



WP 5: Technical and non-technical challenges, regional and sectoral

Deliverable D5.1

Review of multi-use of space and multi-use platform projects

Status: Final

15/02/2016



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652629

About MARIBE

MARIBE is a Horizon 2020 project that aims to unlock the potential of multi-use of space in the offshore economy (also referred to as Blue Economy). This forms part of the long-term Blue Growth (BG) strategy to support sustainable growth in the marine and maritime sectors as a whole; something which is at the heart of the Integrated Maritime Policy, the EU Innovation Union, and the Europe 2020 strategy for smart, sustainable growth.

Within the Blue Economy, there are new and emerging sectors comprising technologies that are early stage and novel. These are referred to as Blue Growth sectors and they have developed independently for the most part without pursuing cooperation opportunities with other sectors. MARIBE investigates cooperation opportunities (partnerships, joint ventures etc.) for companies within the four key BG sectors in order to develop these companies and their sectors and to promote the multi-use of space in the offshore economy. The sectors are Marine Renewable Energy, Aquaculture, Marine Biotechnology and Seabed Mining. MARIBE links and cross-cuts with the Transatlantic Ocean Research Alliance and the Galway Statement by reviewing the three European basins (Atlantic, Mediterranean, and Baltic) as well as the Caribbean Basin.

Project coordinator



MARIBE project partners



Document Information

Title	Deliverable 5.1. - Review of multi-use of space and multi-use platform projects	
Distribution	Public	
Document Reference	MARIBE D-5.1	
Deliverable Leader	Pedro Díaz-Simal	Cantabria
Contributing Authors	Saúl Torres-Ortega Fernando Del-Jesus Raúl Guanche	Cantabria Cantabria Cantabria

Revision History

Rev.	Date	Description	Prepared by (Name & Org.)	Approved By (Work-Package Leader)	Status (Draft/Final)
01	17/08/2015	First Final Draft	Univ.Cantabria	P.D.	Draft
02	10/09/2015	Revised Final Draft	Univ.Cantabria	P.D.	Draft
03	15/02/2016	Final Publishable	Univ.Cantabria	P.D.	Final

Acknowledgement

The work described in this publication has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652629

Legal Disclaimer

The views expressed, and responsibility for the content of this publication, lie solely with the authors. The European Commission is not liable for any use that may be made of the information contained herein. This work may rely on data from sources external to the MARIBE project Consortium. Members of the Consortium do not accept liability for loss or damage suffered by any third party as a result of errors or inaccuracies in such data. The information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and neither the European Commission nor any member of the MARIBE Consortium is liable for any use that may be made of the information.

Executive Summary

The purpose of task “T5.2: Assess key projects that focus on multi-use of space” is to review and assess four key European projects related to multi-use and multi-platforms. This report presents the results of this task.

Four projects were chosen due to its relevance to BG5: MARINA Platform, H2OCEAN, TROPOS and MERMAID. All of these have some in common: all deal with the idea of the development of marine multi-use platforms.

“Marine Renewable Integrated Application Platform” (MARINA Platform) was a project started in 2010 and finished in June 2014. It was funded by FP7-ENERGY-2009-1 program with more than 8.5 million Euros from European Union for a total budget of about 12.7 million Euros. Seventeen partners were involved in this project led by Spanish “Acciona Energía”, which main objective was to develop new multi-purpose platform designs combining wind and wave energy systems.

H2OCEAN brings together 17 partners from 5 countries around Europe, with some expertise in areas like renewable energy, hydrogen generation, fish farming and maritime transport. Project started on January 2012, expecting to last 3 years. The project was supported by the EU through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme. The unique feature of the H2OCEAN concept, besides the integration of different activities into a shared multi-use platform, lies in the novel approach for the transmission of offshore-generated renewable electrical energy through hydrogen.

TROPOS finished on January 2015, after 3 years of work. The project was also funded through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme, with a 4.8 million Euros contribution. The main objective of the project is to develop a modular floating platform, adapted to deep waters, focusing on Mediterranean, subtropical and tropical regions. The platform to be developed will be composed of a central unit and functional modules, in particular the floater concept (submersible, floating or deep submersible units), that will be adapted to each area where it is implemented. Nevertheless, one conceptual design basis will be developed for all versions of the platform.

MERMAID was the third project funded through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme, involving 29 partners from 13 different countries and led by the Danmarks Tekniske Universitet. The main objective of the project is to answer some questions about the possible uses of multi-purpose platforms, studying aspects like the best practices to develop this kind of projects, the possible effects of large structures on the marine environment, the economic feasibility or the best strategies for the construction and operation of a multi-purpose offshore platform. MERMAID project is still under development.

To achieve the proposed objectives in the task description, two main works were developed.

First, a descriptive review for each of all four projects has been made, listing main facts and data, partners, working structure and main deliverables.

Further than this descriptive task, a second work is presented in this report. For each reviewed project, proposed multi-use platform concepts have been identified and their descriptions are presented in different headlines. For all of them, all available and public information has been resumed, identifying the main issues related to technical, environmental, socioeconomically and financial areas. Following four tables and descriptions should serve as a comprehensive summary of this work.

- The main aim of MARINA Platform project was to combine wind turbines and wave energy converters (WEC). After an important process of review and assessment, three concepts were developed: “STC”, a concept with a spar wind turbine and a torus-shape heaving buoy; “SFC”, a four-column semi-submersible concept with one wind turbine

installed on the centre column with oscillating elliptical flaps between the columns; and “OWC array”, a large floater with Oscillating Water Columns with one wind turbine.

- The concept of H2OCEAN project is to develop a flexible design for a multi-component and multipurpose wind-wave farm based platform, which can be varied to address the requirements of the location and local economics. The project developed a unique conceptual system composed by an array of up to 100 coupled wave and wind energy devices and aquaculture cages.
- The main objective of the Tropos Project is to develop a modular floating platform, adapted to deep waters. Thanks to its different modules, the floating platform system will be able to integrate a wide range of possible sectors. Three concepts were developed in the project: “Green and Blue”, combining aquaculture with wind energy; “Sustainable Service Hub”, a platform focused on transport and energy related needs; and “Leisure Island”, a platform orientated to ocean tourism.
- Finally, the fourth project assessed was MERMAID. In this project, four offshore test study sites with different environmental characteristics have carefully been selected for their specific challenges. The sites, which represent different environmental, social and economic conditions, are located at four different seas: Atlantic Ocean, Mediterranean Sea, North Sea and Baltic Sea.

Contents

WP 5: Technical and non-technical challenges, regional and sectoral	1
Review of multi-use and multi-purpose platform projects	1
Executive Summary	4
Contents	6
1 Introduction.....	7
2 MARINA Platform Project.....	8
2.1 Main Description	8
2.2 Members / Partners.....	8
2.3 Main objectives.....	8
2.4 Project structure	9
2.5 Deliverables summary table	10
2.6 Developed concepts description	10
3 H2OCEAN Project.....	15
3.1 Main Description	15
3.2 Members / Partners.....	15
3.3 Main objectives.....	15
3.4 Project structure	16
3.5 Deliverables summary table.....	17
3.6 Developed concepts description	18
4 TROPOS Project.....	25
4.1 Main Description	25
4.2 Members / Partners.....	25
4.3 Main objectives.....	26
4.4 Project structure	26
4.5 Deliverables summary table	27
4.6 Developed concepts description	28
5 MERMAID Project	34
5.1 Main Description	34
5.2 Members / Partners.....	34
5.3 Main objectives.....	35
5.4 Project structure	35
5.5 Deliverables summary table	36
5.6 Developed concepts description	36
6 Conclusions.....	42
7 References	46

1 Introduction

For the present century, oceans have arisen as the natural and logical expansion area for economic and production activities. The development of technical solutions has become a special issue in order to achieve the implementation of Blue Growth sectors (energy, aquaculture, biotechnology, deep sea mining) initiatives.

To deal with this important challenge, European Union has funded different initiatives launched during last years. Some examples of these initiatives are MARINA Platform, H2OCEAN, TROPOS and MERMAID projects. All of these have some in common: all deal with the idea of the development of marine multi-use platforms.

“Marine Renewable Integrated Application Platform” (MARINA Platform) was a project started in 2010 and finished in June 2014. It was funded by FP7-ENERGY-2009-1 program with more than 8.5 million Euros from European Union for a total budget of about 12.7 million Euros. Seventeen partners were involved in this project leaded by Spanish “Acciona Energía”, which main objective was to develop new multi-purpose platform designs combining wind and wave energy systems.

H2OCEAN brings together 17 partners from 5 countries around Europe, with some expertise in areas like renewable energy, hydrogen generation, fish farming and maritime transport. Project started on January 2012, expecting to last 3 years. The project was supported by the EU through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme. The unique feature of the H2OCEAN concept, besides the integration of different activities into a shared multi-use platform, lies in the novel approach for the transmission of offshore-generated renewable electrical energy through hydrogen.

TROPOS finished on January 2015, after 3 years of work. The project was also funded through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme, with a 4.8 million Euros contribution. The main objective of the project is to develop a modular floating platform, adapted to deep waters, focusing on Mediterranean, subtropical and tropical regions. The platform to be developed will be composed of a central unit and functional modules, in particular the floater concept (submersible, floating or deep submersible units), that will be adapted to each area where it is implemented. Nevertheless, one conceptual design basis will be developed for all versions of the platform.

MERMAID was the third project funded through the FP7 Ocean of Tomorrow, “Multi-use offshore platforms” theme, involving 29 partners from 13 different countries and leaded by the Danmarks Tekniske Universitet. The main objective of the project is to answer some questions about the possible uses of multi-purpose platforms, studying aspects like the best practices to develop this kind of projects, the possible effects of large structures on the marine environment, the economic feasibility or the best strategies for the construction and operation of a multi-purpose offshore platform. MERMAID project is still under development.

Although these projects have been independently developed (except a short development made between a H2OCEAN and TROPOS cooperation), the joint analysis of their final contributions represents an interesting analysis that has been committed to the MARIBE H2020 project.

The purposes of this report are:

- To describe these four projects, their different scopes, technological frameworks and maturity level of the solutions and issues addressed.
- To study and assess the proposed multi-use platform concepts developed in each project.

2 MARINA Platform Project

2.1 Main Description

Title: Marine Renewable Integrated Application Platform

Dates: From 2010-01-01 to 2014-06-30, finished project.

Total Cost: EUR 12 761 220,93

Total EU Contribution: EUR 8 708 660

Call for proposal: FP7-ENERGY-2009-1

2.2 Members / Partners

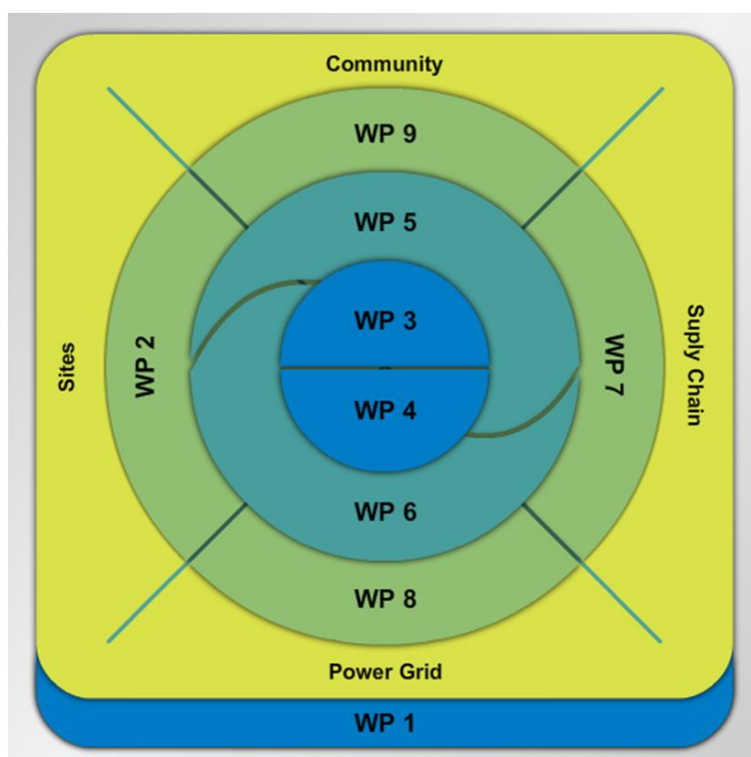
	Name	Country	EU Contribution
Project Leader	ACCIONA ENERGIA S.A.	Spain	EUR 1 034 279
Project Members	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	Norway	EUR 1 351 500
	"UNIVERSITY COLLEGE CORK, NATIONAL UNIVERSITY OF IRELAND, CORK"	Ireland	EUR 789 750
	DONG ENERGY POWER AS*	Denmark	EUR 402 640
	TECHNIP FRANCE SAS	France	EUR 392 500
	ECOLE CENTRALE DE NANTES	France	EUR 750 054
	NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS	Greece	EUR 486 000
	UNIVERSIDADE DO ALGARVE	Portugal	EUR 179 996
	DANMARKS TEKNISKE UNIVERSITET	Denmark	EUR 322 500
	PROGECO S.r.l.	Italy	EUR 298 500
	1-TECH	Belgium	EUR 408 750
	CORROSION & WATER-CONTROL BV	Netherlands	EUR 144 375
	STATOIL PETROLEUM AS	Norway	EUR 369 000
	FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V	Germany	EUR 52 048
	Bureau Veritas Marine Nederland B.V.	Netherlands	EUR 155 100
	FUNDACION TECNALIA RESEARCH & INNOVATION	Spain	EUR 693 329,5
	DONG ENERGY WIND POWER AS	Denmark	

