Environmental aspects of designing multi-purpose offshore platforms in the scope of the FP7 TROPOS Project

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***Abstract* - The objective of the FP7 funded TROPOS project is to design a modular multi-use platform for use in deep waters, with a focus on the Mediterranean, tropical and sub-tropical regions. In this paper, the related environmental aspects are considered, where both legal and technical issues are addressed. The multiple purpose platforms can enlarge the benefit from different functions, and reduce the environmental impacts through synergies among single impact as well. This proposed study demonstrates the impact assessment through multiple, integrated technologies.**

Keywords - environmental impact assessment, multi-purpose, multi-use, offshore, platform.

I. Introduction to the TROPOS EU Project and its Status after Two Years

The TROPOS project is currently designing a modular offshore platform system, aimed for the harnessing and servicing of marine and maritime resources, with Mediterranean, subtropical and tropical regions as main application and geographical focus [1]. The system consists of a central unit, modules and satellites, which can be configured for different functionalities depending on the site. Different combinations of several TEAL-related (Transport, Energy, Aquaculture and Leisure) modules can thus be identified according to the needs and conditions at different locations. In three main configurations, activities such as renewable energy conversion (mainly wind and Ocean Thermal Energy Conversion - OTEC), aquaculture facilities (phytoplankton, fish, macroalgae) and/or services for transport and tourism are considered.

Common to all configurations is one Central Unit (CU), which is similar in the design - size can vary - but can accommodate quite different services inside, depending on the needs of the selected modules (subspaces integrated in the central unit or directly connected to the CU) and satellites (subspaces not connected to the central unit but related to it). A functional design of the relation of the CU, modules and satellites is shown in Figure 1. Adapting the central unit to three defined scenarios is still underway and only some preliminary EIA-relevant information is provided below. The CU will serve core functions, especially in regard to accommodate platform staff and providing general supply and maintenance services. Also it can be adapted for different combinations outside the lifetime of TROPOS. Diverse specific modules can be attached to the CU, so these elements have only one mooring structure together. Modules can provide additional services in the areas of tourism, processing of aquaculture products, energy generation (photovoltaic, OTEC), energy transformation (substation) or for environmental monitoring or other services.

The TROPOS offshore system can be supplemented with the so-called Satellite Units (SU). These are free-floating elements, with their own mooring structures, placed at a distance from the central platform with its attached modules. Satellites are being designed especially for wind energy harvesting combined with fish and algae aquaculture, as well as freestanding aquaculture units.

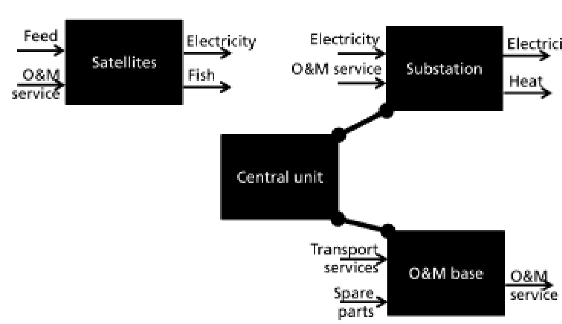

Figure 1: TROPOS platform related model drawing showing two modules (right) and one satellite to the left of the Central Unit (from TROPOS D3.5).

From an EIA point of view the area thus impacted by all of the named elements as well as physical effects of the moorings have to be considered. Also to be studied are total emissions including those from building the whole platform (CU, Modules, SUs) as well as from servicing logistics, operations, repair and maintenance and finally, dismantling.

Figure 2 shows the concept of three scenarios of which one and two are now under further study for location-specific EIA aspects, which are called 1) Leisure Island; 2) Green & Blue platform; 3) Sustainable Production platform [2]. Three regions were selected based on an optimization of GIS model studies for renewable energy, tourism and aquaculture potentials. Then three defined sites were selected, also to cover some diversity in TEAL aspects: Liuqiu Island (Taiwan), Gran Canaria (Spain), and Crete (Greece) for further project work, i.e. technical design, economic, socio-economic and environmental assessments. Figure 3 illustrates the specific platform locations in the selected regions. The Leisure Island concept is designed now for Gran Canaria to develop its tourism potential. The Green & Blue scenario, combining different renewable energy types with aquaculture, will be studied for the two remaining sites, with OTEC for the Taiwan and wind for the Crete site, This is according to the conditions available, also aquaculture species to be reared are based on their natural presence in the area and existing experience at each site.

