2-eq

3.3.2 Impact on CO_2 Emissions

Another environmental effect associated with the Kriegers Flak site is emissions of carbon dioxide (CO_2). Those emissions were possible to estimate through applying a Life Cycle Assessment (LCA) for evaluating the Global Warming Potential (GWP) associated with the multi-use for the Kriegers Flak site.[2] Resulting quantity of emitted CO_2 equivalents (CO_2-eq) for each of the uses, and total amounts of emissions are presented in Tables 3.4 and 3.5; details about the estimations are found next.

Wind Farm The design for Baltic Case includes a wind farm with installed capacity of 600 MW (Energinet.Dk 2013). 8 MW turbines with monopile foundations were chosen among these turbine and foundation types for the LCA study. This choice considers a wind farm consisting of 75 wind turbines. The systems studied

[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.

included production and installation of structures (wind turbine components), electricity transmission system (offshore substation and submarine cables), operation and maintenance activities, disposal of multi-use 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 1 kWh electricity produced. Obtained Global Warming Potential (GWP) impact category result for energy production function of the MUOP is 9.32 g CO_2-eq. This result was then compared with values for producing electricity based on coal. The results showed that producing 1 kWh energy in this farm cause a decrease from 820 to 9.32 g CO_2 equivalents (CO_2eq) which corresponds to a difference of 810.68 g CO_2eq based on average CO_2eq value for electricity production via coal burners (Schlömer et al. 2014). When the European electricity mix value (ENTSO-E network), which corresponds to 462 g CO_2eq/kWh (Itten et al. 2014), was chosen as the comparison parameter, the difference is 452.68 g CO_2 equivalents.

Fish Farm The design for Baltic Case includes a fish farm with a capacity of 10,000 ton salmon production. An offshore salmon farm is designed for Baltic Sea Case by Musholm and DHI in the context of the project. Total capacity of the designed marine net-pen system fish farm is 10,000 tons harvested fish per year, and the fish cages are designed to resist offshore conditions. The systems studied included production and installation of aquaculture structures, operation and maintenance activities, disposal of structures as well as transportation of materials during the life cycles of the MUOPs. Functional unit was selected as one tonne of salmon harvested. The result of LCA study of Salmon fish farm in terms of GWP is 3.6 tonnes CO_2eq per ton of harvested fish.

The emission estimates were monetized by applying the social cost of carbon. This refers to the shadow price of world-wide damage caused by anthropogenic CO_2 emissions (Pearce 2003). According to Arrow et al. (2014), the social cost of carbon is $19.50 per ton of CO_2 using the random walk model in Newell and Pizer (2003), $27.00 per ton using the state-space model in Groom et al. (2007), and $26.10 per ton using the preferred model in Freeman et al. (2013). The monetization was based on the estimate from the state-space model, which correspond to 22.50 € per ton[3] (2013).

3.4 Financial and Economic Assessment

For the Kriegers Flak site, the wind-salmon farm efficiency gains for maintenance, salaries and mortality were expected to be 3%, 2% and 1%, respectively, from the combined use (i.e. 4% total efficiency gains).

The total price of the wind farm is expected to be between 2.0 and 2.7 billion Euro, whereof the grid connection is budgeted at 0.47 billion Euro. With regards to

[3] Exchange rate 0.83 $/€.

salmon farming, in existing 3000 tons farms, production costs are 2.85 Euro per kg and it is expected to have slightly lower production costs in a larger farm, but also slightly higher cost of insurance. Salmon farming costs cover operation, maintenance and depreciation of freshwater and marine activities and the expected revenues for salmon farming are 36 million Euro per year. Seaweed farming is also a future option that requires future testing and market analysis.

3.5 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.

A general expression for 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 K_t is investment costs, B_t is the stream of benefits, C_t is the stream of costs and r is the discount rate. Monetized values of externalities, i.e. the benefits derived by the CO_2 emissions reduction and artificial reefs effect due to wind energy production, were also included in the benefits or costs terms, which is one major feature that distinguishes a SCBA from a typical financial assessment.

However, only the single-use scenario of energy production was examined since there was incomplete information about the costs and benefits of salmon production. A 22-year time horizon was selected for the SCBA.

A triangular distribution was used in energy investment and maintenance. Since there were no information regarding the stochastic factors affecting wind investment, the triangular distribution was considered reasonable, with central value the given investment cost and boundaries at ±15% of the central value.

Furthermore, normal distribution was used in Energy output and artificial reefs. Again, since there was no information about the specific distributions and 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 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: 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

Table 3.6 Net present value estimations for energy production

	Mean NPV(3%)	St. dev. NPV(3%)	Mean NPV(4%)	St. dev. NPV(4%)
Single-use: Wind function operation compared to coal energy production	1283.97	115.22	1018.85	110.61
Single-use: Wind function operation compared to ENTSO-E energy production	1062.20	112.29	823.60	107.31

All values in million Euro. Monte Carlo simulations involving 1000 repetitions were applied for taking uncertainty into account

Table 3.7 Annual equivalent operating cost

	AOC (3%)	AOC (4%)
Single-use: Wind function operation compared to coal energy production	102.01	90.53
Single-use: Wind function operation compared to ENTSO-E energy production	84.39	73.18

All values in million Euro

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 3.6).