2.3 Main objectives

Research in the MARINA Platform project will establish a set of equitable and transparent criteria for the evaluation of multi-purpose platforms for marine renewable energy (MRE). Using these criteria, the project will produce a novel, whole-system set of design and optimisation tools addressing, inter alia, new platform design, component engineering, risk assessment, spatial planning, platform-related grid

connection concepts, all focused on system integration and reducing costs. These tools will be used, incorporating into the evaluation all, presently known proposed designs including (but not limited to) concepts originated by the project partners, to produce two or three realizations of multi-purpose renewable energy platforms. These will be brought to the level of preliminary engineering designs with estimates for energy output, material sizes and weights, platform dimensions, component specifications and other relevant factors. This will allow the resultant new multi-purpose MRE platform designs, validated by advanced modelling and tank-testing at reduced scale, to be taken to the next stage of development, which is the construction of pilot scale platforms for testing at sea.

2.4 Project structure



	Work Package
WP1	Overall methodology and management
WP2	Site assessment and monitoring
WP3	Concepts identification
WP4	Synthesis – modelling and testing
WP5	Technology risk assessment methodology
WP6	Economic feasibility assessment
WP7	Critical component engineering
WP8	Grid connection and macro-system integration
WP9	Exploitation and dissemination

2.5 Deliverables summary table

Technical	Environmental	Socio-economic	Financial
D2.1: Site Assessment Protocol	D2.6: Multipurpose platforms Environmental monitoring protocol		D3.3: Methodologies for analysis and assessment of wind-ocean combined concepts
D2.3: European decision support tool for the identification of deployment locations for combined platforms			D6.4: Life-cycle cost model, energy and risk model figures for 3 concepts investigated in MARINA project.
D2.5: Near real-time prediction of energy production and weather windows for access			
D3.3: Methodologies for analysis and assessment of wind-ocean combined concepts			
D3.5: Executive recommendations on integrated solutions for ocean energy development			
D4.6: Simplified methods for modelling and analysis of combined concepts for concept assessment and selection			
D5.1: Overall methodology for risk assessments			
D7.6: Application of Risk analysis to critical components			

2.6 Developed concepts description

Concepts description (from FINAL PROJECT REPORT)

In this project, two different approaches to the combination of wind turbines and wave energy converters (WEC) were investigated. First, floating wind turbines with WECs, from two designs were developed. Second, the concept of a large floater full of WECs with some wind turbines on it. Four concepts arose from this investigation of combinations.

- The STC (spar-torus-combination) concept with spar wind turbine and torus-shape heaving buoy. The Spar-torus combination includes a 5-MW wind turbine with a torus heaving buoy that will slide along the spar. It has a permanent ballast at the bottom and active water ballast to optimize wave power absorption and to submerge the STC in survival mode. It uses a WEC Power take of system.

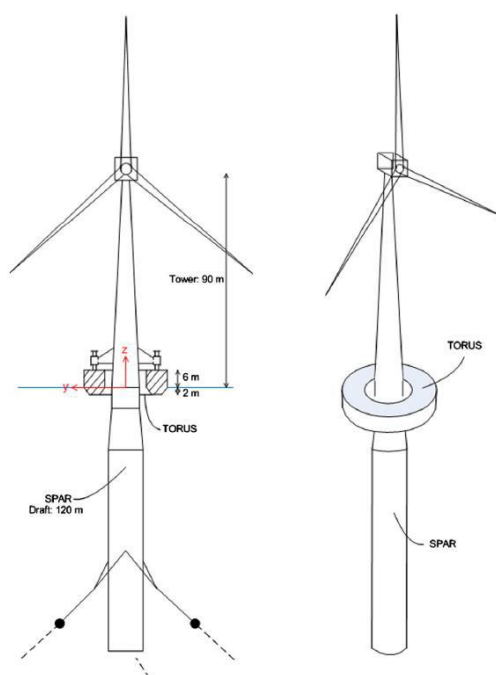


Figure 1: The STC concept (MARINA Platform project).

- The W2Power based concept is a three-column semi-submersible with two wind turbines installed on the two columns and multiple point absorbers between the columns and a simplified Turret mooring system. The WEC's would have their PTO system integrated into the platform for example being placed in the third column. It has a symmetrical shape for wave energy and the turret-type mooring system would allow for weather vaning. The W2Power based system would use a hydraulic PTO for the conversion of wave energy, using seawater pumps and a hydro turbine), but other PTO, or linear generators could also be applied.

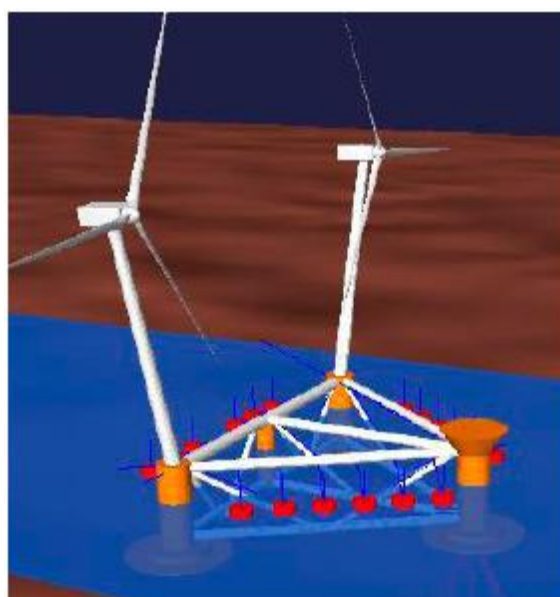


Figure 2: Sketch of the EW2Power based concept (MARINA Platform project).

- The SFC (Semi-submersible Flap Combination) concept is a four-column semi-submersible with one wind turbine installed on the centre column and oscillating elliptical flaps between the columns with a 3 line mooring system. The design studied has a 5 MW wind turbine on the centre column and three rotating flaps (WECs) and is moored with a catenary system.

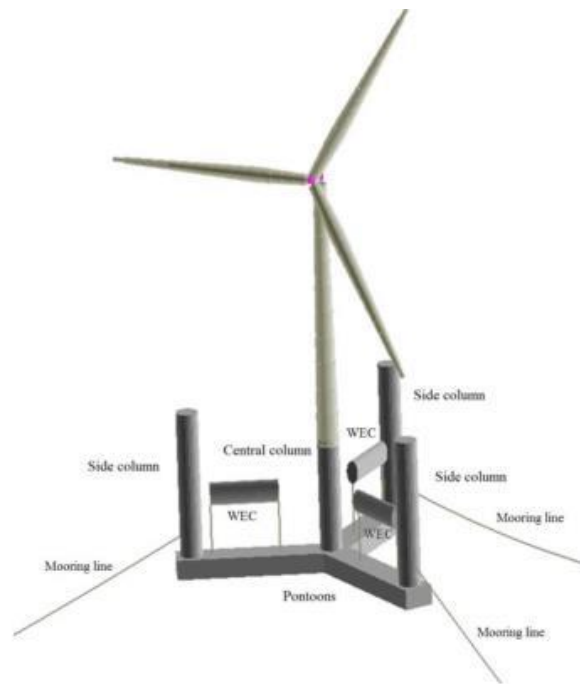


Figure 3: The SFC concept (MARINA Platform project).

- A large floater with OWC (Oscillating Water Columns) array with one wind turbine was also selected. This concept allows the tools to be checked for very large structures that furthermore also are realized as a concrete structure. The delta-shaped large floating platform with OWC wave energy converters and one wind turbine was chosen as a “blue sky” concept for which a lot of detailed data was available and which allowed detecting issues with the numeric modelling tools. (Those indeed came to their limits due to the very large size and the complex geometry of the structure).

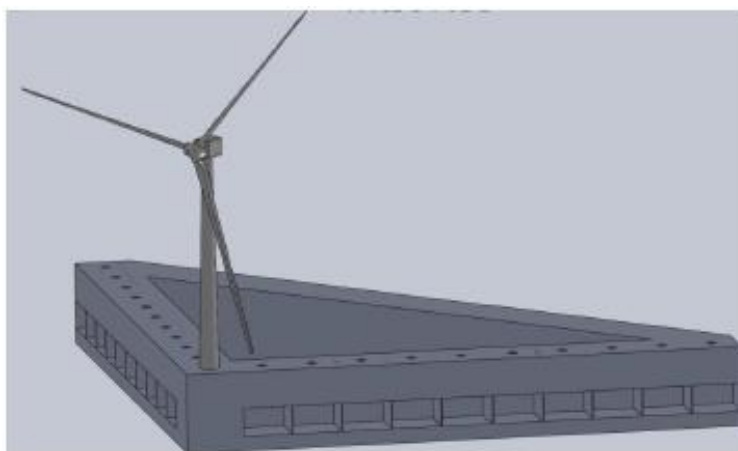


Figure 4: The OWC Array concept (MARINA Platform project).

After the assessment of concepts, three were finally chosen: The STC, the SFC and the OWC array.

After these analysis of the concepts, a screening of the many theoretically conceivable combinations (by simple “traffic-light” diagrams) were developed, in order to study other three specific illustrative case studies, each one combining farms of one of the previous concept with one non-energy economic activity:

- A W2power platform combined with salmon farming, offshore Norway.
- An STC combined with Laminaria spp. algae farming, offshore Iberia.
- A WaveDragon (with wind turbine) with an on-board desalinisation plant, located at a site North West of Sardinia in the Mediterranean Sea.

The results of this analysis were presented in Deliverable 6.2.

Full technical specifications (from FINAL PROJECT REPORT)

In the first combined concepts, the energy production of wave energy converters represents a very small contribution. The synergy of adding the torus WEC to a floating WT was found to increase the wind power production around 6%, with additional wave power production of 5-8% for STC, and to have insignificant change of wind power production for SFC, with additional wave power production of 3-5%. However, the average cost of power for any of the two combined concepts is higher than that of a pure floating wind turbine.

In the OWC Array, a larger floater (with displacement more than 10 times that of the STC and SFC concepts) is needed to accommodate many WECs – which result in a wave power production comparable to that of the wind turbines. However, a larger floater also leads to a higher cost of energy.

Both the numerical and experimental studies have shown that the STC would have much less motions if the torus is fully submerged. In the case of SFC, the flaps are designed to be fully submerged in both operational and survival conditions and the performance of the SFC in extreme conditions are much better. The experimental study of the OWC Array also suggests that the air turbines need to be protected by closing the OWC air chamber to avoid the wave impact force on the air turbines.

Economic Results (from FINAL PROJECT REPORT)

From the financial perspective, some results were obtained and must be highlighted. The OWC Array concept energy balance is almost 50% wind and 50% wave contribution. STC and SFC show 3 to 6% contribution from WECs (and the STC some added production from wind due to the presence of the torus WEC).

The OWC array presents higher risk and more maintenance but redundancy in design to optimize power production, while STC and SFC increase risk and maintenance for a single turbine without any major additional production.

OWC array concept also has high platform CAPEX and OPEX costs, resulting in a high cost of energy. WEC contributes additional CAPEX and OPEX costs compared to a single turbine concept with relatively minor contributions to total energy production.

