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**A SOCIO-ECONOMIC FRAMEWORK FOR
INTEGRATING MULTI-USE OFFSHORE
PLATFORMS IN SUSTAINABLE BLUE GROWTH
MANAGEMENT: THEORY AND APPLICATIONS**

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<cn>1<ct>A socio-economic framework for integrating multi-use offshore platforms in sustainable blue growth management: theory and applications

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<a>1INTRODUCTION

More than 70 percent of the earth's surface is covered by oceans and seas, much of which is either underexplored or unexplored for the time being. Our seas and oceans offer a vast renewable energy resource and production possibilities with great potential for innovation and growth contributing to the welfare of the human beings. The European Union (EU) supports the implementation of Blue Growth Strategy¹ and the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EU, European Commission 2008), which aim to boost growth in marine-related socio-economic activities ensuring the good environmental status of marine waters and applies the Directive for Maritime Spatial Planning (MSP; Directive 2014/89/EU, European Commission 2014),² which requires its member states to develop plans to better coordinate the various marine activities, with regard to environmental efficiency and sustainable development. The Multi-Use Offshore Platforms (MUOPs) are proposed as the means to accomplish efficient use of marine space and they are supported from the EU through marine initiatives and directives. In this chapter we present a tool for assessing the implementation feasibility of MUOPs.

In order to implement a methodology for integrated socio-economic assessment of the MUOPs we have constructed an assessment tool, which is a web-based tool

developed in open source technologies, available through General Public License. This tool helps researchers select the most appropriate platform design by taking into account MUOPs' technical feasibility, legal feasibility, energy production potential, the environmental impact of its operation, the financial feasibility, and the economic and social impact of the designed platform along with its accompanied activities. These elements are integrated in this assessment tool that consists of four parts. The first part corresponds to the technical and legal feasibility of the platforms, based on identified legal and technical constraints. The second part corresponds to the environmental impact assessment, taking into account environmental effects produced by the implementation of the platforms. The third part includes economic and financial data, as well as monetized environmental effects estimated using methods proposed by economic theory (total economic value framework). Finally, all the data collected from the previous steps are used as inputs for a social cost–benefit analysis that produces results that indicate if the implementation of the platform design specified is feasible or not.

We apply the assessment tool to one of the TROPOS project case studies in Taiwan, at Liuqiu Island. The TROPOS³ project is an EU Framework Program 7 (FP7) project funded by the European Commission (EC). The project aims at developing a floating modular multi-use platform in the ocean to facilitate synergies between offshore industries and efficient resource use by combining, for example, offshore wind with offshore aquaculture, to boost offshore renewable energy use as well as to support recreational activities. The flexible design of the platform facilitates the deployment without limitation in geographic scope.

<a>2THE ASSESSMENT TOOL

For the EU, the MSFD requires an initial assessment of the current marine water environmental status and a definition of marine environmental status, including environmental targets and relevant indicators. In addition, the MSFD implies the implementation of a monitoring program for the assessment of progress and regulation to the satisfaction of these defined targets, together with a program of measures. This program of measures can be evaluated using a cost–benefit analysis, which is officially used for the economic assessment of European projects. In the same manner, the MSP enables public authorities to organize marine human activities with regard to satisfaction of ecological, economic and social objectives. It must be noted that these are in line with sustainable development, which requires economic, environmental and social sustainability. Hence, sustainable management of the oceans requires:

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<bt>economic efficiency, where the marginal social cost is equal or less the marginal social benefit, over time and space;

<bt>social effects of the marine management should be acceptable and affordable by different social groups (social equity), intra- and inter-generationally; and

<bt>environmental and ecological effects of activities under consideration to be sustainable over time and space (ecosystem resilience).</list>

In this section, we are describing a tool, which is in agreement with the EU marine initiatives and directives, supporting the requirements for sustainable management of the oceans. More explicitly, this is a tool that helps scientists and policy makers choose the most sustainable multi-use platform design with respect to an efficient MSP. The tool, however, is organized in a way to support decisions over multi-

use platforms around the world. We start with the technical and legal feasibility requirements, followed by the environmental impact assessment and the monetization of the environmental effects produced by the construction and implementation of a multi-use platform. After including the financial costs and revenues produced by the MUOP, a social cost–benefit analysis is applied indicating whether the proposed design is sustainable and whether there are sensitive variables with regards to the socio-economic and financial data.

2.1 Technical and Legal Considerations

2.1.1 Technical feasibility

Constructing an offshore platform that incorporates energy extraction technologies and aquaculture systems, as well as other recreational facilities and maritime services, is based on a technical design that takes into account different technological aspects that ensure its future implementation. Regarding energy, the different resources should be identified and in addition, and the different possible technologies of energy converters must be assessed, according to technological parameters. Since we are considering the possibility of combining different uses, the feasibility of combining the different energy converters in a multi-use platform should also be examined. Following the same procedure, testing is also required if aquaculture systems and recreational facilities can be added into the design. These tests can be based on previous findings, other projects or even laboratory testing under specific conditions.