Figure 2: FP7 TROPOS Project artistic representation of the conceptual designs (above) and three locations for TROPOS platform design scenarios (below) [3]

II. ENVIRONMENTAL ASPECTS IN DESIGNING MULTIPURPOSE OFFSHORE PLATFORMS

Developing oceanic platforms may result in both positive and negative environmental impacts, many of which remain unknown given the emerging nature of this field. The environmental aspects of the TROPOS platform design will be summarized by comparing the aspects of the design to existing single and dual purpose installations as well as to floating platforms. It is of special interest, whether synergies between the uses enable potentially negative impacts to balance one another and thus will result in reduction of overall impacts. Surely, the joint logistics for erection, supply and maintenance are envisaged to save cost as well as reducing the environmental footprint.

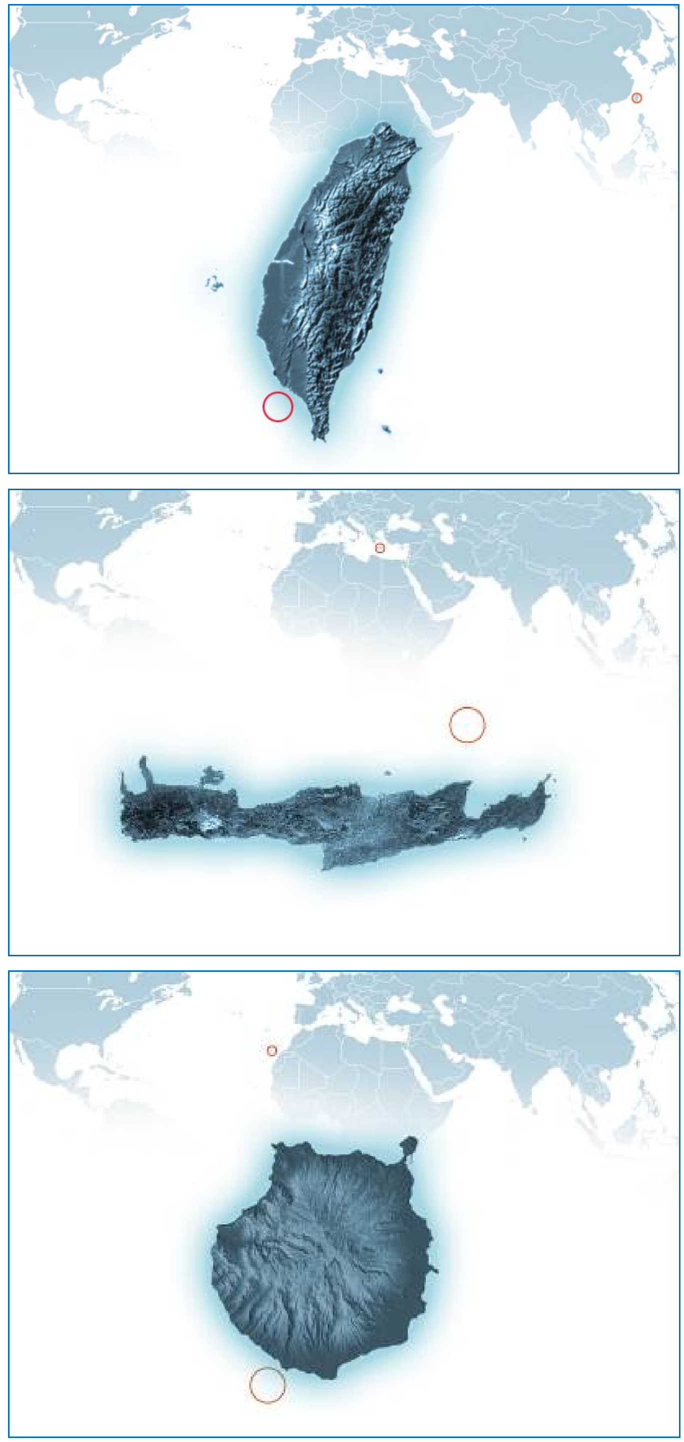

Figure 3: Specific platform locations in the selected regions [3]

