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Marine Renewable Integrated Application Platform

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MARINA PLATFORM

Deliverable D1.12
Final Summary Report

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Summary

This report outlines the activities undertaken within the MARINA Platform project during the duration of the project, being the full 54 Months of the project.

It summarizes the activities and major developments realised in the WPs during the project trying to give a summarised view of what has being achieved in the project.

CONTENT

EXECUTIVE SUMMARY

MARINA Platform is a large European collaborative R&D project on multi-purpose offshore renewable energy platforms that has run from January 2010 through June 2014. The project is the first EU supported R&D effort to study combined offshore renewable energy systems.

The project was led by the Spanish utility Acciona Energía and included a series of universities, technology centers and specialised companies from many European countries. The 15 partners participating in the project were: Acciona Energía, the Norwegian University of Science and Technology (NTNU), The University of Edinburgh (UEdin), University College Cork (UCC-HMRC), Tecnalia, DONG Energy, Technip, Ecole Centrale de Nantes (ECN), the National and Kapodistrian University of Athens (NKUA), Universidade do Algarve (UAlg), Risø DTU, 1-Tech, Corrosion and Water-Control (CWC), Statoil, Fraunhofer IWES and Bureau Veritas (BV).

The primary objective of the MARINA Platform Project was to provide a set of protocols covering the engineering and economic evaluation of multi-purpose Marine Renewable Energy (MRE) platforms, taking into account also non-energy uses and planning & consenting issues surrounding their deployment.

The major objectives have been reached within the foreseen time frame, including the following: A Wind-Wave-Current (W2C) atlas with the associated Decision Support tool was developed. A set of integrated design methods and tools have been developed, tested, used and validated. Recommendations for the certification bodies to enhance the development of standards have been gathered. Simplified numerical analysis methods for conceptual design and refined methods have been developed and applied to analyse combined concepts. The methods were found to readily reduce the number of possible concepts from more than 100 down to a select group of 10, whereas making a restricted selection of 3-4 was challenging. Functionality and survivability model tests have been conducted. The motion and structural responses of the combined concepts as well as observations of the nonlinear hydrodynamic phenomena were reported. A toolbox to support the design and evaluation of critical system components including a component selection toolbox for combined wind-wave concepts; a time series resource-to-wire model; qualitative and quantitative risk assessment of critical components in combined systems; general assessment of components and potential issues for combined RE systems was developed. Sophisticated cost evaluation tools have been developed. Integration of power produced offshore into the onshore grid and optimal layout were investigated with grid studies and reinforcement plans, components for collection and delivery of power to the grid, including reviews or case studies, of grid-codes, market strategies, alternative business model examples, studies of HVDC capabilities, future Northern European HVDC network and infrastructure studies from an electrical and resource perspective. A large, still growing number of scientific & technical publications have been generated and one patent awarded. Seminars and specialised courses at different venues have been held to educate the next generation researchers in different MRE relevant areas.

All these achievements will enable future developments to take place at much higher speed and with a much higher level of confidence in the results, due to the system design, modelling and optimization tools that were developed within the MARINA Platform project.

The new GIS system is made publicly available and incorporates a Europe wide combined W2C atlas into its database together with constraints arising from maritime spatial planning (MSP) considerations and engineering constraints such as distance to port. For the first time this will provide an integrated decision support tool for identification of possible deployment locations. The resulting MSP decision support tool will far exceed the capabilities of current MSP systems as well as any existing resource atlases in supporting policy makers, utilities and project developers. It will be an invaluable tool for ensuring that any platform designs can be evaluated and assessed on an equitable basis and, for the first time, many possible benefits for other maritime stakeholders are identified.

SUMMARY DESCRIPTION OF CONTEXT AND OBJECTIVES

The MARINA Platform project is the first EU supported research effort to study combined offshore renewable energy systems, greatly extending the results of the coordination action ORECCA, completed in 2012. A starting point for both projects was that offshore renewable energy resources are much more than wind, so it would seem important to consider possible joint or coordinated development with resources such as wave and tidal energy.

MARINA has established criteria for generating, assessing and evaluating combined concepts for wind & ocean energy utilisation, produced an atlas for the combined offshore renewable energy resources, and a wide set of system design, modelling and optimisation tools. Cost aspects, risk modelling, key components, grid issues, and other relevant aspects of multi-purpose energy platforms have been addressed. The project has taken an inclusive approach, evaluating "all" known designs, not only those originating within the consortium. It started being technology-agnostic, with no pre-conceived notions of how successful multipurpose platforms will look.

MARINA Platform has been a challenging project due to the novelty of the application field and its ambitious objectives: the development of new combined offshore wind & ocean energy concepts and new methodologies and tools to assess them.

Despite some delays along the way, substantially all goals have been completed. Instrumental in accomplishing this has been the background of the Consortium partners, drawing on both, industrial and research experience, careful planning, coordination and follow-up, and perhaps most of all the partners' willingness to share information and work in a coordinated way.

This report gives a short summary of the achievements by Work Package (WP) and references the many Deliverables and other outputs of the MARINA Platform project.

Offshore wind has been growing quickly in European shallow seas recently, and during the MARINA period, more prototypes for deep-water wind development have been announced and even installed across the world. By its wide range of results, many of which are public, whilst others are available for sharing with European technology and industry developers, the MARINA Consortium hopes to have made a contribution towards the growing EU technology base for exploiting the offshore renewable energy sources in the years and decades to come.