2.1.2 Legal feasibility

Institutional and legislative frameworks and policies relevant for the selected designs need to be taken into account. Offshore platforms should follow marine guidelines defined by legal bodies and institutions. In the case of the EU, as mentioned before, the MSFD and the MSP should be considered. These are entirely conjoint to the European economic growth, always taking into account the aspect of sustainability (social, economic and environmental). Constructing and implementing an MUOP in European marine waters should comply with legal and institutional requirements mentioned in the MSFD and the MSP. European Union offshore wind, coastal wind energy and marine aquaculture policies and legislation should be considered as well as birds and habitats directives. Furthermore, international legislation and policies that correspond to wind farms may include United Nations Convention on the Law of the Sea (UNCLOS) and the International Maritime Organization (IMO) Conventions on Maritime Safety policies. Finally, international legislation and policies on marine aquaculture are related to environmental control and the Law of the Sea, which includes the maritime jurisdiction, territorial sea, exclusive economic zone, continental shelf and high seas.

<c>2.1.3Technical and legal feasibility assessment

The technical and legal feasibility assessment (TLFA) section of the assessment tool identifies if an MUOP design is feasible by taking into account legal and technical considerations regarding its installation and operation.

Scientists are required to consider the availability of information regarding costs and revenues of the installation and operation of the platform, to define the project's time horizon, to identify any existing possibilities of combined use and finally to identify if there are any options for technological upgrades. Simultaneously, a set of

risks should be identified and taken into account. Technical risks could include for example structural failure (regarding modular or single structure, geotechnical failure and moorings), power take off and pollution. There might be also financial risks concerning the capital and operation and maintenance (O&M) costs related to the installation depth, materials, power extraction and storage, moorings and transportation. This is done for each of the functions considered to combine into an MUOP, considering also the impact diffusion (that is, correlation of risks between functions), the political uncertainty and any unclear definition of property rights.

In addition, legal and institutional constraints related to the platform design should be examined and included in the assessment for the implementation of each proposed design. Together with the technical considerations, Table 1.1 lists a set of questions needed to be considered and answered by the scientists during the implementation of the web-based assessment tool. This part of the assessment tool provides researchers with a starting point with regards to the technical and legal feasibility of the platform.

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Table 1.1 *Technical and legal feasibility assessment (TLFA)*

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Please select the appropriate answer	Yes	No
Do you have approximations to production parameters (capital costs, O&M costs, administration costs and revenues)?		
Do you have a definition of project time horizon?		
Are there any possibilities of combined use?		
Is there any possibility for technological upgrades?		

Is there uncertainty about the reliability of technique?		
Is there any uncertainty about estimates of costs and revenues?		
Are there correlated risks between functions that can cause impact diffusion?		
Is there political uncertainty?		
Is there unclear definition of property rights?		
Legal considerations: is the placement possible?		
Technical considerations: is the placement possible?		

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The user is prompted to input the answers and, based on the input, the tool presents an answer as to the feasibility of the placements, along with a summary of the questions that contribute to the result. If the answers to the two final questions are negative, it means that the placement of the platform is not possible. Then, the assessment tool notifies the user that the selected design does not satisfy the appropriate requirements and indicates which functions cannot be included in the multi-use platform.

2.2Environmental Considerations

<c>2.2.1</c>Environmental impact assessment

To begin with, the environmental impact assessment (EIA) is an internationally recognized method for scrutinizing the likely impacts of a project on the surrounding environment, including hydro-morphology, chemistry and biology in a broad sense, before its development has occurred. Historically, regarding European territory, a common EU EIA directive (Directive 85/337/EEC, European Council 1985) was adopted in 1985 before the expansion of intense marine fish farming and offshore wind. Furthermore, a more recent alteration to the EIA directive (Directive 2014/52/EU,

February 2014) underlines that impact assessments must take account of additional environmental factors, such as biodiversity and climate change.

The EIA involving the ecosystem services (Landsberger et al. 2013), proposes a sequence of steps that include: (1) screening to recognize whether an EIA is required, (2) scoping for the identification of important possible impacts together with the identification of relevant ecosystem services, (3) examination of alternatives and effective policies for aiming at less impact on the ecosystem services, (4) impact analysis with regards to the proposed platform design in relation to the prioritized ecosystem services, (5) mitigation and impact management to minimize the most important negative effects on those services, (6) evaluation of the significance of the impacts that cannot be mitigated, (7) preparation of a report, (8) review of the report by the authorities and policy-makers, (9) decision-making with regard to the proposed project and (10) monitoring the impacts and follow up. Consequently, concerning our topic of interest, the MUOPs need also to undergo an EIA process which will focus on impacts produced by energy facilities (offshore wind farms, wave energy converters, and so on), aquaculture, and accommodation and transport facilities.

The EIA method should, first and foremost, be quantitative; that is, it should forecast the area to be affected, as well as the level and duration of the effects. Also any anticipated changes in the conditions, biology and morphology shall be evaluated and compared with the primary conditions (known as baseline conditions). Moreover, the scientists should also consider the relevant qualitative aspects to maintain a good environmental status which is related to biological diversity, existence of non-indigenous species, food web, eutrophication levels, seabed integrity, contaminants, marine litter, commercial fishing and noise pollution. An EIA provides ample support

and information so that the policy-makers take also into consideration the environmental impacts before implementing an MUOP project.