It is important to note that from this evaluation, all concepts studied resulted in a high CoE and are not currently cost-effective as combined multi-purpose platforms. Concepts would require further technological advancement and a refined evaluation to prove their effectiveness.

Receptor	W2power platform combined with salmon farming	STC combined with Laminaria spp. algae farming	WaveDragon (with wind turbine) with an on-board desalinisation plant
Cost of Energy	0.130 €/kWh	0.160 €/kWh	0.163 €/kWh

3 H2OCEAN Project

3.1 Main Description

Title: Development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy

Dates: From 2012-02-01 to 2014-12-31, finished project.

Total Cost: EUR 6 454 782,73

Total EU Contribution: EUR 4 525 934

Call for proposal: FP7-OCEAN-2011

3.2 Members / Partners

	Name	Country	EU Contribution
Project Leader	AWS TRUEPOWER SL	Spain	EUR 526 101
Project Members	VIRTUALPIE LTD	United Kingdom	EUR 620 956
	DEXA Wave Energy ApS	Denmark	
	UNIVERSIDAD DE VALLADOLID	Spain	EUR 175 136
	FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V	Germany	EUR 181 331
	CHLAMYS S.R.L	Italy	EUR 201 879
	VIKING FISH FARMS LIMITED	United Kingdom	EUR 287 311
	INSTITUT FÜR SEEVERKEHRSWIRTSCHAFT UND LOGISTIK	Germany	EUR 186 885
	DANMARKS TEKNISKE UNIVERSITET	Denmark	EUR 461 894
	SETA SOCIEDAD ESPANOLA DE TRATAMIENTO DE AGUA SL	Spain	EUR 111 510
	FUSION MARINE LIMITED	United Kingdom	EUR 139 520
	TREELOGIC TELEMATICA Y LOGICA RACIONAL PARA LA EMPRESA EUROPEA SL	Spain	EUR 93 240
	D'APPOLONIA SPA	Italy	EUR 363 836
	UNIVERSIDAD DE OVIEDO	Spain	EUR 79 966
	IT Power Ltd	United Kingdom	EUR 359 044
	CRANFIELD UNIVERSITY	United Kingdom	EUR 416 845
	SUSTAINABLE TECHNOLOGIES SL	Spain	EUR 139 600
	FLOATING POWER PLANT A/S	Denmark	EUR 180 880

3.3 Main objectives

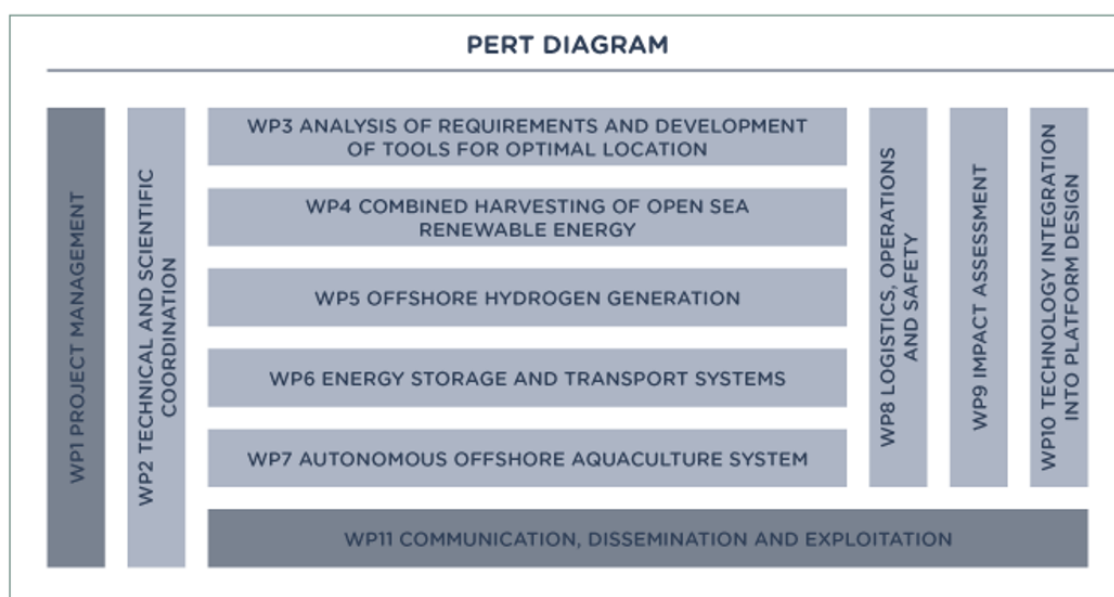
The concept of the project is to develop a flexible design for a multi-component and multipurpose wind-wave farm based platform, which can be varied to address the requirements of the location and local economics. The system will comprise hydrogen generation in open-sea from renewable sources (wave and wind), a facility for fresh water production and multiple uses of the electrical energy produced in open-sea: support for aquaculture, communications, etc...

The sustainable exploitation of ocean resources is seen as a crucial source of renewable energy, food and water security. In the future, offshore platforms that can combine many functions within the same infrastructure will offer significant benefits in terms of economics, optimising spatial planning and minimising the impact on the environment.

The unique feature of the H2OCEAN concept, besides the integration of different activities into a shared multi –use platform, lies in the novel approach for the transmission of offshore-generated renewable electrical energy through hydrogen. This concept allows effective transport and storage of the energy, decoupling energy production and consumption, thus avoiding the grid imbalance problem inherent in current offshore renewable energy systems. Additionally, this concept also eliminates the need for a cable transmission system which takes up a significant investment share for offshore energy generation infrastructures, and so increasing the price of energy.

3.4 Project structure

The H2Ocean work plan is structured around three interdependent and multidisciplinary components: the design of the platform concept, the development of technical solutions and the assessment of impact at different levels. The work structure has been designed to ensure the appropriate involvement and contribution from all Partners, the accurate integration of the different activities and the assessment of the platform as a whole.



	Work Package
WP1	Project Management
WP2	Technical and Scientific Coordination
WP3	Analysis of requirements and development of tools for optimal location
WP4	Combined harvesting of open sea renewable energy
WP5	Offshore hydrogen generation
WP6	Energy storage and transport systems
WP7	Autonomous offshore aquaculture system
WP8	Logistics, operations and safety

WP9	Impact assessment
WP10	Technology integration into platform design
WP11	Communication, dissemination and exploitation

3.5 Deliverables summary table

Technical	Environmental	Socio-economic	Financial
D3.1 Report on location requirements of platform		D8.1 Report assessing relevant legislation at 3 sites and design standards	D7.2 A full economic appraisal of the aquaculture system
D3.2 Database of resources conditions	D8.5 Decommissioning methodology and cost report		D8.5 Decommissioning methodology and cost report
D3.3 Software tool for assessment of location	D9.1 Environmental impact scoping study		D9.7 Alternative uses assessment
D4.1 Report assessment of wind turbine types	D9.3 Environmental recommendations for installation of platforms, discharge pipelines and moorings		D9.8 Report on economic viability
D4.2 Mechanical design of VAWT and power take off system	D9.4 Report on concentration of wastes and their dilution and dispersion		D10.4 Full capital, maintenance and cost of ownership evaluation
D4.3 Recommendations for installation requirements on platform	D9.5 Analysis of the Reduced Environmental Impact of the Proposed Multi-trophic Integrated Aquaculture System		D10.5 Project risk register
D4.4 Seakeeper calculations report	D9.6 Environmental impact assessment		
D5.1 Report on expected marinised hydrogen generator performance	D9.9 LCA report		
D5.2 Report on desalination unit performance	D9.10 Online collaborative Life Cycle Analysis platform		
D5.3 Report on advanced control system performance			
D6.1 Design outline for gas compression, storage and fluid handling systems			
D6.2 Report identifying risk analysis requirements for integration of packages into service module			
D6.3 Safety systems and procedures compilation including emergency response			

Technical	Environmental	Socio-economic	Financial
D7.1 A full functional specification and for the integrated aquaculture system			
D7.3 An operating manual for the multi-trophic aquaculture system			
D8.2 Defined deployment and connection methodologies			
D8.3 Logistics report covering all inputs and outputs to platform			
D8.4 Conceptual maintenance manual			
D8.6 Report on security risks, hardware/software requirements and procedures for risk mitigation			
D8.7 Software tool to manage security risks in flammable gases			
D9.2 Meso and microscale hydrodynamic models of 3 locations			
D10.1 Design definition including interfaces and functional requirements			
D10.2 Definition of process module design			
D10.3 Integrated analysis of hydrogen and power generation capabilities			

3.6 Developed concepts description

The H2Ocean project aimed to offer a conceptual proof of design for an innovative multi-use open-sea platform. Integrated wind and wave energy generators harvest renewable energy from ocean resources and use this electrical power for multiple applications on-site, including the electrolysis of seawater into hydrogen that can be stored and shipped to shore as a green energy carrier. This capability is coupled with a multi-trophic aquaculture farm, freshwater production and oxygen production.

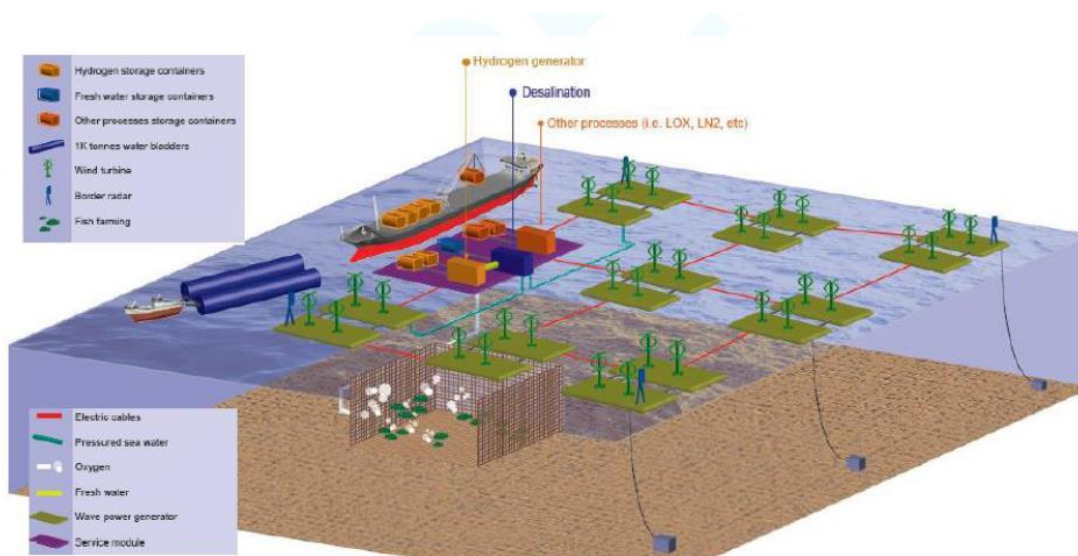


Figure 1. H2OCEAN concept ©Copyright 2011 by VirtualPIE Limited

The H2Ocean platform aims to produce fish, shellfish and hydrogen. Drinkable water and oxygen have been considered as by-product. (*Deliverable 9.9*)

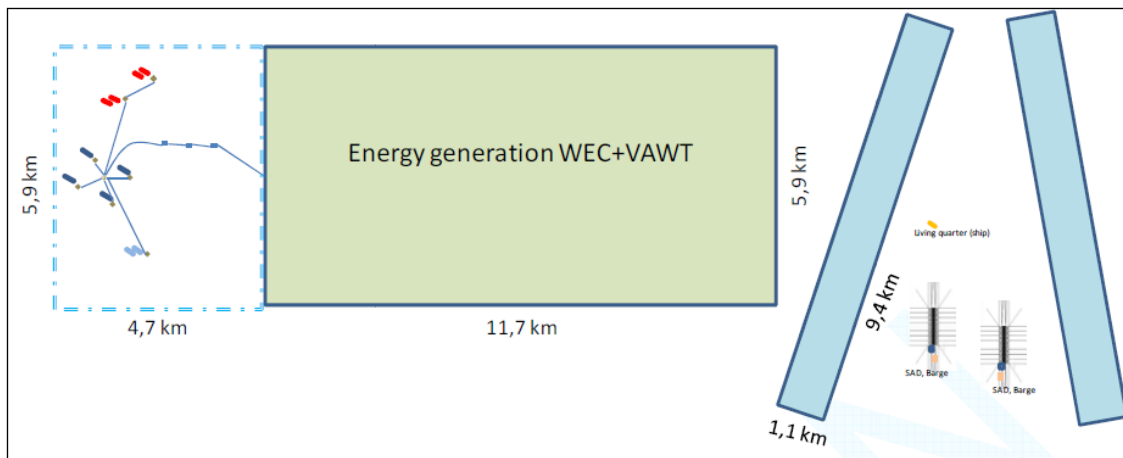
An “open sea” installation has been designed, involving a fleet of about 95 WEC ships; one large FPSO for electrolysis; two large compressed hydrogen and oxygen storage tankers for temporary storage; plus three large compressed hydrogen and oxygen carriers, moving up and down the port installation; one ship, hosting sea water demineralization and drinkable water production plant; and the EMCS (Energy Management Control System) hardware.