The important issue in this site was that there was no information regarding operating cost. To obtain insights into the profitability of the project we worked as follows. The single-use scenario of wind energy production will be profitable if the NPV of the operating costs, NPV(OC), is less than the mean NPV under the corresponding alternative assumptions regarding the discount rate and savings related to the reduction of CO_2 emissions. This NPV(OC) can be transformed to annual equivalent operating costs (AOC) using the relationship:

$$NPV\left(OC\right) = \sum_{t=4}^{22} \frac{AOC}{\left(1+r\right)^{t}}$$

Thus if annual operating costs are below the above values for each discount rate and savings related to the reduction of CO_2 emissions, the project will pass the SCBA test (Table 3.7).

3.6 Concluding Remarks

Lack of data has rendered difficult the complete production of the Social Cost Benefit Analysis for the multi-use scenario of the MERMAID site in the Baltic Sea. However, communications with the economists of the Baltic site revealed that the multi-use platform scenario is expected to be economically viable in the future. An additional point to consider is associated to the time horion considered. A longer time horizon in the SCBA, extending beyond 22 years could change the outcomes. This can be associated to possible differences in energy prices and long run environmental effects, for example changes in the level of eutrophication.

References

Arrow, K. J., Cropper, M. L., Gollier, C., Groom, B., Heal, G. M., Newell, R. G., Nordhaus, W.D., Pindyck, R.S., Pizer, W., Portney, P.R., Sterner, T., Tol, R.S.J., & Weitzman, M. L. (2014). Should governments use a declining discount rate in project analysis. *Review of Environmental Economics and Policy*, *8*(2), 145–163. doi:10.1093/reep/reu008. [Online] Available at: http://scholar.harvard.edu/files/weitzman/files/rev_environ_econ_policy-2014-arrow-145-63_0.pdf

Dasgupta, P. (2008). Discounting climate change. *Journal of Risk and Uncertainty, 37*(2–3), 141–169.

Energinet.Dk. (2013). Technical project description for the large-scale offshore wind farm (600 MW) at Kriegers Flak.

Freeman, M., Groom, B., Panipoulou, K., & Pantelides, T. (2013). *Declining discount rates and the fisher effect: Inflated past, discounted future* (Centre for Climate Change Economics and Policy Working Paper No. 129).

Groom, B., Koundouri, P., Panopoulou, E., & Pantelidis, T. (2007). Discounting the distant future: How much does model selection affect the certainty equivalent rate? *Journal of Applied Econometrics, 22*, 641–656.

ISO (International Organization for Standardization). (2006a). *International Standard 14040. Environmental management – Life cycle assessment – Principles and framework*. Geneva: International Organisation for Standardisation.

ISO (International Organization for Standardization). (2006b). *International Standard 14044. Environmental management – Life cycle assessment – Requirements and guidelines*. Geneva: International Organisation for Standardisation.

Itten, R., Frischknecht, R., & Stucki, M. (2014). Life cycle inventories of electricity mixes and grid version 1.3. http://www.esu-services.ch/fileadmin/download/publicLCI/itten-2012-electricity-mix.pdf. Accessed 10 Sept 2015

Loomis, J. B., & White, D. S. (1996). Economic benefits of rare and endangered species: Summary and meta-analysis. *Ecological Economics, 28*, 197–206.

MERMAID project. (2013). Stakeholder views. Innovative multi-purpose offshore platforms: Planning, design & operation (MERMAID), EU FP7 granted project, Deliverable: D2.2.

MERMAID project. (2015). Platform solutions. Innovative multi-purpose offshore platforms: planning, design & operation (MERMAID), EU FP7 granted project, Deliverable: D2.4. [Online] Available at: http://www.mermaidproject.eu/sharepoint/func-startdown/407. Accessed 7 Feb 2016.

MERMAID project. (2016). Site specific design conditions. Innovative Multi-purpose offshore platforms: Planning, design & operation (MERMAID), EU FP7 granted project, Deliverable:

D7.3. [Online] Available at: http://www.mermaidproject.eu/sharepoint/func-startdown/435. Accessed 7 Feb 2016.

Newell, R., & Pizer, W. (2003). Discounting the distant future: How much do uncertain rates increase valuations? *Journal of Environmental Economics and Management, 46*(1), 52–71.

Pearce, D. (2003). The social cost of carbon and its policy implications. *Oxford Review of Economic Policy, 19*(3), 362–384.

Ressurreição, A., Gibbons, J., Kaiser, M., Dentinho, T. P., Zarzycki, T., Bentley, C., et al. (2012). Different cultures, different values: The role of cultural variation in public's WTP for marine species conservation. *Biological Conservation, 145*(1), 148–159.

Schlömer, S., Bruckner, T., Fulton, L., Hertwich, E., McKinnon, A., Perczyk, D., Roy, J., Schaeffer, R., Sims, R., Smith, P., & Wiser, R. (2014). Annex III. Technology-specific cost and performance parameters. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate change 2014: Mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge/New York: Cambridge University Press.

van den Burg, S., Stuiver, M., Norrman, J., Garcao, R., Söderqvist, T., Rockmann, C., Schouten, J-J., Petersen, O., Gunache, R., Diaz-Simal, P., De Bel, M., Menses Aja, L., Zagonari, F., Zanuttigh, B., Sarmiento, J., Giannouli, A., & Koundouri, P. (2016). Participatory design of multi-use platforms at sea. *Sustainability*, *8*(2). [Online] Available at thttp://www.mdpi.com/2071-1050/8/2/127/html