<c>2.2.2Environmental impact assessment tool section

After the application of the EIA, in the second section of the assessment tool, the scientists of a project will recognize all the important positive and/or negative environmental impacts (at local, regional and global level) and examine if there is an EIA available for any other similar project(s) in the region. In parallel, it is necessary to conduct a thorough inquiry of the qualitative and quantitative measures that will provide and guarantee a good environmental status (GES). It is also essential to address possible risks related to the uncertainty about climate change and other environmental parameters, as well as examine the existence of non-linear or irreversible environmental effects of the operation of the platforms.

The web implementation of the assessment tool includes a form based on Table 1.2, on which the user is expected to input the answers. Based on the input, the tool presents an answer regarding the feasibility of the placements from an environmental point, along with a summary of the questions that contributed to the result. Similarly to the TLFA section, if the experts' assessment concluded that the MUOP design was not environmentally feasible then no further assessment is required.

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Table 1.2Environmental impact assessment (EIA)

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Please select the appropriate answer	Yes	No
Are there any significant negative environmental impacts (local, regional, global)?		
Are there any positive environmental impacts (local, regional, global)?		
Is there EIA available for similar project in the region?		
Is there uncertainty about climate change and other environmental parameters?		
Are there non-linear environmental effects and is the threshold identified?		
Is it possible for the MUOP to produce irreversible environmental effects?		
Environmental considerations: is the placement possible?		

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It is expected that the multiple functions of MUOPs will have several environmental effects on marine ecosystem services, directly or indirectly. The impacts that could not be identified and mitigated in an earlier stage, that is, prior to installation, will be identified and evaluated during the installation period of the MUOPs and also during their operation (for example, energy-fish-mussels storage and transportation) and decommissioning process. On the one hand, there are several potential negative impacts concerning the MUOPs that need to be assessed. Some of these are loss of area and disturbance of biota, potential risk to affect the seabed, risks to jeopardize native habitats and species (biodiversity), including fish, mammals and birds, visual and noise impacts, use of marine space (other than used by marine communities), water or fish pollution because of toxic materials, and coast modifications.

On the other hand, there are also some possible positive impacts created by MUOPs which should be taken into account, such as the reef effects of MUOPs' structures that can attract species and enhance biodiversity (Krone et al. 2013). In addition, MUOPs can help to mitigate for global warming, since they incorporate energy extraction technologies that do not emit greenhouse gasses and substitute non-environmental friendly technologies. Accordingly, by going offshore, coastal space is

available for other uses (that is, added value of open space), while offshore aquaculture does not affect the coastal water quality by creating eutrophication. An excess of continental nutrients in coastal waters causes eutrophication. Moving to the open sea has naturally less nutrient values from coastal areas where the topography is more shallow and complex, restricting easy water exchange (Orive et al. 2002). Finally, by applying the assessment tool, which is consistent with environmental sustainability, the scientist considers technological alternatives of MUOP synergies that will secure the highest possible mitigation for the possible negative environmental effects.

<c>2.2.3Ecosystem services approach and the total economic value

Following the Total Economic Value of Ecosystems and Biodiversity initiative (TEEB), ecosystem functioning generates a wide range of services to be used either by humans or by other ecosystems. These services can be sorted into four categories, namely, provisioning, regulating, and cultural and supporting services (Table 1.3). More specifically, provisioning services refer to the supply of food and raw materials to humans, regulating services refer to the functioning of the ecosystem in such a way that controls for any shocks to the status quo, cultural services relate to the enjoyment and spiritual enrichment generated from environmental goods and supporting services relate to environmental processes that sustain the status of an environmental good (Millennium Ecosystem Assessment 2005).

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Table 1.3 *Categories of ecosystem services*

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Provisioning services	Regulating services	Cultural services	Habitat or supporting services
Food Raw materials Medical resources	Local climate and air quality Carbon sequestration and storage Moderation of extreme events Waste-water treatment Erosion prevention and maintenance of soil fertility Biological control	Recreation, mental and physical health Tourism Aesthetic appreciation and inspiration for culture, art and design Spiritual experience and sense of place	Habitats for species Maintenance of genetic diversity

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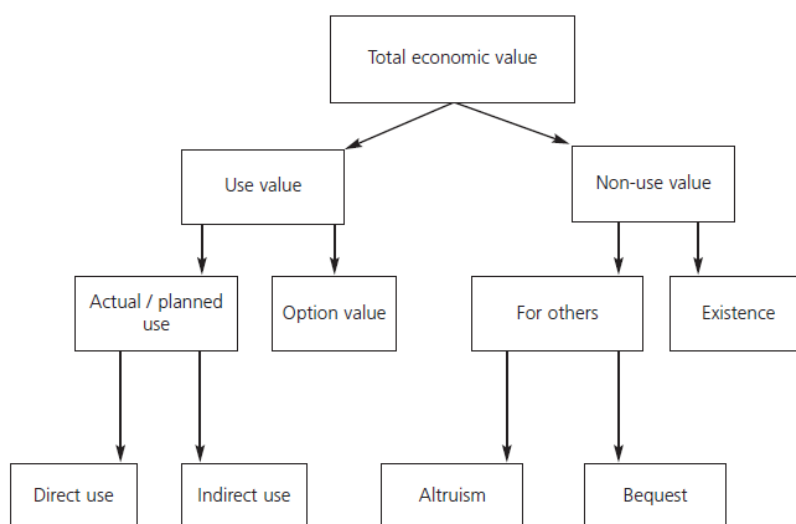
Source: Adopted from De Groot et al. (2002).