In addition, 34 large cages for aquaculture have been considered plus the relevant ships, barges and workboats. A Floating Anaerobic Digester (FAD) completes the installation allowing an offshore waste treatment combined with electric production. The biogas generated by the FAD feeds an Internal Combustion Engine (ICE) that produces electric power. (*Deliverable 10.3*)

Although three different locations have been analysed in different deliverables (Scotland, Portugal and Sardinia), one is finally chosen and its main key performance indicators that describe the sea deployment installation are:

- Sea deployment 50km far from the Portuguese coast.
- Hydrogen production: up to 74.000 Nm³/h (delivered at 200 barg, gaseous).
- Oxygen production: up to 37.000 Nm³/h (delivered at 200 barg, gaseous).
- Fish from aquaculture: 10.000 tonnes/year.
- Drinking water (from RO): 20 m³/h
- Solid waste treatment: up to 4.200 kg/day.

Full technical specifications (from deliverables D9.9 and D10.3)



The conceptual proposed design has 11 different units.

U1 – Energy Station

The energy station is composed by 67 Hybrid Systems (VAWT and WEC) and 28 WEC Systems. Three types of WEC Systems are inserted in this unit, in particular 13 are “WEC only”, 5 WECs host radar and anemometric instruments and 10 WECs are coupled with an innovative aquaculture system.

The electrical power supplied by the hybrid systems is 400 MW (320 MW by VAWTs and 86 MW by WEC), and by the WEC systems 35,84 MW.

U2 – Water Pre-treatment

In the pre-treatment process, the water collected from sea is managed to operate further with the reverse osmosis plant. This step is crucial, since it facilitates and optimizes the following process steps.

U3 – Desalination

The water from the pre-treatment unit is collected in a storage tank and then treated with sodium metabisulphite and antiscalant.

U4 – Drinking Water Generation

Part of water collected in the intermediate storage tank, after the first reverse osmosis step, is sent to a drinking water station. Feeding is supplied by 2 water pumps, with capacity of 20 m³/h at 3,5 bar of pressure each. Water fills an accumulation tank with capacity of 80 m³, equipped with re-mineralization filter, chlorine dosage, CO₂ dosage system and recycling pump.

U5 – DEMI Water Production

The other part of water collected in the intermediate storage tank is sent to the second reverse osmosis stage, after being subjected to an antiscalant dosage and passing through the cartridge filters. This is made by semi-permeate membranes wound in a spiral (to reduce the tendency of fouling and to get a more flexible pre-treatment) and with flow around 30-35 l/m²h. Osmosis of water produced will accumulate in a PRFV (fiberglass-reinforced polyester resin) tank to supply water for the hydrogen generation system.

U6 – Hydrogen Generation

The electrolysis is the process of splitting the water molecule into hydrogen and oxygen using electricity. In H2Ocean project, both oxygen and hydrogen are collected to be sold separately.

Water coming from DEMI station feeds the electrolyzer group. The electrical power required from the station needs to be balanced in order to flat the fluctuations of wind energy.

U7 – Oxygen Storage

The oxygen produced in the U6 is firstly compressed through compressors at 5 barg and then it is stored in a spherical buffer storage tank of 1383 m³ capacity. Oxygen can pass from electrolyser ship to oxygen temporary storage ship.

U8 – Compressed Hydrogen Storage – Fuel Station – Ship

Gaseous hydrogen can be stored at high pressure to reduce its volume and the relative tank weight. Hydrogen from electrolyzers feeds a preliminary buffer storage with the aim to smooth the pressure and flow variations. The buffer storage is composed by a spherical tank of 2681 m³, and allows a safety stock of 2 minutes between electrolyzers and compressors, in order to preserve both from a temporary shut-down of one of them. Hydrogen can pass from electrolyzer ship to hydrogen temporary storage ship. Gaseous hydrogen is the pumped from the storage tank to the cargo ship though the fuel station.

U9 – Fish farm – Fish farm utilities – Ship

This unit can produce Sea Bass, Sea Bream and Salmon. The fish feed is fed through a feeding system in the net cages. The waste (fish faeces and non-eaten feed) produced from the fishes is dispersed.

U10 – ICE power Generation

Algal mass and sea water are collected by feed pumps into a shredder. The generated mixture is sent to an anaerobic reactor. The biomass contained in the reactor destroys the organic matter producing biogas. The reactor is floating horizontally and the gas is collected from the top of the reactor. Biogas is purified in a system that eliminates H₂ and CO₂ and feeds an internal combustion engine (ICE) with the resulting CH₄. Such engine is connected with an alternator that generates electricity to help the full H2Ocean system internal requirements.

U11 – EMCS

EMCS (Energy Management and Control System) is a system that combines supervisory control and data acquisition with power management system capabilities in a single platform to allow facilities to monitor plant performance, safety, energy usage and power quality.

EMCS receives energy input from vertical axis wind turbines, wave energy converters and internal combustion engine, and distributes it through the main grid lines. The system is able to analyse power quality and reliability to manage alarms and critical situations to reveal waste energy or unused capacity to improve efficiencies and to balance source fluctuations.

Socio-Economic Results (from deliverables D9.8 and D10.3)

	Portuguese Coast
Market size	-
Jobs (FTE)	183
GVA	WECs and VAWTs GVA - €69mill Aquaculture €12.6mill Drinking water GVA €40,000 / year
Funding (CAPEX)	There was no assumption for public funding or subsidy in the economic calculations.
Funding (OPEX)	
Impact	High
Marine spatial	150 km ²
Ports	Yes
Infrastructure	Yes
Grid	No

Environmental (from deliverable D9.6)

The Life cycle analysis reported in deliverable 9.9 of this project shows that the material and energy requirements for the construction phase produce a carbon debt that is never recovered throughout the history of the installation. For this reason, careful consideration must be given to the validity of this concept. It is possible that the use of the ocean for the purposes designed in H2Ocean may be worth the carbon cost of the installation, but at this stage it is not possible to envisage a situation where this concept provides an environmentally sound solution.

The assessment of the anchoring requirements suggests more than 1000 structures and interactions with the sea bed would be required. Combined with the requirements of the installation vessels for anchoring and site work, the construction of this proposed installation will have a deep and lasting effect upon the benthic ecosystem. Highly detailed study would be required to assess the long term effect of these interactions.

The number of floating structures envisaged within this concept will require constant maintenance and operational input. For this reason, the original concept of an unmanned autonomous structure seems impossible to achieve. Aquaculture requires daily human input, whilst electrolyzers, WECs, VAWTs and FPSO's will all need maintenance and monitoring input on a basis that will require personnel to be on site on an almost daily basis. This requirement for personnel must be addressed by either a large amount of shore to site traffic, or by the housing of the key personnel in an accommodation vessel on site. The damage to the ecosystem produced by the traffic is currently only an estimate; however it will increase noise and ecosystem damage (through mooring etc.)

The key structures of the installation will produce both noise and electromagnetic interference with marine species, as examined in Deliverable 9.3. A great amount of research has been concluded upon the interaction of various marine species with noise and electromagnetic interference and it is clear that the H2Ocean installation would produce environmentally sensitive levels of both forms of interference. This would have potentially harmful effects upon several classes of marine biota, and must also be considered carefully and subjected to further study.

The marine environment is harsh and gives rise to a number of maintenance requirements to provide structures with protection and damage limitation strategies. These range from simple painting through to the applications of potentially harmful anti fouling paints and coatings. The impact over the 25 years of these materials is currently an unknown factor. All the materials studied are in current usage, but no current system uses them in the quantities and frequency that would be required by the H2Ocean installation. The impact of these actions and materials would require intense study to understand the interaction of the oceanic species with the operational requirements of the installation.

The outputs of the system have been studied and shown to have limited effect in a short term vision. These include the brine from the reverse osmosis desalination plant, uneaten fish food, fish excreta, potential pollutant outputs from the personnel units and the heat produced by the operational plant. Whilst it appears that the effects of these outputs would be localised and minimal, the expected design life is 25 years. Linked to the other damaging effects of the system outlined previously, it is likely that this installation would effect a change in biomass which may be further affected by the nutrient and pollutant outputs of the system

From the work carried out by the partners in the H2Ocean consortium, it is clear that the impact of this proposed installation would be highly significant. Extremely close attention would need to be paid to the selection of the site for such a project to minimise the environmental risk. Consideration should be given to all levels of the ecosystem from seabirds to benthic biota. The assessment of the environmental impact to any section of the marine biota should then be treated as a trophic cascade and modelled against population dynamics to assess the final impact of this proposal.

Receptor	Portuguese Coast
Air Quality	Low
Water Quality	Medium
Water Temperature	Low
Sediment Dynamics	High
Sediment Quality	Medium
Landscape/Seascape	Low
Microorganisms	Medium
Benthic Fauna & Flora	High
Pelagic Fauna & Flora	High
Fish and Turtles	High
Birds & Bats	Medium
Marine Mammals	Medium
Humans	Medium

Economic Results (from deliverable D9.8)

Total investment cost of all groups ("U1" to "U10") can be estimated (including necessary replacement of objects after lifetime less than 25 years) by 9.5 billion € within 25 years. For unrecognized residual quantities and missing value sizes in the equipment list, a surcharge of 3% has been used on top to quantify the total investment costs over 25 years of all necessary object of the H2Ocean project. The investment costs are finally estimated at 12.2 billion € for 25 years.

Mill €	Total Investment Cost	Total Investment Cost (with replacement)
U1	7,434.900	9,520.909
U2	151.068	152.136
U3	0.488	0.977
U4	0.742	0.894
U5	0.093	0.187
U6	748.000	748.000
U7	406.494	406.494
U8	560.053	560.053
U9	288.725	511.195
U10	1.654	1.654

All annual operational costs together are shown in a summary in the following table. Total operating cost are estimated with a value of 11.4 billion € during the operating time of 25 years of the H2Ocean project.

Year	O+M Personnel	Maintenance	Insurance	Fish feed*	P+M transport	Total mill €
1	14.38	357.1	66.7	5.9	3.03	441.7
2	14.38	357.1	67.3	20.2	3.03	456.6
3-25	14.38	357.1	67.6	21.8	3.03	458.5
Total (25 years)	359.5	8,792.3	1,689.4	526.9	75.8	11,443.9

The benefits of the H2Ocean project are determined by the deliverable production volumes of hydrogen, oxygen, drinkable water and the aquaculture products and the adopted market prices for all these products, shown above. The merge of this data are shown in the following benefit calculation which is an estimation based on constant prices over the duration period of the H2Ocean project of 25 years.

Products	Annual quantity	Physical unit Products	Price per unit (€)	Annual benefits in million €	Total benefits in (25 years) in million €
<i>Hydrogen (delivered)</i>	16,463.531	tons	1,617	26.62	665.5
<i>Oxygen (delivered)</i>	411,588.266	tons	80.85	0.67	16.6
<i>Drinkable water (delivered)</i>	49,837	m ³	2.00	0.10	2.5
<i>Total</i>	-	-	-	27.39	684.7

The benefits of the aquaculture production in the H2Ocean project are shown in detail in the H2Ocean Deliverable 7.2. Only a draft overview of expected benefits of aquaculture production for the Atlantic region near Portugal is given in the following.

The benefits of the aquaculture production within the H2Ocean project are determined by the deliverable production volumes of the aquaculture products and the adopted market prices for all these products. The merge of this data are shown in the following benefit calculation for aquaculture (in Portugal) which is an estimation (based on constant prices) over the duration period of the H2Ocean project of 25 years.

Products	Total quantity (25 years)	Physical unit of products	Price per unit (€)	Total benefits in (25 years) in million €
<i>Sea bass</i>	245,072	Tons	5,300	1,298.9
<i>Mussels</i>	10,336	Tons	1,020	10.5
<i>Oysters</i>	604.9	Tons	10,110	6.1
<i>Sea urchin</i>	551.3	Tons	10,500	5.8
<i>Total</i>	-	-	-	1,321.3

The total benefits (revenues) of all H2Ocean activities can be estimated with 2.0 billion € (based on constant prices) over the duration period of the H2Ocean project of 25 years.