From an EIA point of view the area may be impacted by several of the named elements and activities, including physical effects of the moorings, emissions during construction, installation and decommissioning, servicing logistics, operations or repair and maintenance. The potential environmental and socio-economic impacts during the construction and the operational phases are examined and identified for the core platform and for modules on marine energy generation, aquaculture production, tourism and other related transport activities.

Background work involved the collection and study of current literature and real experience, such as publicly available EIAs of (floating) oil and gas platforms, offshore wind-energy or aquaculture farms, artificial islands, artificial reefs, etc. for guidance on the design of a sustainable TROPOS platform. In the following sections some aspects of EIA will be discussed, including the difference between single and multiple purpose designs.

2.1 Legal Aspects in EIA

The procedures in Europe (Directive 97/11/EC) are similar, with a few slight differences and thus not repeated here. Important to understand is that EIA is a process not a document. One document which is done by the proposer or a subcontractor to him, the environmental impact statement (EIS), is just one part of this. A generic EIA workflow is shown in Figure 4. For the TROPOS design project it was deemed important also to study SEA or strategic environmental assessment legislation (Directive 2001/42/EC), which is for plans, programs and strategies i.e. on a higher level of planning.

Finally it was decided to use elements of the regular EIA procedures as far as suitable for the TROPOS design scenarios, but with a focus to providing guidance and examples. When a real platform is going to be built, one specific full EIS and EIA still needs to be done, based on baseline data for the site chosen and on the final combination of Modules and Satellites chosen for one Central Unit. Then also the local permitting agency, or competent authority, has to be involved, applying supra-national and national law, maybe even local law, according to the legal framework applicable in relation to the selected site, e.g. its closeness to the shore, protection status etc.

Further legislation to be considered is mainly international law with a focus on IMO rules and regulations, esp. the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78 and its annexes as applicable for offshore platforms. Annex 1 of MARPOL relates to prevention of oil pollution and has provisions for machinery space drainage that are applied to offshore platforms, other relevant provisions of MARPOL have to be applied to offshore installations, e.g. Annex 5 on waste management.

In Taiwan, the assessment of environmental impacts has been promoted for over a decade. The EIA involves the processes of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to make major decisions and commitments. The purpose of the assessment is to ensure that decision-makers consider environmental impacts before deciding whether and how to proceed with new projects and to ensure minimum impacts through monitoring and mitigation measures (EPA, Taiwan, 2007).

Important issues for EIA in Taiwan are the following:

- Site Allocation
  - To ensure the proposed development site is not located in environmentally sensitive areas (ex. water supply protection zone, wildlife refuge, national parks, geological sensitive areas etc.), specific land use (ex. military control, air traffic control zone etc.).
  - To avoid that the proposed plan may violate prohibitions and restrictions by laws and regulations in Taiwan.
  - To appropriately adjust plans (testing alternative sites).
- Environmental Survey:
  - Data collection: physical, biological, chemical, social, economic environment.
  - Potential impact during and after construction.
  - Comprehensive assessment.
- Prediction and Assessment: Forecast and prediction.
- Alleviation/Mitigation Strategies:
  - Strategies for avoidance, mitigation, and compensation.
  - During construction and operation stages.
  - Monitoring strategies.
- Alternative Plan: alternative plans in terms of site location, materials, construction methodologies and others.