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From an economic perspective, the importance of this framework is realized when it is combined with the total economic value of ecosystem services. According to this, each good or bad yielded from natural environmental processes can benefit or harm humans. In economic terms, these benefits or costs are seen as changes in the level of utility of humans. More accurately, an environmental resource – being at a certain status, in chemical, physical and biological terms – functions in a certain way that produces a certain level of goods (services). Any change in its characteristics can alter the way the resource performs its natural functions, thus causing changes in the level of generated services. Humans who are part of the environment perceive these alterations as variations of the utility (enjoyment, comfort, happiness, and so on) they obtain from the resource. This is because services are direct or indirect benefits to humans (Freeman III et al. 2014).

For the management of a natural resource, it is important to value these changes in order to identify the impact they have on human welfare (Fisher et al. 2009; Turner et al. 2010). For this task, the concept of total economic value (TEV) is used (see Figure 1.1). According to this concept, the value to humans associated with changes in circumstances can be divided into several components. Two broad categories are recognized, namely, use and non-use or passive values. Values related to the first category are planned or future uses of the resources in order to cover certain needs (for example, fishing for consumption). On the other hand, passive values refer to benefits that humans enjoy without necessarily acting on to cover a specific need, but rather enjoy by the existence of a resource. Therefore, utility derived from the maintenance of a resource in order to pass it on to future generations falls under this category.

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Source: Defra (2007).

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Figure 1.1 *Total economic value of ecosystem services according to DEFRA*

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Owing to the public nature of the characteristics of environmental goods, economic techniques that are able to elicit market and non-market values are needed. More specifically, revealed and stated preference techniques are two families of methods that are able to assign a price on environmental goods when markets fail to do so. Revealed preference techniques use actual market data by observing the way individuals make choices in real markets. Hedonic pricing that compares the price of two markets with similar characteristics but different levels of environmental goods and averting behavior techniques that observe the cost that individuals are willing to undertake in order to avoid degradation of an environmental good, belong to this family of methods. Alternatively, stated preference techniques, make use of surveys that describe a hypothetical market and directly ask individuals about their preferences on environmental goods. Based on a set of hypothetical situations with variations on the price they would be willing to pay based on the characteristics of a good, and using econometric techniques, these techniques can create preference maps of the individuals. Using their stated socio-economic characteristics, their hypothetical willingness to pay is estimated. Contingent valuation and choice modeling are two methods that belong to this family of techniques. One main difference between the two families is that revealed preference techniques can only be used to estimate the use values associated with a good, whereas stated preference techniques are able to elicit both use and non-use values (Pascual et al. 2010; Freeman et al. 2014).

After the valuation of economic benefits derived from the effects on the marine ecosystem services, the user is asked to add these values manually into the tool by

uploading a comma separated value (csv) formatted file, a format that can be easily exported from all industry standard spreadsheet software such as Microsoft Excel[®]. The user will need to consider the time horizon that the effects will take place, as well as the population and area affected.

2.3 Financial and Economic Considerations

2.3.1 Financial and economic analysis

Regarding the financial and economic figures related to a platform design, the financial costs (investment, O&M and administrative) of the MUOPs and potential financial revenues as well as efficiency gains from combined use of the platform should be included in the analysis. In addition to financial costs and revenues, economic costs and revenues should be taken into account. An investment may not be financially efficient at the level of a private firm, but may be economically efficient at the level of the national economy. This means that for the assessment of an MUOP, it is necessary to evaluate its effect on the national economy. Hence, socio-economic benefits should be estimated by calculating efficiency prices for inputs and outputs of the investment, determining indirect and induced effects (that is, creation of jobs, increased economic activity, increased incomes, and so on), discounting investments' cash flows and by identifying economic efficiency indicators. Efficient prices should replace the corresponding market prices regarding financial costs and revenues of the multi-use platform.

2.3.2 Financial and economic assessment (FEA)

The financial and economic assessment (FEA) section of the tool requires the scientists to add as an input financial costs and revenues with regards to the examined MUOP design. Users of the assessment tool are requested to fill and upload a file with the required data that is analyzed during the social cost–benefit analysis. Similar to the EIA section of the tool, the user is requested to upload the data using a csv formatted file.

2.4 Social Cost–Benefit Analysis (SCBA)

A social cost–benefit analysis (SCBA) is an economic tool that assesses the socio-economic costs and benefits of an investment project over a time period compared with alternative scenarios, for example, a zero-alternative scenario where no action is made or the business as usual (BAU) scenario. Traditional cost–benefit analysis augmented with the ecosystem services framework applies for the estimation of the market value of the investment at regional and national economy. The evaluation of any investment project at the level of regional or national economy usually includes the following steps (MERMAID 2013):

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- 1. Calculation of efficiency prices for the inputs and outputs of the investment.
- 2.Economic assessment of externalities, which are created from the investment (for example, environmental externalities).
- 3.Determination of indirect and induced effects.
- 4.Discounting of the investment’s cash flows.
- 5.Calculation of economic efficiency indicators such as economic net present value (NPV), economic internal rate of return (EIRR) and benefit–cost ratio (BCR).</list>

A project is regarded sustainable when the total discounted economic benefits exceed the total discounted economic costs. The net economic revenues are discounted according to a chosen discount rate in order to include the time preference, reflecting the present monetary value of the flows generated during the project's time horizon.