The net value of the H2Ocean project is with its three components of the total investment costs of 12.2 billion € and all the operational costs of 11.4 billion € and the expected benefits of 2.0 billion € with - 21.6 billion € negative.

Depending on the permanent loss in all periods a NPV (net present value) as well as an IRR (Internal rate of return) cannot be calculated.

This huge loss of -21.6 billion € depends on the total autonomous strategy of the production of energy, hydrogen, oxygen, water and last but not least aquaculture products. In a set of alternative scenarios of hydrogen as well as oxygen productions taking place completely not fully offshore may lead to more economic feasible results as currently expected.

Future Business plans (from deliverable D10.3)

The realisation of this sea deployment seems not imminent, many parts have a low TRL and some systems have never been assembled in such configuration.

The installation is huge and involves a great number of vessels and the investment cost for such and installation can reach 8 billion euro. Furthermore, in order to build the whole installation many years can be necessary and an important number of yard ships to build 95 WEC and 4 Floating Process units, 2 gas storage ships and 3 carriers need to be involved. Sea deployment cannot be unmanned due to maintenance and security reasons.

4 TROPOS Project

4.1 Main Description

Title: Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources

Dates: From 2012-02-01 to 2015-01-31, finished project

Total Cost: EUR 6 726 623,82

Total EU Contribution: EUR 4 877 911

Call for proposal: FP7-OCEAN-2011

4.2 Members / Partners

	Name	Country	EU Contribution
Project Leader	CONSORCIO PARA EL DISEÑO, CONSTRUCCIÓN, EQUIPAMIENTO Y EXPLOTACIÓN DE LA PLATAFORMA OCEÁNICA DE CANARIAS	Spain	EUR 643 380
Project Members	THE UNIVERSITY OF EDINBURGH	United Kingdom	EUR 403 575,03
	WAVEC/OFFSHORE RENEWABLES - CENTRO DE ENERGÍA OFFSHORE ASOCIACIÓN	Portugal	EUR 379 280
	UNIVERSITÄT BREMEN	Germany	EUR 227 520
	UNIVERSIDAD POLITÉCNICA DE MADRID	Spain	EUR 519 596,56
	FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V	Germany	EUR 344 101,88
	TOULON VAR TECHNOLOGIES	France	EUR 147 827
	NORSK INSTITUTT FOR VANNFORSKNING	Norway	EUR 340 751,97
	DANMARKS TEKNISKE UNIVERSITET	Denmark	EUR 326 485,88
	ABENGOA SEAPOWER SA	Spain	EUR 66 942,12
	PHYTOLUTIONS GMBH	Germany	EUR 294 169,75
	HELLENIC CENTRE FOR MARINE RESEARCH	Greece	EUR 166 702,38
	NATIONAL SUN YAT-SEN UNIVERSITY	Taiwan	
	ADVANCE INTELLIGENT DEVELOPMENTS S.L.	Spain	EUR 259 170
	BUREAU VERITAS-REGISTRE INTERNATIONAL DE CLASSIFICATION DE NAVIRES ET D'AÉRONEFS SA	France	EUR 191 186
	ÉCOLE CENTRALE DE NANTES	France	EUR 195 603,75
	EnerOcean S.L.	Spain	EUR 202 715

	Name	Country	EU Contribution
	UNIVERSITY OF STRATHCLYDE	United Kingdom	EUR 74 712
	ACCIONA INFRAESTRUCTURAS S.A.	Spain	EUR 31 500
	DCNS SA	France	EUR 24 500
	INSTALACIONES INABENSA SA	Spain	EUR 38 191,68

4.3 Main objectives

The main objective of the Tropos Project is to develop a modular floating platform, adapted to deep waters. The Tropos Project will focus on Mediterranean, subtropical and tropical regions, in particular on the EU Outer-Most Regions (OMRs), composed by the Azores, the Canary Islands, Guadeloupe, Guiana, Madeira, Martinique and Reunion.

Thanks to its different modules, the floating platform system will be able to integrate a wide range of possible sectors: ocean renewable energy and food (aquaculture) resources will be exploited, the platform will serve as a hub for maritime transport and innovations in the leisure sector, and will also fulfil functions for oceanic observation activities.

The platform will be composed of a central unit and functional modules, in particular the floater concept (submersible, floating or deep submersible units), that will be adapted to each area where it is implemented. Nevertheless, one conceptual design basis will be developed for all versions of the platform.

The Tropos Project will tackle a few issues in each of the three regions studied:

- To determine, based on both numerical and physical modelling, the optimal locations for multi-use offshore platforms in Mediterranean, sub-tropical and tropical latitudes;
- To explore the relations and integration into the platform on a broad range of sectors including energy, aquaculture and related maritime transport;
- To research the relations between oceanic activities, including wind energy, aquaculture, transport solutions for shipping, and other additional services;
- To develop novel, cost-efficient, floating and modular multi-use platform designs, that enable optimal coupling of the various services and activities;
- To study the logistical requirements of the novel multi-use platform;
- To assess the economic feasibility and viability of the platform;
- To develop a comprehensive environmental impact methodology and assessment;
- To configure at least three complete solutions, for the Mediterranean, Sub-tropical and tropical areas.

4.4 Project structure

	Work Package
WP1	Project Management
WP2	Geographic and Module Benchmarking and Decision Methodology
WP3	Conceptual Design of Platform Components and Integration
WP4	Engineering Specification for Chosen Platform Designs
WP5	Strategy: Economics, Infrastructure and Logistics

WP6	Environmental and Socio-Economic Impact, Legal Issues
WP7	Communication, Dissemination and Technology Transfer
WP8	Scientific and Technical Coordination

4.5 Deliverables summary table

Technical	Environmental	Socio-economic	Financial
D2.1 Report on methodology, evaluation matrix and overall constraints		D5.2 An assessment of the Economic impact, on local and regional economies, of the large scale deployment	D5.3 Technology pricing of multi-use marine platforms
D2.2 Fact sheets about potential components	D6.1 Report describing a framework for the environmental and socio-economic study		
D2.3 Sample locations and setups for further design	D6.2 Report on Environmental Impact Assessment and Mitigation Strategies	D6.4 A framework for describing the social impacts with concrete examples that apply for the Canary Islands	
D2.4 GIS tool	D6.3 Report on recommended monitoring strategies		
D3.2 Technical concept dossier for the central unit	D6.5 Comparative statement/assessment for selected deployment locations including comparison to non-multiuse platforms		
D.3.3 Technical dossier for each of the established modules including key features	D6.6 A framework for describing the social impact with concrete examples that apply for Taiwan		
D.3.4 Technical concept dossier for the satellite unit			D7.1 Stakeholders Network Constitution and Operation Report
D3.5 Integrated Concept Offshore Platform System Design			
D4.1 Report on hydrodynamic simulations of platform models and model validation			
D4.2 Final Design Specification of base platform			
D4.3 Complete Design Specification of 3 reference TROPOS systems			
D4.4 Third Party Validation Report for 3 reference TROPOS Systems			
D4.5 Aquaculture Pilot Scale			
D5.1 Landscaping & Methodology for Overall Deployment Strategy			

Technical	Environmental	Socio-economic	Financial
D5.4 Life cycle assessment of multi-use marine platforms			
D5.5 Supporting infrastructure, supply chains and logistics for the deployment of multi-use marine platforms			
D5.6 Viability Strategy for the Deployment and Exploitation of Multi-use Marine Platforms			
D5.7 Technical Strategy for the deployment and exploitation of multi-use marine platforms			
D5.8 Overall Deployment Strategy for the deployment and exploitation of multi-use marine platforms			

4.6 Developed concepts description

Concepts description (from Project Final report)

Official final solutions

Leisure Island (Gran Canaria). This scenario involves a multitude of leisure facilities for tourist and local residents, including the full range of hotel services. Energy demand of the platform is partially met by a photovoltaic (PV) plant; as backup additional electricity might be provided via an HVAC cable from land. This scenario does not involve satellites (other minor structures), but several modules integrated into the central unit platform: a visitor's centre, food and beverages, accommodation, monitoring, energy storage, and marina. Visitors as well as staff are transported via daily shuttle transfers between Gran Canaria and the platform. Visitors can also approach the platform with private yachts by entering the marina.

Green and Blue (Crete). In this scenario fish and microalgae aquaculture are combined with a floating offshore wind farm. The aquaculture units are part of 30 floating satellite units, each consisting of one fish cage and one algae floater. Each satellite unit is equipped with two 2-3.3 MW wind turbines; some also include small photovoltaic (PV) units. Aquaculture units, wind turbines and PV units are controlled and monitored online from the central unit. The central unit includes a workshop, a fish processing unit, an algae bio-refinery, storage facilities, accommodation for staff, and substation for the electrical connection between wind turbines, central unit and onshore grid.

Sustainable Services Hub (Dogger Bank). This scenario focuses on transport and energy related needs of the offshore renewable energy sector and serves as an offshore wind hub for a wind farm assembled around the platform. The service hub consists of 4 modules: a quick reaction maintenance base, a substation, and an accommodation module for service staff and a helipad. The electrical energy generated by the wind turbines directly supplies the electrical power consumers of the entire facility. Due to the accommodation infrastructure for the workforces, this concept has capacity to host a large number of people. The infrastructure is also available for external visits. The waste heat of the electricity generation is used for heating purposes.

Future scenarios

Green and Blue (Taiwan). In this scenario fish and macroalgae aquaculture are combined with a floating Ocean Thermal Energy Conversion (OTEC) for energy supply. The 8 MW OTEC plant, operated as a closed cycle system, uses the ocean's naturally available vertical temperature gradient to produce electrical energy. Beside the type of renewable energy source, another difference to the Green and Blue scenario in Crete is that the Liutiu Island scenario platform also includes some (limited) leisure facilities, such as cafes, bars, restaurants and observatories for the public, and provides accommodation for visitors. Fish and macroalgae aquaculture units are located on 30 floating satellite

constructions. The macroalgae floaters are located downstream of the fish cages, allowing for the recycling of nutrients from fish excrement by the algae.

Offshore Container Terminal (Gulf of Panama). The principal services which are provided by this platform concept include the provision of means and the organisation for container exchange, container loading/unloading and storage, receiving and shipping of containers, and staff accommodation.

Full technical specifications (from D4.3)

Green and Blue Concept (Crete) (focused on fish and algae aquaculture and wind energy generation)

The concept is composed by three different parts: i) satellite units are composed of two wind turbines, an algae farm and cages for fish aquaculture; ii) the central unit, where focused on the main services; and iii) the floating module for containers traffic.

The central unit has two different parts, the inner part and the hexagonal part around the column. The inner part includes: storage and consumable tanks, pumps room, Gen.Sets and electric control, workshop and maintenance, ventilation and vapour services, accommodation, platform control and communications. The hexagonal part includes: wind farm transformer, fish processing plant, bio-reactor, storage and cranes for TEUs, small OSV berthing, accommodation for workers and helideck.

The floating module has storage capacity for up to 232 TEUs and/or turbine parts, in order to operate this it has a crane. It has been designed in rectangular shape with 160m of length and 30m of width. The pier of this module can provide berthing for a container ship with up to 160 meters of length. There is a berthing for smaller ships on the inner pier fitted for large OSVs.

The satellite unit is designed with a triple purpose: wind energy generation including two wind turbines attached to a floating triangular shaped structure specially fitted for it, with an aquaculture cage for fish in the centre of the triangular shape structure, and a floating algae farm also attached to it.

Sustainable Service Hub Concept

The sustainable service hub is designed to support an offshore wind farm, including installation and maintenance and it is composed by several parts.

The central unit is divided in two parts. The first one, the inner part includes the storage and consumable tanks, the pumps room, Gen. Sets, electric control, workshop and maintenance, ventilation and vapour services, accommodation, platform control and communications. The hexagonal shaped includes the 500MW transformer, the storage and cranes for TEUs, the small OSV berthing, the living area for SSH workers, the accommodation for SSH workers and the helideck.