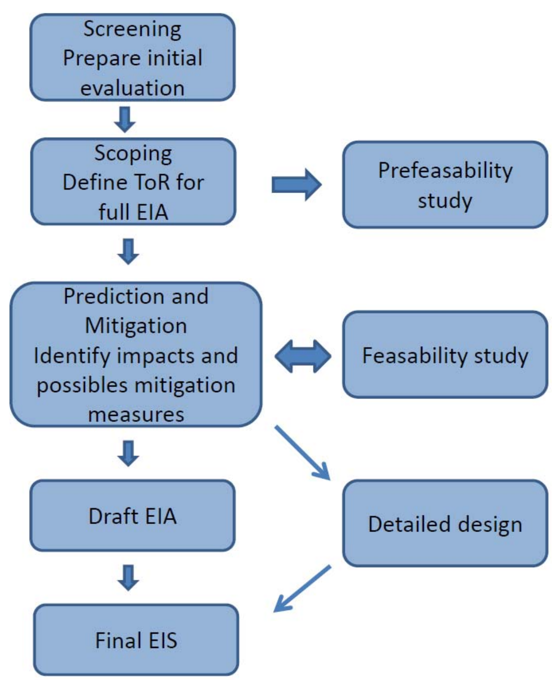

Figure 4: Flowchart describing the EIA procedure and links to the technical design process (from TROPOS D6.1 on Scoping)

2.2 Generic Environmental Aspects

All ocean renewable energy projects carry risks during construction. There could be possible damage from operating machinery, and there could be an impact on the marine environment or the social economy. Studies on the environmental impact of renewable ocean energy are scarce [4,5]. Most analyze the impact of specific cases (offshore wind farm or coastal construction) or specific species (birds or cetacean), but not on a case-by-case basis (e.g., the noise and electromagnetic wave impact on marine mammals and migratory fish [6,7] or the impact on birds of developing offshore wind farms [8]. However, some researchers have indicated that integrated and strategic environmental assessment is a key to developing renewable ocean energy [9,10]. Ignoring environmental impact when developing renewable energy usually causes local resident conflict. The U.S. Cape Cod offshore wind farm led to local resident and environmentalist protests [11]. In Taiwan, the wind farms established due to low frequency noise also caused a severe rebound from the local community, resulting in wind energy-related environmental impact assessment regulation modification in 2013. All of these show that to assess environmental impact, we should consider not only the ecological environment but also the social economy. This helps to decrease the social cost of local protests, raises the local awareness of the environment and renewable energy, and further develops a long-term cooperation strategy between local and sustainable energy [12].

2.3 State of the Art on Offshore EIAs for Single Purpose Platforms

Developing oceanic platforms may result in both positive and negative environmental impacts, many of which remain unknown given by the emerging nature of this industry. To reduce the environmental footprint, floating structures were chosen in this proposed study as they may be more costly, but are a much easier to build and decommission, therefore much less impact on the sea floor can be expected. Scoping identification and analysis is the first step in the EIA process, which can be identified as environmental, social and economic aspects. To begin the process of EIAs for multiple purpose TEAL (transport, energy, aquaculture, leisure) platforms, impacts from single platform and module need be identified first. Table 1 illustrates the framework of positive-negative, and direct-indirect impacts for each TEAL platform and its related activities.

2.4 Offshore EIAs for Multiple Purpose Platforms

The concept of multiple purpose platforms is to enlarge the benefit from various platform combinations. At the same time, the multiple purpose platforms may reduce the cumulative impacts from more than one platform modules, or reduce negative impacts based on synergies strategies (Fig. 5).