The European Commission, for the programming period 2014–20, recommends the use in cost–benefit analysis (CBA) of a social discount rate (SDR) of 5 percent for cohesion countries and 3 percent for other member states (MS). The social discount rate (SDR) is the discount rate used in the case of social projects. An SDR extends the efficiency criterion of accepting a project, while costs and benefits occur over time. The idea is to secure the viability of projects that generate social benefits and the use of the financial discount rate will not reflect its future importance.

The SCBA section encloses the data collected for the costs and benefit expressed in efficient prices during the third part of the assessment tool and the monetary values of the environmental externalities. In addition, 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.

In the final step, the results based on the design of the platform will be subjected to risk analysis, since uncertainty is present at all stages of the assessment process regarding market prices, the macroeconomic development, the life span of the platform and other parameters. A sensitivity analysis will be carried out to identify the parameters which are sensitive for the analysis and create significant impacts on the overall outcomes of the SCBA.

The TROPOS project aimed at developing an MUOP system, which allows for sustainable and eco-friendly uses and a synergistic exploitation of oceanic resources. The key features of the developed platform system are (1) the floating design which facilitates access to deep sea areas and resources where deployment of conventional platform types is not possible, (2) the multi-use concept which supports the integration of different functions and services at one site and facilitates synergies, for example, by joint logistic, and (3) the modular approach which allows for a flexible combination of different types of modules adapted to requirements.

The general conceptual design of the developed platform system includes a floating central unit which can be moored to the sea floor and builds the core of the platform, modules with different functions that can be integrated into the central unit, and satellite units which can be indirectly connected (via undersea cables) to the central unit and are fixed on the sea floor with an own mooring (TROPOS 2013, 2015a).

By combining different functions and services, several platform concepts were designed, for example, the ‘Green and Blue’ concept combining offshore aquaculture with harnessing of renewable energies, the ‘Leisure Island’ platform involving multiple leisure facilities and services, and the ‘Sustainable Service Hub’ concept focusing on transport and energy related needs of the offshore renewable energy sector (see TROPOS 2014a, 2015a). By selecting optimum sites for the deployment of particular concepts, theoretical platform scenarios were developed and specified in great detail. One of these scenarios, the Green and Blue concept to be deployed southwest of Taiwan, serves as a case study to demonstrate the applicability of the assessment tool. The results from the Green and Blue concept are compared with the baseline scenario where no platform will be built.

The deployment site for the Green and Blue platform is located at a distance of 3 nautical miles from Liuqiu Island, southwest of Taiwan, in 300–400 meters depth of water. In this scenario, fish and macroalgae aquaculture are combined with an 8 MW ocean thermal energy conversion (OTEC) plant (uses the ocean's naturally available vertical temperature gradient to produce electrical energy) for energy supply. Fish and macroalgae aquaculture units are located on 30 floating satellite constructions. The aquaculture production was estimated with 3000–4500 tons of fish per two-year production cycle and 110 tons of algae per year. Fish and algae are both processed directly and stored on-site, in the aquaculture processing module integrated into the central unit. This Green and Blue scenario in Taiwan also includes some (limited) leisure or recreation facilities (for visitors and staff), accommodation including food and beverages, which are represented in the accommodation module.

3.1Technical and Legal Assessment

<c>3.1.1Technical considerations

An offshore platform system not only needs to be technically feasible, the technology also has to be safe, resistant, economically viable and eco-friendly to obtain official approval and acceptance by society, in particular by potential users and investors.

The technical design solutions for the TROPOS concepts were tested for their safety and resistance (both in model simulations and experimental tests using models). The multi-use approach allows for shared use of infrastructure and services (workshops, monitoring, and so on). The lower part of the central unit is equipped with a double hull to prevent oil spills. A desalination unit on board the central unit generates fresh water.

All waste and wastewater is treated and stored following best practice. The grey water system is a system that works by gravity; the black water system is a vacuum system. The wastewater produced on the platform is stored in tanks and will be treated on board of the central unit in a septic plant before being discharged. The storage capacity of the tanks will allow for five days of autonomy. Solid waste is treated on board the central unit following best practice, including compacting, a high-quality incinerator and subsequent transport to shore.

In the Green and Blue scenario the macroalgae floaters are located downstream of the fish cages, allowing for recycling of nutrients from fish excrement by the algae. The water discharge from the OTEC plant is below the pycnocline, and not within sensitive water layers.

<c>3.1.2Legal considerations

Design and technology has to comply with legal requirements and constraints. The policy and legal framework to be considered for an offshore deployment depend on the deployment site (territorial waters, exclusive economic zones – EEZs, and international waters) and involve different levels, for example, national legislation as well as international policy. When designing the TROPOS platform scenarios, all current national environmental laws (here Taiwan), European Directives, international commitments and conventions were considered with the aim of developing an eco-friendly design with the lowest possible negative impact on the environment (reviewed in TROPOS 2014b) (Table 1.4).