The floating module has storage capacity for 112 TEUs and/or turbine parts, in order to operate this in has traveling rail crane. There are two workshops located at the outermost ends of the module, with each one having an overhead crane with capacity for 50 t, offices, presentation rooms and storehouses. The pier of this module can provide berthing for a barge or jack-up up to 85 meters of length. In the inner side of the module there is a spot available for OSV berthing. There are two workshops prepared to support the wind farm, with a rolling type hatch cover at the top which is the opening to introduce the turbine parts that are going to be repaired or inspected.

Leisure Island Concept

The leisure island concept is designed to be a floating hotel, oriented to the tourism sector, including hotel, restaurants, bar and shops. It includes also berthing for private yachts and big cruiser ships.

The central unit is divided into two parts. The inner part includes the storage and consumable tanks, pumps room, Gen., Sets, and electric control, workshop and maintenance, ventilation and vapour

services, accommodation/living quarters, platform control and communications. The hotel is placed in the hexagonal part.

The floating module is based on a marina which acts as a point of tourist access to the complex. It has 7 private piers and berthing for big cruise ships, a snack bar, a diving club with dressing rooms, and a visitor's reception centre with shops, bathrooms and a submarine life observatory. Furthermore, the marina has a big curve cover with a PV panels that provides electric energy and protects the incoming passengers from rain and sun.

Green and Blue Concept (Taiwan) (from D3.4)

There are some differences between this concept and the one proposed in Crete, especially in the satellite unit. The most important one is that OTEC is used to generate electric power and indirectly the water is desalinated. This fact means that the satellite unit is designed as a typhoon-proof unit.

Socio-Economic Results (from D5.2)

Offshore Container Terminal	Canary Islands	Crete	Taiwan*
Market size			
Jobs (FTE)	6635	9068	-
GDP (M€)	268.29	308.17	161
Funding(CAPEX)	437	452	435
Funding(OPEX)	41	38	28.43
Impact	666	675	954
Marine spatial			
Ports	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes
Grid	Yes	Yes	Yes

Aquaculture Activities	Canary Islands	Crete	Taiwan*
Market size			
Jobs (FTE)	1367	1680	-
GDP (M€)	45	53.86	32
Funding(CAPEX)	67	79	54
Funding(OPEX)	39	39	38
Impact	104	115	137
Marine spatial	-	--	
Ports	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes
Grid	Yes	Yes	Yes

Leisure Island	Canary Islands	Crete	Taiwan*
Market size			
Jobs (FTE)	-	1283	-
GDP (M€)	26	43.47	12.95
Funding(CAPEX)	29.35	50.50	35.35
Funding(OPEX)	4.05	4.8	4.88
Impact	63.3	95	61.37
Marine spatial	-	-	-
Ports	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes

Grid	Yes	Yes	Yes
------	-----	-----	-----

Offshore Energy Hub	Canary Islands	Crete	Taiwan*
Market size			
Jobs (FTE)	1051	2701	-
GDP (M€)	34.75	98.84	32
Funding(CAPEX)	55.8	148.4	80
Funding(OPEX)	36.44	38	36
Impact	82.3	215.18	144
Marine spatial	-	-	-
Ports	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes
Grid	Yes	Yes	Yes

*Taiwan case is not as detailed as Canary Islands or Crete.

Environmental (from D6.2)

Receptor	Canary Islands	Crete	Liuqiu Island
Air Quality	Medium	Medium	Low
Water Quality	High	Medium	Medium
Water Temperature	Low	Low	Medium
Sediment Dynamics	Low	Low	Medium
Sediment Quality	Medium	Low	Medium
Landscape/Seascape	Medium	Low	Low
Microorganisms	Medium	Low	Low
Benthic Fauna & Flora	High	Medium	Medium
Pelagic Fauna & Flora	High	Low	Low
Fish and Turtles	High	Low	High
Birds & Bats	High	Medium	Medium
Marine Mammals	High	High	Medium
Humans	Medium	Medium	Medium

Regulations

The regulations mentioned and considered in the project are shown in the following:

- National Legislation (Spain, Crete and Taiwan)
- European Policy
 - Environmental Impact Assessment Directive
 - Strategic Environmental Assessment Directive
 - Habitats Directive
 - Wild Bird Directive
 - Water Framework Directive
 - Marine Strategy Framework Directive
 - Renewable Energy Directive
 - Directive on Animal Health Requirements
 - Waste Framework Directive
 - Seveso 3 and IPPC Directives
- International Commitments and Conventions
 - United Nations Convention of the Law of the Sea
 - Regional Sea Conventions
 - Convention on Biological Diversity
 - Bonn Convention on the Conservation of Migratory Species of Wild Animals
 - UNESCO Convention on the Protection of the Underwater Cultural Heritage

- United Nations Framework Convention on Climate Change
- IMO Rules and Regulations
- Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area

Economic Results (from D5.3)

Offshore Container Terminal

		Reference Scenario	500k TEU	100k TEU	50k TEU	10k TEU
Berths	Feeder	2	2	1	1	1
	Megavessel	1	0	0	0	0
Vessel TEU Capacity	Feeder	1000	1000	400	400	400
	Megavessel	5000	n/a	n/a	n/a	n/a
Calls	Feeder	500	500	250	125	25
	Megavessel	100	n/a	n/a	n/a	n/a
Platform Area (m ²)		264.000	138.600	39.160	28.480	21.360
CAPEX (k€)		440.339	246.217	124.935	114.992	108.404
OPEX (k€/yr)		26.075	17.144	11.597	1.1057	10.651
Revenues (k€/yr)		65.252	33.154	7.374	3.687	737
NPV (k€) ¹		-14.539	-71.353	-168.587	-192.516	-213.286
LCOC (€/TEU)		133.22	159.23	465.94	865.66	4125.78

Offshore Wind Service Hub

Platform topside area (m ²)	1.000	2.500	4.000
Platform Weight (ton)	5.709	7.523	9.336
Platform CAPEX (k€)	47.172,19	56.747,26	66.322,32
Platform OPEX (k€)	35.985,21	36.355,61	36.726,01
Levelized cost (€/MWh)	21,40	22,04	22,69

Aquaculture On-Growing Unit

On-growing Unit	
Revenues (k€/yr)	45.837
CAPEX (k€)	87.232
Annual OPEX (k€/yr)	39.360
NPV* (k€)	-8.816
IRR (%)	6%

Leisure Island

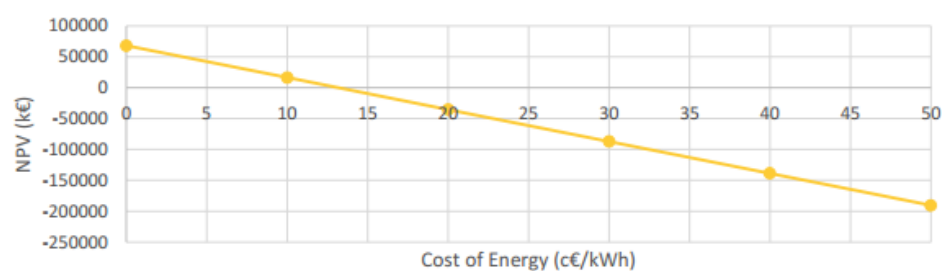
Leisure Centre	
Revenues (k€/yr)	7.753
CAPEX (k€)	44.723
Annual OPEX (k€/yr)	6.257
NPV* (k€)	-24.090
IRR (%)	-2%

Other parameters

Activity	Insurance (M€/yr)	Decommissioning (M€)	Project Length (yr)
Offshore Container Terminal	4.194	22.017	20
Offshore Wind Service Hub	0.537	-	20
Aquaculture	0.755	3.965	20
Leisure Island	0.387	2.033	20

Cost of Electricity

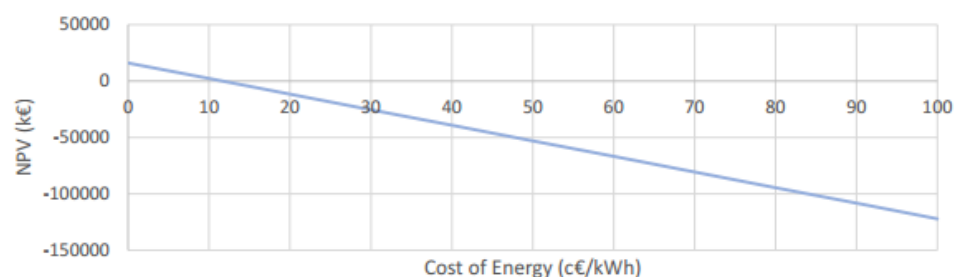
Offshore Container Terminal



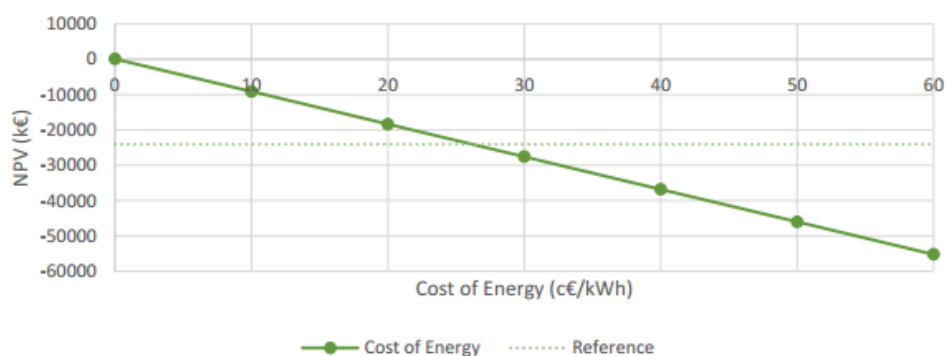
Offshore Wind Service Hub

No info

Aquaculture On-Growing Unit



Leisure Island



5 MERMAID Project

5.1 Main Description

Title: Innovative Multi-purpose off-shore platforms: planning, Design and operation

Dates: From 2012-02-01 to 2015-12-31, ongoing project

Total Cost: EUR 7 376 567,6

Total EU Contribution: EUR 5 483 411

Call for proposal: FP7-OCEAN-2011

5.2 Members / Partners

	Name	Country	EU Contribution
Project Leader	DANMARKS TEKNISKE UNIVERSITET	Denmark	EUR 806 239
Project Members	ALMA MATER STUDIORUM-UNIVERSITA DI BOLOGNA	Italy	EUR 333 538
	UNIVERSIDAD DE CANTABRIA	Spain	EUR 284 058
	STICHTING DELTARES	Netherlands	EUR 352 706
	DHI	Denmark	EUR 377 611
	ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS - RESEARCH CENTER	Greece	EUR 383 274
	VLAAMS INSTITUUT VOOR DE ZEE VZW	Belgium	EUR 220 078
	STICHTING DIENST LANDBOUWKUNDIG ONDERZOEK	Netherlands	EUR 327 407
	STATOIL PETROLEUM AS	Norway	EUR 177 800
	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italy	EUR 148 864
	TECHNISCHE UNIVERSITAT BRAUNSCHWEIG	Germany	EUR 135 018
	HAVFORSKNINGSINSTITUTTET	Norway	EUR 188 939
	THE CYPRUS RESEARCH AND EDUCATIONAL FOUNDATION	Cyprus	EUR 138 520
	HORTIMARE BV	Netherlands	EUR 122 516
	UNIVERSITA DEGLI STUDI ROMA TRE	Italy	EUR 133 056
	HVALPSUND NET AS	Denmark	EUR 107 300
	BOLDING & BURCHARD APS	Denmark	EUR 111 317
	INSTYTUT BUDOWNICTWA WODNEGO POLSKIEJ AKADEMII NAUK	Poland	EUR 126 840
	TECHNICAL UNIVERSITY OF ISTANBUL	Turkey	EUR 115 164
	CHALMERS TEKNISKA HOEGSKOLA AB	Sweden	EUR 156 170
	MUSHOLM AS	Denmark	EUR 74 701
	DANSK AKVAKULTUR FORENING	Denmark	EUR 56 460

	Name	Country	EU Contribution
	UNIVERSITY OF DUNDEE	United Kingdom	EUR 131 880
	STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND	Netherlands	EUR 67 947
	DONG ENERGY POWER AS	Denmark	EUR 63 600
	ENEL INGEGNERIA E RICERCA SPA	Italy	EUR 98 647
	KEFALONIA FISHERIES INDUSTRIAL AND COMMERCIAL COMPANY AE	Greece	EUR 87 287
	NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS	Greece	EUR 96 224
	NORWIND INSTALLER AS	Norway	EUR 60 250

5.3 Main objectives

In order to fulfil EU strategies for reduction of fossil-based energy and to become a major player in sustainable aquaculture the MERMAID project aims to address the following key-questions:

- What are the best practices to develop a project on multi-use platforms?
- What are the accumulated effects of large scale structures on the marine environment?
- What are the best strategies for installation, maintenance and operation of a multi-purpose offshore platform?
- What is the economic and environmental feasibility of multi-use platforms?