Table 1: Examples for potential impact from single purpose platform

Direct Positive-Negative Impacts					
Scope	Platform	Positive Impact	Scope	Platform	Negative Impact
Econ.	W	increase economic growth	Env.	W	environmental pollution issues
Econ.	W	increase industrial growth	Env.	W	affect ecosystem
Econ.	W	resource reuse	Env.	E	changes of coastal topographic
Econ.	L,T	improve regional transportation	Soc.	T	pollution/emissions affect public health
Econ.	E	energy generation	Soc.	W	affect natural landscape
Soc.	W	employment opportunities	Econ.	W	increase transportation cost
Soc.	A	increase food			
Soc.	E	increase recreation value			
Indirect Positive-Negative Impacts					
Scope	Platform	Positive Impact	Scope	Platform	Negative Impact
Env.	E	reduce CO_2 emission	Env.	W	long-term ecosystem degradation
Env.	E	seawater desalination	Econ.	W	market monopolizing by corporation
Env.	A	endangered species breeding	Econ.	W	increase traffic complexity
Env.	W	reduce carrying capacity on shore	Soc.	W	public health and safety issues
Soc.	E	provide lower cost of energy for coastal resident	Soc.	W	the culture and industrial changes in coastal communities
Econ.	W	marine science and technology development	Soc.	W	over-exploitation
Econ.	W	develop of green energy	Soc.	W	increase risk of disaster

Env.: Environment; Soc.: Society; Econ.: Economic; E: Energy; A: Aquaculture; T: Transportation; L: Leisure; W: Whole

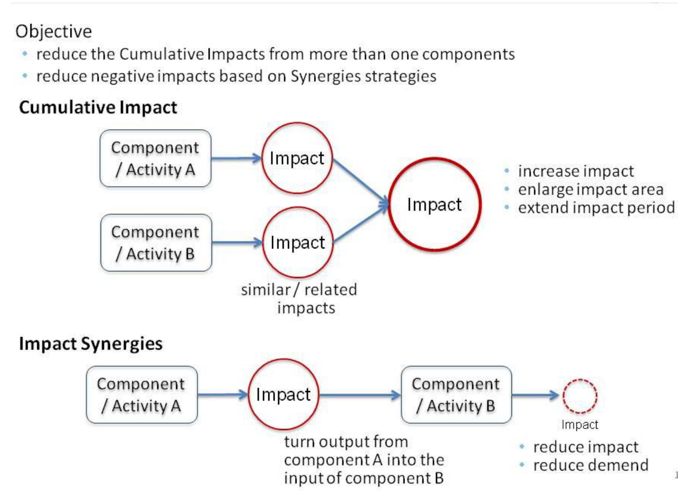

Figure 5: Objectives for multiple purpose platforms regarding the EIA

- Central unit as core service unit

The central unit (CU) for all three scenarios is designed as a floating SWATH (Small Waterplane Area Twin Hull) element. It is similar for all TROPOS scenarios, but different modules can be attached and different service implemented within the CU. In all cases a floating structure is designed to be installed in deep waters at sites in the Mediterranean and in tropical and subtropical regions on the North Atlantic and near Taiwan, with a basic design flexible enough to be adapted to other areas. It has up to 12 decks as can be seen in Figure 6 with general technical specifications in the following table below.

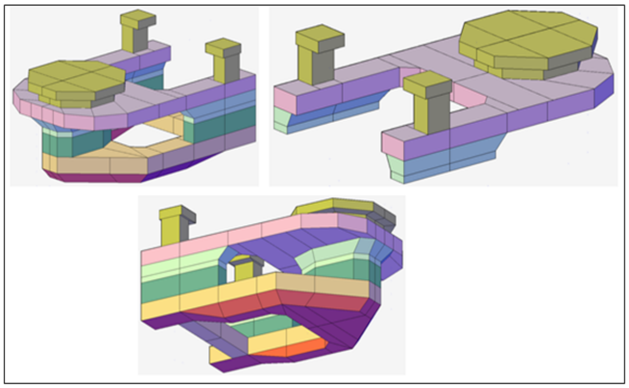

Figure 6: Structure of the SWATH floating platform model selected, Elaborated by UPM & AID (from D3.1)

Table 2: Principal dimensions of the Central Unit

Length	Beam	Dead works (to deck 11)	Dead works (to deck 12)	Underbody
80 m	56 m	18.4 m	24 m	17.2

The number of persons on board determined so far are as a minimum the following: Leisure Island is estimated at 223 passengers and 45 people including crew and employees, and Green & Blue is estimated at 55 people including crew and employees (some passengers would be also considered for the Green & Blue platform). These numbers may vary in function of the needs for each of the established modules. Thus different waste streams are to be expected. However, some fish processing is planned for at least one Green & Blue scenario, which will add further waste streams to be deals with in a possibly synergistic fashion to this platform.