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However, there are still many constraints and uncertainties, and the novel multi-use approaches for offshore activities still require the development of an integrated regulatory framework to facilitate permission, operation and management of these deployments and activities (Buck et al. 2004).

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Table 1.4 TROPOS project – Taiwan: technical and legal feasibility assessment

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Please select the appropriate answer	Aqua	Aqua	Ener	Ener	Recr	Recr
	cultu	cultu	gy	gy	eatio	eatio
	re	re	extra	extra	n	n
	Yes	No	Yes	No	Yes	No
Do you have approximations to production parameters (capital costs, O&M costs, administration costs and revenues)?	X		X		X	
Do you have a definition of project time horizon?	X		X		X	
Are there any possibilities of combined use?	X		X		X	
Is there any possibility for technological upgrades?	X		X		X	
Is there uncertainty about the reliability of technique?		X		X		X
Is there any uncertainty about estimates of costs and revenues?		X		X		X
Are there correlated risks between functions that can cause impact diffusion?		X		X		X

Is there political uncertainty?		X		X		X
Is there unclear definition of property rights?	X		X		X	
Legal considerations: is the placement possible?	X		X		X	
Technically considerations: is the placement possible?	X		X		X	

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3.2Environmental Impact Assessment and Value of Environmental Effects

For all TROPOS platform scenarios, a virtual EIA was carried out. For each element and function of the platform the potential ‘stressors’ (which can induce an adverse response) were defined, and scenario-specific ‘receptors’ (ecosystem elements that may respond to an impact) were identified (for details see TROPOS 2014b). In the following, the most important potential effects of the Green and Blue concept are summarized assuming a multi-use platform scenario that includes a central unit, aquaculture satellites and module, the OTEC plant (satellites), as well as the accommodation module (including food and beverages).

Aquaculture (fish and macroalgae) has a major negative effect on water quality, sediment quality, benthos, plankton, fish and turtles, marine mammals and humans, which is expected from solid and liquid wastes produced during daily operation of the aquaculture farm. Noise and vibrations due to vessel traffic and daily aquaculture operation may significantly affect fish and turtles and marine mammals. The artificial lighting of the platform and the satellite units may particularly affect fish and turtles, birds and bats, and marine mammals. The potential escape of cultured fish from the farm cages and the introduction of alien species into the natural ecosystem may pose a

major threat to plankton, benthos, and fish and turtles. The aquaculture farm might attract wild animals (for example, fish, turtles, mammals and birds). The installations of the moorings to fix the central unit and the aquaculture satellite units to the sea floor will have a negative impact on sediment dynamics and the benthos.

The operation of the accommodation module goes along with additional negative impacts on water and sediment quality, plankton, benthos, fish and turtles, and marine mammals owing to noise and vibration, artificial lighting and solid and liquid wastes. The OTEC plant may alter water temperature and salinity in particular layers, which might affect in particular plankton organisms and water column stratification on a small scale. Noise and vibrations during operation may also disturb fish and turtles and marine mammals.

The majority of possible negative impacts identified can be avoided, or at least minimized, if appropriate mitigation strategies are applied. In a real-world deployment of such a platform system, all these potential effects would require strict monitoring, in particular because Liuqiu Island and the waters around it are inhabited by the endangered green turtle (*Cheloniemydas*).

However, the floating platform may also have a beneficial impact on the environment: shading from the central unit is supposed to have a positive effect on fish and turtles, and the physical presence of the structure is expected to provide shelter with a positive impact on fish and turtles and marine mammals (Table 1.5).

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Table 1.5 *TROPOS project – Taiwan: environmental impact assessment*

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Please select the appropriate answer	Yes	No
Are there any significant negative environmental impacts (local, regional, global)?		X
Are there any positive environmental impacts (local, regional, global)?	X	
Is there an EIA available for similar project in the region?		X
Is there uncertainty about climate change and other environmental parameters?	X	
Are there non-linear environmental effects and is the threshold identified?		X
Is it possible for the MUOP to produce irreversible environmental effects?		X
Environmental considerations: is the placement possible?	X	

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Choice modeling was used to estimate the value of environmental effects of the Green and Blue concept. The marginal and total willingness to pay (WTP), for different environmental impacts, are derived. A full ranking method was used to provide a more sophisticated map of individual preferences. A survey was carried out in November 2014 on Liuqiu Island, Taiwan. Tourists and residents in the area were the target population of the survey. Of 250 randomly chosen tourists and residents, 129 tourists and 43 residents were included in the final analysis. Three alternative designs were provided to the respondents via choice cards. The first and the second were different hypothetical designs of the platforms. The first design includes aquaculture facilities (fish and algae production), while the second design includes aquaculture production, renewable energy production and leisure facilities. The attributes used were the environmental impacts of the modules, the level of mitigation and the existence of renewable energy production and leisure facilities. The third was the opt-out alternative referring to the status quo where no platform will be built. The respondents were asked to choose the most and least preferred alternative. As the results for residents have no statistical power, only the results for tourists are presented here.

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The results indicated that each tourist was willing to pay NT\$53.66 per day to have access to the multi-use platform. Assuming that the platform will operate 354 days per year, for 20 years and with 32 566 tourist visits in 2013, the platform will gain a total non-market benefit of NT\$618.25 million per year.