It is essential that all work under the MERMAID project contributes directly towards real design concepts and industrial applications. For this reason test sites will be studied to develop innovative plans and designs for harvesting ocean energy, aquaculture and logistic support.

Four offshore test study sites with different environmental characteristics have carefully been selected for their specific challenges. The sites, which represent different environmental, social and economic conditions, are located at four different seas:

- The Baltic Sea - a typical estuarine area with fresh water from rivers and salt water.
- The trans-boundary area of the North Sea-Wadden Sea - a typical active morphology site
- The Atlantic Ocean - a typical deep water site
- The Mediterranean Sea - a typical sheltered deep water site.

With the results from these studies, a verified procedure will be created to select the most appropriate design options for a given off-shore area. This procedure should be generic so stakeholders and end users can use it for marine planning strategies.

5.4 Project structure

	Work Package
WP1	Project Management
WP2	Assessment of policy, planning and management strategies
WP3	Development of renewable energy conversion from wind and waves
WP4	Systems for sustainable aquaculture and ecologically based design

WP5	Interaction of platform with hydrodynamic conditions and seabed
WP6	Transport and optimization of installation, operation, and maintenance
WP7	Innovative platform plan and design
WP8	Economical, technical and environmental feasibility of multi-use Platforms
WP9	Project dissemination & outreach activities

5.5 Deliverables summary table

Technical	Environmental	Socio-economic	Financial
D3.1 Energy resources	D2.6 Report on integrated sustainable planning	D2.1 Inventory, legislation and policies	D2.2 Stake holder views
D3.2 Offshore Technology	D3.5 EIA of energy converters	D2.7 Policy recommendation: Blueprint of Policy Recommendations for the whole of EU	D2.3 Report on stakeholder views
D3.3 Report on energy converters	D4.6 In and offshore fish farming	D7.2 Site specific impact of policies	D2.4 Platform solutions
D3.4 Integration into MUP	D4.7 Ecology	D8.1 Method statement ISEA	D2.5 Guidelines - Lessons learned
D4.1 Physical test of offshore cage reported	D5.1 Metocean conditions	D8.2 Socio-economics, Baltic	D6.2 MUP business case
D4.2 Sites for seaweed		D8.3 Socio-economics, North Sea	
D4.3 Test of seaweed farm		D8.4 Socio-economics, Atlantic	
D4.4 IMTA offshore		D8.5 Socio-economics, Mediterranean	
D4.5 Fish farming opportunities	D8.6 Risk assessment for the four sites		
D5.2 Numerical tools			
D5.3 Interaction between currents, wave, structure and subsoil			
D5.4 Guidelines for seabed support structure interaction			
D6.1 Operators tool-box			
D6.3 Report on Synergies in MUP's			
D6.4 DSS			
D7.1 Site specific conditions			
D7.3 Site specific design conditions			

5.6 Developed concepts description

MERMAID project centers its research into four regional zones: Baltic Sea, North and Walden Sea, Atlantic Ocean and Mediterranean Sea. All of these represent regional European waters where there

are requirements for sustainable activities, including sectors like energy, transport, fisheries or tourism. The four regions have both common and unique drivers of change that impact ecosystem services. These regional case studies are designed to integrate understanding through novel approaches.

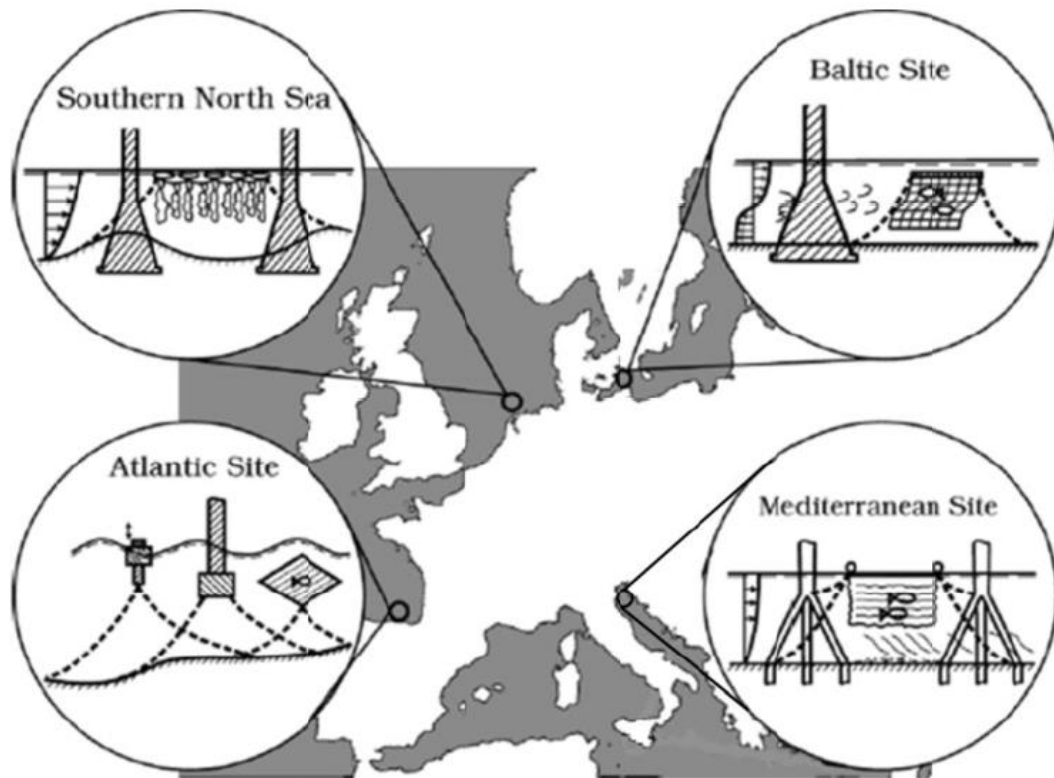


Figure 5: Map of Europe with the four MERMAID locations (MERMAID project).

In each of these zones, a different concept is proposed:

- “A Deep Water Site / Atlantic Ocean”. In this design 77 multi-use platforms must be deployed. Each of them should mix wind (2.5MW) and wave (5MW) energy. Water depth in the site varies from 50 to 250m. The area presents good wave and wind resource potential.

There are some environmental restrictions that have to be studied due to possible impacts: windmill impacts on birds, soil effects due to interconnections; electrical interaction with local fauna; or natural mobility disruption.

From the socioeconomically point of view, there are some issues that can be translated into opportunities for the region and involved stakeholders, such as technological transfers between sectors or competitive advantages and benefits for the region. On the other side, there are some aspects that can limit the development of this system, mainly related to uncertainty on regulatory conditions and on the availability of funding.

- “A Sheltered Deep Water Site / Mediterranean Sea”. The concept in this site is based on the idea to integrate renewable energy production and aquaculture, which would be both not feasible for single purpose installations. Wave energy converters were selected for this site.

A preliminary environmental impact assessment shows non-significant effects from fish farming due to the distance from the coast and existing currents. However, the platform will be designed to be as green as possible by reducing structural impacts.

A preliminary Input-Output Analysis shows non-significant differences in direct and indirect employment at regional level arising from alternative platforms. Neither impacts on regional GDP levels arise.

- “An Active Morphology Site / North Sea-Wadden Sea”. The proposal in this design is to develop a 600MW wind farm, a shellfish and a seaweed farm. An offshore hotel and support centre for more than 100 persons is also designed.

The main technical problem with this site is the exclusion of fish culture in this part of North Sea due to the relatively shallow water depth in combination with a too high water temperature during summer. Shellfish were then chosen to complete the possible activities in the site.

Based on experiences from other existing wind farms and aquaculture, non-major negative environmental impacts are expected.

As there is a good potential for growing seaweed and an increase of mussel production, from the financial point of view the concept is interesting.

- “Estuarine Area / Baltic Sea”. This concept starts from the design of a planned wind farm to be built in Denmark to be completed finished on 2022. The proposal of this design is to add to wind production, fish farming (salmon and/or trout) seaweed farming with shellfish farming.

The optimal technical design for the wind farm will depend in a range of factors such as turbine type, costs of foundations and shadow effects, and will be decided by the concessionaire. The fish farming is planned to separate two facilities between two groups of turbines. Each fish farm section will consist of 12-14 cages with a depth of 12-15m and a diameter of 45m.

The technical feasibility of this solution has been analysed, and an issue raised during those studies is that when a wind and a fish farm are combined, more ships will enter the area, which means more traffic and higher risks of accidents.

Environmental studies have been made, studying the possible effects of the plant on fish, birds, marine mammals and seabed flora. The major concerns include aspects such as sediment spill and noise under construction phases, and after that, the turbines as a risk to migrating birds. Other possible impact can be the spill of nutrients, antifouling and medicaments from fish farming.

The planned windmill park is expected to create 10 000 jobs during construction phase. After construction, O&M of both wind and aquaculture farms will secure jobs and will at the same time act as an international window for Danish know-how.

A socioeconomic study showed positive attitudes towards wind farms and a willingness to pay to place future farms away from the shore to minimise visual impacts.

Full technical specifications

Baltic Sea

It is planned an offshore wind farm, combined with aquaculture, and possibly seaweed farming. The offshore wind farm would have 600 MW. The salmonid farm would produce 10000t/y and the seaweed production would be based on *Furcellaria*.

The wind farm would occupy 180km² and it would be 32 km offshore. The foundation system selected is gravity base or monopile. The construction horizon is 2021 and the lifetime is 25 years.

The fish farm will have two sections with 12-14 round cages with a diameter of 45 meters and a feeding barge. The project time horizon is 5-10 years.

The seaweed farm production, in best case, is 6 tons dryweight/ha/y.

North Sea

In this case the multi-use platform combines wind, mussel and seaweed farm. The location proposed is Wadden Sea, Gemini. An offshore hotel and a support centre are included in the proposal. The production expected is 600MW/yr from the offshore wind farm, 48kton WW/yr of mussel and 480 kton WW/yr from the Seaweed farm.

The total use area will be 10.2 ha with a non-wind use are around 55%. The mussels-seaweed area ratio proposed is 1:3, which means that there would be 48 plots for mussels and 144 plots for seaweed.

The wind farm will occupy around 68 km² with spacing between turbines of 750 meters and 200 meters of access space around turbines for maintenance purposes. The lifetime of the project is 20 years.

The mussel farm area would be 1600ha with 120 meters longlines at 3 meters depth with buoys at ends to keep under tension. Droplines for mussel cultivation would be used. The project time horizon would be 5-10 years.

The seaweed farm area would be 4800 ha. It would consist of 3 species cultivated in a row. The preparation, seeding and harvesting of the substrate would take place by special service vessel. The project time horizon is also 5-10 years.

Atlantic Sea

In the same platform wind and wave energy converters are combined. The location is in the Cantabrian Sea, at La Virgen del Mar. The offshore energy farm will consist of 77 multi-use platforms with 5 MW wind turbines and three 1150 KW oscillating water columns.

The surface would be 100 km². The depth range is 40-200 meters. The seabed is sands and rock and the distance to shore is between 3 and 20 km. It is important to highlight that data information is available due to the existence of a monitoring grid at the location. Wind a wave converters would share the same floating platform.

The wind energy part would produce 77,256 GWh. The project time horizon is 25 years and 1 km spacing is considered to minimize wake effects. Wave energy annual production would be 1.3 GWh.

Adriatic Sea

The proposal at this location is formed by a MUP based on four wind turbines (3.3 MW) combined with a fish farm (2000 tons/y).

The area assumed is 1 km² per MUP due to user conflicts. The depth is at least 27 meters.

The wind farm energy production is 5.6 GWh/y per turbine. The transportation of the turbines is assumed to be by means of regular vessels. The project time horizon is 30 years.