Environmental measures: Sewage and waste treatment are planned on the Central Unit according to best practice, including compacting, high-quality incinerator and return to shore. Energy will be generated through renewables as far as feasible with diesel generators as back-up. Double bottom for all fuel and lubrication oil tanks as well as collection, safe storage and return of all oily wastes to shore are planned as well. Desalination and vacuum toilets will help to reduce fresh water demand and waste water volumes.

- Aquaculture Fish Processing module

On the CU in the green and blue concept applied in Crete a processing unit is considered that is expected to receive a total of 5500 t of fish annually and to process in three different levels. The basic processing unit is planned for "fresh-in-ice" products, the second level processing for filets and products in MAP while the third level processing is for IQF products. The annual consumption of energy and the requirements in fresh water, including ice, are presented in Table 3.

Table 3: Main characteristics of the Processing Unit

Processing	Energy (MWh y^{-1})	Fresh water (Km^3 y^{-1})	Treated water (Km^3 y^{-1})
1st level	36.0	5.88	4.5
2nd level	29.0	6.4+	6.4
3rd level	222.0	15.8	15.0

Emphasis has been given in the use of the by-products from the processing that are treated a primary material and therefore not as wastes but as products. Regarding the treatment of the waste water, this will involve removal of particles, lipids and soluble proteins via skimmers, reduction of organics by bio-filtration and regaining of nutrients in algae cultures. The amounts of treated water released in the environment are also presented in Table 3.

The operation of the Processing unit requires additional auxiliary facility such as a desalination and an ice production module, while storage facility of the products before export is also required. The estimated annual energy consumption is 92MWh, 316MWh and 80MWh respectively. The desalination unit will require 153.5 Km^3 sea water and will return to the sea 122.8 Km^3 sea water with 20% increased salinity.

- Fish Aquaculture

The Green and Blue concept both for Crete and Taiwan includes fish aquaculture as a major activity. For Crete the planned annual production is of 5,500t finfish while for Taiwan a 2,000 t production is foreseen. In Table 4 the major parameters of the production in the two sites are shown including energy demand, amount of feed used together with the estimated amounts of released nutrients in the environment (as total N and total P). The quantities of nutrients are estimated base on the assumption that 65.3kgr N and 3.2 kgr P as dissolved and 15kgr N and 4.8 kgr P as particulate are released per ton of fish produced [18].

Table 4: Main annual parameters of the fish aquaculture activity

	Energy (MWh)	Feed (KT)	Ice (KT)	Total N (T)	Total P (T)
Crete	1,723	9.0 (FCR 1.7)	2.7	420.0	42.0
Taiwan	1,790	3.0 (FCR:1.5)	1.0	167.0	16.0

In both sites an additional Algae producing unit is planned for both micro-algae and macro-algae which are placed downstream of fish culture units regaining partially the releasing from fish production nutrients.

- OTEC

The green and blue concept applied in Taiwan will focus on the OTEC energy and aquaculture. OTEC is the major ocean energy source for the site of Taiwan where next to the Kaoping undersea canyon and very close to the continental shelf margin as well. The temperature difference between the surface and the deep layer at the Kaoping Canyon site is 15°C at 300m depth. There are two basic types of OTEC operation, open cycle (OC) and closed cycle (CC). There are also hybrid versions, and combinations with secondary cycles. The OC uses a small part (≈10%) of the warm seawater as the driving fluid for the turbine, which CC uses a medium like ammonia for this. Most recent designs are based on CC operation because of its reliable and cost-efficient, mostly off-the-shelve components. The OC operation has advantage of producing potable water from the condensing driving fluid, and the driving fluid poses no environmental concern (ammonia may, but now there is safe handling procedures and standards for ammonia). However, the disadvantage of OC operation is the need for a large vacuum chamber, to house evaporation/ condensation units and the turbine.