3.3Financial and Economic Assessment

This section evaluates the macroeconomic impact of multi-use platform systems and is based on TROPOS D5.2 (TROPOS 2014c). We identify the economic benefits and the magnitude of the economic impact of installing a floating platform of 28 hectares. The platform is designed to operate 24 hours a day, three shifts per day, with four teams being employed each week. The reference platform is 1200 meters long and 240 meters wide.

The system-wide economic impact of each of the multi-uses of platforms is identified separately by the contribution of transport, energy, aquaculture and leisure (TEAL) activities to each platform. Input–output analysis is used to simulate exogenous demand shock from both capital and operational expenditures related to the deployment of the platforms. The input–output analysis performed is based on the standard type I approach (Miller and Blair 2009). This implies household consumption is assumed to be exogenous as are all the other elements of final demands, such as exports, government expenditure and investments. In addition, the supply side is passive and only final demands drive economic activity.

Here, we summarize the results for key macroeconomic indicators, such as gross domestic product (GDP), employment and the total output multiplier effects. The Green

and Blue concept of Taiwan consists of three functional modules, the aquaculture, the OTEC plant and the leisure module respectively. The total macroeconomic impact of the platform is the sum of the impacts of the three modules. The output multiplier is generated in the input–output analysis after imposing the demand disturbance. It is defined as the ratio between the total output effects and the direct effects.

In the first instance the simulated shock is assumed to be the same every year over the time span of 20 years. It is also assumed that the expenditures associated with the construction of the multi-use platform consist of goods and services purchased within the region. In the sensitivity analysis, stochastic simulations for different scenarios are performed to reflect the uncertainty related to the scale of the demand disturbance. The hypothesis on certain imported goods and services is also tested in the sensitivity analysis. Results from the sensitivity analysis are not presented in the section and refer to TROPOS D5.2 (TROPOS 2014c). The input–output table for Taiwan is constructed for the year 2006 and is disaggregated into 30 economic activities.

In TROPOS D5.2 (TROPOS 2014c) the cost of energy module is estimated according to one offshore wind service hub, the results is directly used in this section as an approximation for OTEC owing to lack of capital expenditure (CAPEX) and operational expenditure (OPEX) estimation for OTEC in the literature.

Table 1.6 lists the CAPEX, OPEX, the GDP impacts, the approximated employment effects⁴ and the total multiplier effects of the investments for the Green and Blue concept of Taiwan. It shows that the GDP impact for leisure module is the lowest among the three modules. It is about NT\$670 million for CAPEX and NT\$189 million for OPEX. The employment impact is 547 full time equivalent (fte) and 104 fte for CAPEX and OPEX respectively. The GDP impact for the energy hub is the highest and

is about NT\$1118 million for CAPEX and NT\$542 million per year for OPEX.

Employment impact is 878 fte for CAPEX and 391 fte for OPEX. The multiplier effect per annum is between 1.72 and 2.19.

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Table 1.6 GDP impacts and the total multiplier effects of CAPEX and OPEX for the Green and Blue concept in Taiwan

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	Cost (NT\$ million)		GDP impacts (NT\$ million)	Employment impact (fte)	Multiplier effect per annum
Leisure	CAPEX	1 767	670	547	1.91
	OPEX (annual)	179	189	104	2.19
Aquaculture	CAPEX	2 759	955	753	1.83
	OPEX (annual)	1 565	672	580	1.85
Energy	CAPEX	3 198	1 118	878	1.95
	OPEX (annual)	1 448	542	391	1.72
Total monetary value	CAPEX	7 724	2 743	2 178	–
	OPEX (annual)	3 192	1 403	1 075	–

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3.4 Social Cost–Benefit Analysis

The social costs and benefits are represented by the total economic value (TEV). The TEV includes directly use value (that is, economic benefits and costs for market goods such as provision services and cultural services) and indirectly use value (that is, environmental effects such as regulating services) for the platform. The estimation of the TEV is the sum of two parts: value of economic benefits and costs for market goods

and the value of environmental effects, which are imported in the tool using a customized spreadsheet that allows the tool to run the social cost–benefit analysis. The results in this section refer to TROPOS D5.2 (TROPOS 2014c) and TROPOS D6.6 (TROPOS 2015b).

Net present value (NPV) of the platform follows equation (1.1):

<equation>

$$NPV = -I + GDP_{impact} + \sum_{t=1}^{20} (B_t - C_t)/(1+r)^t \quad \langle rr \rangle (1.1) \langle /rr \rangle$$

</equation>

where I is the total monetary capital cost, GDP_{impact} is the GDP impact of CAPEX, B_t is the annual benefit of the platform, C_t is annual cost of the platform, t is the life span of the platform and r is the annual interest rate. The project is accepted if $NPV > 0$, otherwise it is rejected. When the NPV is used to decide between alternative projects, the project with the highest positive NPV is preferred. By including the non-market value of environmental effects, NPV could be regarded as social net present value.

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Table 1.7 provides the variable explanation and values used in NPV estimation.