Socio-Economic Results

	Baltic	North Sea	Atlantic	Adriatic
Market size	-	-	-	-
Jobs	10000+120/y	500+120/y	1000+500/y	-
GDP (M€)	280M€/y	430M€	-	17M€
Funding(CAPEX)	1800M€	3000M€	1800M€	48M€
Funding(OPEX)	40M€/y	200M€	590M€	-
Impact	-	-	-	-
Marine spatial	180km ²	130km ²	60km ²	1km ²
Ports	Yes	Yes	Yes	Yes
Infrastructure	Yes	Yes	Yes	Yes
Grid	Yes	Yes	Yes	Yes

Environmental

Barriers Encountered

Baltic Sea

- Disturbance during the construction phase.
- Emissions of nutrients, medicaments and antifouling from fish farming.
- Pollution due to increased ship traffic.
- Changes in hydrodynamic regime.

North Sea

- Disturbance during the construction phase.
- Emissions of nutrients, medicaments and antifouling from fish farming.
- Pollution due to increased ship traffic.
- Changes in hydrodynamic regime.

Atlantic Sea

- Visual impact up to 10 km offshore.
- Birdlife may be affected.
- Wind turbines make sound that affect animal life.
- Marine life affected all along the site and radiation pollution.
- Heat, light, vibration.
- Interference with ship tracks.

Adriatic Sea

- Increase of nutrients induced by the presence of the fish farm.
- Effects on soft bottom assemblages in the areas covered by the piles.
- Disturbance of the area in the construction phase.

Regulations

Baltic Sea

- Danish marine spatial policy stresses: Lack of legal and regulatory basis for MUPs
- Danish offshore aquaculture sector sees market opportunities for a total yearly production of 500,000 tonnes.
- Current obstacles
 - Spatial plans for the Baltic Sea do not designate areas for aquaculture.
 - Regulators lack handling practise.
 - Regulatory framework for MUPs is missing.
 - Third party access of OWFs is currently forbidden to avoid question on risks and responsibilities.
 - New renewable energy subsidy program no longer includes offshore wind developments.

North Sea

- Dutch marine spatial policy stresses the need for space-efficient use, such as multiple use of offshore platforms; and the need to follow an ecosystem approach.
- Dutch mussel sector sees market opportunities for a total yearly production of 100,000 tons of mussels.

- Current obstacles
 - Spatial plans for North Sea do not designate areas for aquaculture.
 - Regulatory framework for MUPs (including risk assessment, insurance issues) is missing.
 - Regulators lack handling practice.
 - Third party access to OWFs is currently forbidden in NL, to avoid question on risks and responsibilities.
 - New renewable energy subsidy program no longer includes offshore wind developments.

Atlantic Sea

- Renewable Energies in Spain: General Framework.
- Royal Decree No.661/2007.
- Royal Decree No.1028/2007.
- Administrative Procedures.
- Current obstacles
 - Lack of social consensus.
 - Social sensitivity towards aesthetic and functional impact of the facilities.
 - Social perception on Environmental requirements.

Adriatic Sea

- Legislative Decree No.11954 of 2010, Art 4(1) on the Production of marine animals and algae by biological aquaculture states that “in order to reduce impacts on the sea bed and on rounding sea water, current must be greater than 0.02 m/s on average per year, and sea depth must be greater than 20 m”.
- Regulatory framework for MUPs is missing.
- The renewable energy subsidy program does not include offshore developments.
- Current obstacles
 - High costs of the offshore installations due to immature technologies.
 - Mild climate conditions for renewable energy conversion.
 - Potential cumulative impact of nutrients induced by the fish farming.
 - High distance from shore and therefore high costs for connection to grid.
 - Renewable energy availability and discontinuity do not allow for an efficient non-connected to grid solution for fish farm energy supply.

Economic Results

	Baltic	North	Atlantic	Adriatic
CAPEX (M€)	1800	3000	1800	48
OPEX (M€)	40	200	590	-
INSURANCE (M€)	-	-	365.8	-
DECOMMISSIONING	-	-	110	-
PROJECT LENGTH	25	20	25	30
NUMBER OF UNITS	80	120	77	1
COST OF ELECTRICITY	-	-	-	-
NPV	-	-	-	-
IRR (%)	10	-	-	10

6 Conclusions

The purpose of task “T5.2: Assess key projects that focus on multi-use of space” is to review and assess four key European projects related to multi-use and multi-platforms. Four projects were chosen due to its relevance to BG5: MARINA Platform, H2OCEAN, TROPOS and MERMAID. To achieve the end of this task, the present report focuses on different aspects.

First, a descriptive review for each of all four projects has been made, listing main facts and data, partners, working structure and main deliverables. With this last information, a preliminary study of the level of development of the deliverables has been realised. All deliverables have been rated according to a four level rating, in a way to assess the grade of maturity of the work done. This scale goes from “Problem identified” to “Solution proposed”, “Solution developed” and finally “Solution assessed”.

It is important to note that the use this scale for the assessment of project deliverables does not imply the evaluation of the quality of the deliverable or the tasks developed during the projects. It only tries to give a simple indicator of the maturity of the solution proposed. But we must remember that in research work, it is usually as important the review and development of ideas as the construction of proposed concepts.

Further than this descriptive task, a second work is presented in this report. For each reviewed project, proposed multi-use platform concepts have been identified and their descriptions are presented in different headlines. For all of them, all available and public information has been resumed, identifying the main issues related to technical, environmental, socioeconomically and financial areas. Following four tables and descriptions should serve as a comprehensive summary of this work.

- The main aim of MARINA Platform project was to combine wind turbines and wave energy converters (WEC). After an important process of review and assessment, three concepts were developed: “STC”, a concept with a spar wind turbine and a torus-shape heaving buoy; “SFC”, a four-column semi-submersible concept with one wind turbine installed on the centre column with oscillating elliptical flaps between the columns; and “OWC array”, a large floater with Oscillating Water Columns with one wind turbine. The summary of three concepts is presented in Table 1.

Table 1: MARINA Platform project concepts summary.

Concept	Technical	Environmental	Socioeconomics	Financial
STC	▪ increase the wind power production around 6% ▪ additional wave power production of 5-8% ▪ 3 to 6% contribution from WECs			▪ high CoE ▪ not currently cost-effective as combined multi-purpose platforms
SFC	▪ increase the wind power production around 6% ▪ additional wave power production of 3-5% ▪ 3 to 6% contribution from WECs			

Concept	Technical	Environmental	Socioeconomics	Financial
OWC array	▪ wave power production comparable to that of the wind turbines ▪ energy balance is almost 50% wind and 50% wave contribution			

- The concept of H2OCEAN project is to develop a flexible design for a multi-component and multipurpose wind-wave farm based platform, which can be varied to address the requirements of the location and local economics. The project developed a unique conceptual system composed by an array of up to 100 coupled wave and wind energy devices and aquaculture cages (see Table 2).

Table 2: H2OCEAN project concepts summary.

Concept	Technical	Environmental	Socioeconomics	Financial
	▪ 100 coupled wave and wind energy devices and aquaculture cages ▪ requires a great number of vessels ▪ many years ▪ considerable number of shipyards ▪ many parts have a low TRL ▪ realisation of the concept does not seem imminent ▪ one single WEC can satisfy energy requirements of an array of aquaculture cages ▪ interferences with navigation routes	▪ the impact of the installation of the conceptual design will be highly significant ▪ during O&M, huge amount of vessels		▪ total investment costs are 12.2 billion € ▪ operational costs 11.4 billion € ▪ expected benefits vary from 2.0 billion € to -21.6 billion € negative

- The main objective of the Tropos Project is to develop a modular floating platform, adapted to deep waters. Thanks to its different modules, the floating platform system will be able to integrate a wide range of possible sectors. Three concepts were developed in the project: “Green and Blue”, combining aquaculture with wind energy; “Sustainable Service Hub”, a platform focused on transport and energy related needs; and “Leisure Island”, a platform orientated to ocean tourism. The main information and developments of these concepts is summarised in Table 3.

Table 3: TROPOS project concepts summary.

Concept	Technical	Environmental	Socioeconomics	Financial
Green and Blue	this concept combines aquaculture facilities (producing both fish and algae) with an offshore wind farm	- reduced negative effects of construction and operation - solid and liquid waste linked to algae and fish farms - physical impact of the wind farms	- economic benefits for other related industries - direct employment generation - Gross Value Added	- existing grant support to the aquaculture sector - feed-in tariffs coupled with capital grant investments impacts wind farms - required stable political environment with long-term and consistent policies, grid connections or the development of a favourable power market
Sustainable Service Hub	- This concept consists on an offshore structure focused on transport and energy related needs - The main purpose of the concept is the support during installation and provision of service and maintenance during operation of a wind farm.	- no critical impacts - installation of the platform and moorings, could affect water quality and organisms - increase of vessel traffic	- new ports development - more job opportunities - revenues in taxes, fees, licenses and also - increase of consumption	- reduction of O&M costs - increase of revenues
Leisure Island	This concept is platform orientated to the tourism and leisure operation	- vessel traffic emissions and traffic - major impact on air quality - impact of noise and vibrations	- new job opportunities - important cash flow - generation of local, regional and national Gross Value Added	income does not currently cover operational and investment costs

- Finally, the fourth project assessed was MERMAID. In this project, four offshore test study sites with different environmental characteristics have carefully been selected for their specific challenges. The sites, which represent different environmental, social and economic conditions, are located at four different seas: Atlantic Ocean, Mediterranean Sea, North Sea and Baltic Sea. In each of those locations, different sectors have been combined as shown in Table 4.

Table 4: MERMAID project concepts summary.

Concept	Technical	Environmental	Socioeconomics	Financial
Atlantic Ocean	wind and wave energy	- windmill impacts on birds - soil effects due to interconnections - electrical interaction with local fauna - natural mobility disruption	- technological transfers between sectors - competitive advantages and benefits for the region - uncertainty on regulatory conditions - uncertainty on the availability of funding	
Mediterranean Sea	wave energy converters and aquaculture	non-significant effects	non-significant effects	
North Sea-Wadden Sea	- wind farm, a shellfish and a seaweed farm - exclusion of fish culture	non-major negative impacts		good potential for growing seaweed and an increase of mussel production
Baltic Sea	- wind production, fish farming, seaweed farming and shellfish farming - more ships will enter the area - more traffic and higher risks of accidents	- sediment spill and noise under construction phases - turbines as a risk to migrating birds - spill of nutrients, antifouling and medicaments from fish farming	- jobs creation - positive attitudes towards wind farms	

7 References

MARINA Platform Project

- Project Website: <http://www.marina-platform.info/>
- Available information on CORDIS: http://cordis.europa.eu/project/rcn/93425_en.html
- Project Deliverables
- Project final report
- Direct communication with project partners

H2OCEAN Project

- Project Website: <http://www.h2ocean-project.eu/>
- Available information on CORDIS: http://cordis.europa.eu/project/rcn/102016_en.html
- Project Deliverables
- Direct communication with project partners

TROPOS Project

- Project Website: <http://www.troposplatform.eu/>
- Available information on CORDIS: http://cordis.europa.eu/project/rcn/101556_en.html
- Project Deliverables
- Shiau-Yun Lu; Yu, J.C.S.; Golmen, L.; Wesnigk, J.; Papandroulakis, N.; Anastasiadis, P.; Delory, E.; Quevedo, E.; Hernández, J.; Llinás, O., "Environmental aspects of designing multi-purpose offshore platforms in the scope of the FP7 TROPOS Project," *OCEANS 2014 - TAIPEI*, vol., no., pp.1,8, 7-10 April 2014. doi: 10.1109/OCEANS-TAIPEI.2014.6964306
- Quevedo, E.; Carton, M.; Delory, E.; Castro, A.; Hernandez, J.; Llinas, O.; De Lara, J.; Papandroulakis, N.; Anastasiadis, P.; Bard, J.; Jeffrey, H.; Ingram, D.; Wesnigk, J., "Multi-use offshore platform configurations in the scope of the FP7 TROPOS Project," *OCEANS - Bergen, 2013 MTS/IEEE*, vol., no., pp.1,7, 10-14 June 2013. doi: 10.1109/OCEANS-Bergen.2013.6608061
- Quevedo, E., Delory, M., Castro, A., Llinas, O., & Hernandez, J. (2012). Modular multi-purpose offshore platforms, the tropos project approach. *Proceedings of the 4th International Conference on Ocean Energy (ICOE)*, Dublin, Ireland (pp. 1-5).
- Direct communication with project partners

MERMAID Project

- Project Website: <http://www.mermaidproject.eu/>
- Available information on CORDIS: http://cordis.europa.eu/project/rcn/101743_en.html
- Project Deliverables
- Direct communication with project partners