The design proposed in Taiwan is based on the CC operation. The satellite module containing OTEC will be connected to the central unit by tethers. A power cable and fresh water hose will run between. There is no strict minimum or maximum criterion for the distance, 70-100 m is assumed to be sufficient. The base-load power needs for platform was not yet determined exactly, but in units like for aquaculture figures of up to 10 MW are in the present schemes. The OTEC plant will be an independent module that has the systems and equipment necessary for the production of electrical energy. According to the connection with several power modules in parallel, the proposed design can provide more energy to aquaculture and leisure for using.

The water temperature difference between cold deep layer and the warm surface offers the opportunity to implement OTEC. The deep layer water is also nutrient rich that can supply algae growth modules and adjust the surface temperature to fit the algae growth environment all-year-round. Additionally, the cold water can provide opportunities for rearing native cold water species by the fish aquaculture module. The algae aquaculture can reduce the nutrients which produce from fish farms and keep the water quality. The synergies among different modules will reduce the negative impacts and improve the environmental qualities (Fig. 7).

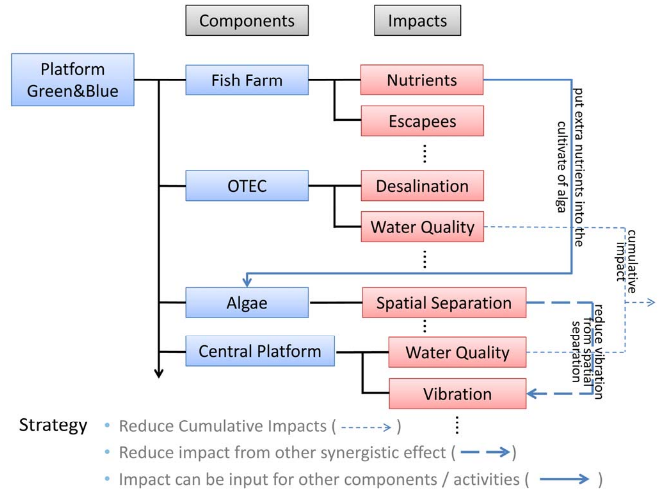

Figure 7: Potential impact synergies between OTEC and aquaculture

Research is ongoing on the environmental impact assessment of a TROPOS floating multi-purpose offshore platform including best practice to determine mechanisms for monitoring, forecasting and mitigation of impacts in the context of the three locations. Joint work with two other Ocean of Tomorrow Projects: H2OCEAN [13], MERMAID [14] is also being done related to environmental impact assessment. Monitoring and mitigation mechanisms are devised to determine and reduce effects on water quality, ecology and environment. Monitoring is not only seen as a necessity for the EIA itself, but also can provide an added value due to have a permanent manned offshore observatory. Such an observatory can provide useful marine and weather data for shipping, for various renewable energy concepts and other oceanographic and environmental data, i.e. on climate change, water quality, status of biodiversity and ecology [15].

III. Synergies and Added Value of Multi-Purpose Combinations

3.1 Reduced Footprint Due to Joint Logistics

Strong synergies between the uses are expected from joint logistics in order to minimize negative impacts and to reduce overall impacts, as compared to single-purpose wind farms, aquaculture or tourism installations. Joint logistics can start in the planning and building phases, reducing the need for material and ship voyages to the site, thus reducing fuel consumption and noise. Even more positive effects are expected during the lifetime of the multi-purpose platform, when integrated planning of supply and maintenance trips are envisaged to save cost as well as reducing the environmental footprint.

Due to personnel living on the central unit, the length of most trips for inspection, harvesting, repair are substantially shortened, even an electrically powered vessel is an option, saving on noise and fossil fuel for transporting personnel and small equipment. Also small repair work can be done on the CU, so that the number of long supply trips with big ships is substantially reduced. Final calculations are still underway but the reduced environmental impact (less noise, less fuel use and emissions, less risk for introduced chemicals like antifouling, foreign species) can be already clearly foreseen.