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Table 1.7Variables explanation and values used in NPV estimation

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Variable			Unit	Value for each variable
B_t	Market benefit	GDP impact (OPEX aquaculture + leisure + energy)	NT\$ million	1403
	Non-market benefit	Aquaculture + leisure + energy	NT\$ million	618.25
C_t		OPEX (aquaculture + leisure + energy)	NT\$ million	3192
R	Interest rate			0.04
T	Project life span		Year	20
I	CAPEX	Aquaculture + leisure + energy	NT\$ million	7724
GDP_{impact}	GDP impact of CAPEX	Aquaculture + leisure + energy	NT\$ million	2743

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We assume that annual benefit and cost is the same over the 20 years and the discount rate is 4 percent.

Table 1.8 shows the estimation of NPV at an annual base for the multifunctional platform with and without considering the non-market value of environmental effects. As presented in the table, the NPV values are both negative no matter that the non-market value of environmental effects are included or not, mainly owing to the huge investment costs.

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Table 1.8 NPV for the platform with aquaculture, OTEC and leisure: with and without non-market value of environmental effects, $r = 4\%$ and $t = 20$ (unit: NT\$ million)

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	Green and Blue concept: aquaculture + OTEC + leisure	
	Without non-market value of environmental effects	With non-market value of environmental effects
NPV	-29 294.41	-20 892.21

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Sensitivity analysis is carried out with a 5 percent discount rate and a 70 year time span (TROPOS 2015b). The results show that the NPVs are all negative under the analysis. Therefore we reach the conclusion that although the non-market value of environmental effects is large, they are still trivial compare with the huge investment costs in the project. To be able to make the project feasible, a new design or a smaller-scale design to save the investment costs may be needed.

<a>4DISCUSSION AND CONCLUSIONS

The aim of this chapter was to present the assessment tool used in the implementation of the methodology for an integrated socio-economic assessment of MUOPs designed in the MERMAID project (MERMAID 2015) and implemented both in the TROPOS and MERMAID projects. The assessment tool is in line with the European Union's Water Framework Directive (WFD) and the MSFD. The WFD provides an integrated framework for water resources management and protection, both in terms of quality and quantity, in order to achieve sustainable water resources management (EC 2000). In particular, the WFD states that in preparing environmental policies, the European Community

<quotation>

is to take account of available scientific and technical data, environmental conditions in the various regions of the Community, and the economic and social development of the Community as a whole and the balanced development of its regions as well as the potential benefits and costs of action or lack of action. (EC 2000, p. 2)

Further, the WFD highlights the role of economics in reaching good ecological status of water bodies.⁵ On the other hand, the MSFD establishes that EU member states ‘should undertake an analysis of the features or characteristics of, and pressures and impacts on, their marine waters, identifying the predominant pressures and impacts on those waters, and an economic and social analysis of their use and of the cost of degradation of the marine environment’ (MSFD 2008, p. 22). Therefore, during the design and implementation of the assessment tool it was of the utmost importance to take into account the technical, legal, environmental and socio-economic conditions and impacts that would affect the regions where the development of MUOPs was proposed. It is evident that an MUOP cannot be developed if there are technical and legal constraints in place. Thus, such conditions are assessed in the first section of the tool. Once it is established that an MUOP can be developed given the technical and legal conditions, the EIA section provides valuable information for the appropriate mitigation and management measures, in order to reduce the negative environmental effects, preserve a sustainable marine environment and subsequently augment the overall social welfare. Financial and economic costs and revenues are taken into account in the third section of the tool. An investment may not be financially efficient at the level of a private firm, but may be economically efficient at the level of the national economy. Finally, it is important to mention that the assessment tool allows the performance of a social cost–benefit analysis and the estimation of the TEV taking into account the value of

economic benefits and costs for market goods and the value of environmental effects.

The TEV represents the social costs and benefits of the platform and includes direct and indirect use values.

The application of the MUOP assessment tool in the Taiwanese case study of the TROPOS project shows that the assessment tool can be successfully used in order to evaluate the feasibility of the development of a MUOP in Europe and in other regions of the world. The basic considerations in terms of technical, legal, environmental and socio-economic conditions and impacts still hold and provide an appropriate baseline for making policy choices. The assessment tool is a web-based instrument developed in open source technologies and is available through a General Public License. Therefore, it is expected that researchers and policy-makers will make an extensive use of this tool in order to assess the feasibility of MUOPs in the near future. It is considered that the tool will help to comply with good governance objectives as well as with sustainability objectives in regional and national plans of development.

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MERMAID (<http://www.mermaidproject.eu/>) Consortium.

TROPOS (<http://www.troposplatform.eu/>) Consortium.

<a>NOTES

1.http://ec.europa.eu/maritimeaffairs/policy/blue_growth/ (accessed 4 May 2016).

2.Id. Art.6 at 2014/89/EU; Id. Art.7 at 2014/89/EU; Id. Art.8 at 2014/89/EU; Id.

Art.9 at 2014/89/EU.

3.<http://www.troposplatform.eu/> (accessed 4 May 2016).

4.The employment effect is estimated according to contribution of GDP to employment in Gran Canaria. The assumption is made due to lack of data in Taiwan.

5.The economic elements of the WFD are discussed in Article 5 ‘Characteristics of the river basin district, review of environmental impact of human activity and economic analysis of water use’, Article 9 ‘Recovery of costs for water services’, Article 11 ‘Program of measures’ and Annex III ‘Economic analysis’.

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