Use of renewable energy directly on the platform, e.g. for fish processing, water desalination, cooling and heating as well as and consumption of seafood, also produced there, is a very strong factor in reducing needs for transport of goods, fresh water and fossil energy on the way to creating an autonomous platform in some respects.

3.2 Reduced Wastes Due to Integrated Technology

This study will integrate waste treatment of grey, black and fish processing waste water into one state-of-the-art sewage treatment plant. For Leisure Island desalination, a vacuum system and maximum awareness raising measure will help to reduce water use and related waste water to be treated.

3.3 Reduced Fossil Energy Use Due to Renewable "Ocean" Energy Generated On Site

The advantages of ocean energy are not only decreasing CO2 emission, dependence of fossil energy use, and the global carbon footprint, but also can provide different energy generated ways, including offshore wind, wave energy, tidal and thermal, by creating and designing multifunction electrical platforms. Renewable energy sources from ocean, particularly in the context of TROPOS are solar, wind and OTEC, directly supply to the multi-purposes platforms can significantly reduce the conventional fossil energy use, both in consumption and transport. Besides the emergency situation, energy requirements for these three TROPOS sites are designed to generate "on site". SV and wind turbines are designed for the sites at Gran Canaries and Crete on satellites surrounding the central units. OTEC is the major ocean energy source for the site of Taiwan.

Generally, the greatest potential for OTEC should probably use on small island developing states (SIDS). Although the cost of electricity generated is higher than fossil energy use cost [16]. But, island is the unique geographical environment, which is surrounded by the ocean. In the case of Taiwan, the potential of generated ocean energy is worthy to be developed, offshore platforms could also provide active diversity, including some of ancillary benefits, such as aquaculture, tourism and job opportunity for local residents. The cold water is not only using in the aquaculture, but also cooling greenhouses. In other to keep the temperature of machine operating in, the cold water also can be used to air-conditioning system or some important cooling system, and make sure the OTEC could operate sustainably [17].

3.4 Using Offshore Platform for Monitoring and as Ocean Observatory

Currently under study, the TROPOS EIA monitoring service will also be assessed for enhanced functionality. For example, similar to current developments like the Oceanic Platform of the Canary Islands (PLOCAN), the oceanic infrastructure can be utilised as a permanently manned offshore observatory [15]. Such an observatory can provide useful marine and weather data for several purposes and activities, like shipping, renewable energy resource assessment, oceanographic and environmental data relevant to climate change, water quality, status of biodiversity and ecology [15]. This potential will be considered when designing the monitoring strategy of the TROPOS platforms EIA. The result may contribute to further exemplify the potential and added value of the multiuse offshore platform concept.

IV. CONCLUSION

Given the significant pressure caused by the energy shortage and to achieve sustainable development, exploiting clean energy becomes a critical global objective. This study examines and recognizes the potential environmental effects during both construction and operational phases for generating oceanic energy from three various regions, Liuqiu Island (Taiwan), Gran Canaria (Spain), and Crete (Greece), and combine with multiple purpose functions to increase benefits and reduce impacts. The study will provide the required data to modify the design, and to develop a forecasting and mitigation assessment mechanism for further implementation.

To summarize the environmental aspects of the TROPOS platform design assessed so far, some synergies could be identified, but not yet quantified. I.e. joint waste and waste water treatment between the uses enable potentially negative impacts to balance one another and thus will result in reduction of overall impacts. The joint logistics for erection, supply and maintenance are envisaged to save costs as well as reducing the environmental footprint overall. Use of renewable energy directly on the platform and consumption of seafood, both produced there will also reduce needs for transport logistics and energy.

Floating structures were chosen for our design study as they may be more costly, but are a much easier to build at the shore, can be towed to the location for erection and released for decommissioning. Therefore much less impact on the sea floor can be expected. The potential environmental and socio-economic impacts during the construction and the operational phases are still being examined in detail as identified for the core platform and for modules on marine energy generation, aquaculture production, tourism and other related transport activities.

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