WP1 - Methodology and Management

The main objectives of this work package were to adequately coordinate and organise the project as well as assuring the communication flow between partners and work packages, the project follow-up with respect to the project progress and planning and to define the decision making procedures.
WP1 established the overall methodology within the MARINA Platform project, managing the communication and data flow between partners and work packages, assessing the progress towards the objectives of the project and towards results, and supervising the WPs deliverables to be sent on due time. The WP set up the correct economic reporting procedures within the project and hand out according to the original budget approved within the Description of Work the pre-finance payments and further reimbursements per periodic review, after the final certificate was provided by the Commission.

WP2 - Site Assessment Monitoring

The aim of WP2 was to define, test and implement criteria for the selection of sites for offshore renewable energy platforms. A protocol for assessing site suitability was developed and tested at some pre-selected locations. A 10-year high resolution hourly atlas of uniquely co-located, co-temporal wind, wave and tidal current resource data was created and combined in a GIS with bespoke decision-support tools to implement the site selection. Protocols for environmental monitoring were developed, including both surveys and real-time monitoring requirements.

WP3 - Concepts identification

This WP has established criteria for assessing the viability of concepts that integrate conversion of wind, wave and current energy and, applies these criteria to the identification of a small number of novel concepts, based on previously known ideas as well as new ideas. WP3 also develops and assesses novel concepts of wave and wind energy converters. The WP3 has evaluated “all” concepts, both those previously known and those originating from within the consortium by a set of open transparent criteria and well documented procedures performing a technology assessment in two phases. It defined the optimal solutions to develop and validate the numerical and testing of offshore combined concepts to be developed within WP4 using the best available state-of-the-art experimental and modelling tools. The final concepts were chosen to then investigate the numerical modelling and the related tests and validations of the tools on those concepts further in WP4.

WP4 - Synthesis – modeling and testing

WP4 has dealt with the development of numerical methods for dynamic analysis of combined concepts subjected to stochastic wind and waves, automatic control of combined concepts, model testing of selected concepts and validation of the developed numerical models, and also a study of the performance of these concepts with respect to functionality (power production) and survivability (structural integrity). The focus has been on the three combined concepts, which were recommended in the final selection of combined concepts in WP3, namely: the spar torus combination (STC), the semi-submersible flap combination (SFC) and the large floater with multiple oscillating water columns and one wind turbine (OWC Array).

In particular, the synergy of combining wind and wave devices on a single platform was investigated by numerical methods and presented for the STC and SFC concepts as examples by comparing power production and representative motion and structural responses of a combined concept with that of a wind turbine alone. Both simplified numerical analysis methods for conceptual design and refined methods were discussed and applied to analyses of the three combined concepts. Functionality and survivability model tests of the SFC and OWC Array concepts and survivability test of the STC concept have been conducted. Motion and structural responses of the combined concepts as well as observations of the nonlinear hydrodynamic phenomena were reported. Experimental techniques for combined concepts were documented and discussed and the associated challenges in model testing were highlighted. The numerical models and methods were validated by comparison with the model test measurements for selected cases.

WP5 - Technology Risk Assessment

WP5 aimed to develop/review risk analysis methods and apply them in assessing risks associated with choice of concept, installation, operation & maintenance, and survivability of wind and ocean energy facilities. Identified methods have been identified, developed and applied on relevant MARINA scenarios. Prototypes have been developed under the MS Office platform to support quantitative methods. A dedicated discrete event simulation engine has been developed to support calculations where analytical methods cannot cope with the complexity of the problem.

WP6 - Economic Feasibility Assessment

The aim of this Work package is to assess, on the “validated concept” level of detail, the cost and energy benefit of integrating wind and ocean energy technologies including non-energy uses.
The analysis of cost of electricity has been carried out in a first step using generic parameters. Input from different partners (industry, research institute) and literature were collected in order to provide a valuable database and to develop a methodology of Cost of

electricity calculation that can be applicable for the different concepts.
In a second step, a detailed analysis has been performed on the selected concepts, taking in account reliability, availability and maintainability (RAM), as well as specific site condition and probabilistic analysis for the CAPEX estimation.
Synergies between ocean energy technologies and non-energy uses have been analysed, for three specific cases:
- A semisubmersible platform (W2Power) combined with salmon farming offshore Norway
- The STC combined with Laminaria algae farming at the CaboSillero site (off Portugal)
- A large wave & wind platform coupled with wind turbine and desalinisation plan at a site in the North West of Sardinia, Mediterranean Sea.

WP7 - Critical Component Engineering

The aim of WP7: Critical Component Engineering work package was to identify the critical components for wind and wave energy integrated platforms; to develop risk assessment methodologies for these critical components; and to produce a toolbox to support the design and evaluation of system components.
The work package was divided into a series of tasks according to the component systems of a combined wind and wave energy platform i.e. the platform and moorings (task 1), the wind turbine (task 2), wave energy devices (task 3) and the integrated electrical components (task 4), with two additional tasks dedicated to the reliability of the components (task 6) and looking at the feasibility of introducing other uses to the platform (task 5) e.g. aquaculture or hydrogen storage.
The primary outputs include a number of public deliverables which were re-visited and updated at the end of the project; a component selection toolbox for combined wind-wave concepts; a time series resource to wire model; a qualitative and quantitative risk assessment of components in combined systems; general assessment of components and potential critical issues in terms of combined offshore renewable energy systems; an analysis of the means of aggregating the power from these combined systems.

WP8 - Grid Connection and Macro System Integration

Work Package 8 has been dealing with how to collect the power produced offshore, bring it onto shore and integrate it into the onshore grid. In addition WP8 have looked at how MARINA devices can be spaced in a farm to create the most optimal layout.
Initially a number of important European grid studies were reviewed to provide an overview of grid capabilities, reinforcement plans and the drivers behind this. Second, the WP looked at optimal layout of farms and infrastructure both from an electrical and resource perspective.
Third step was to look at physical components for collection and delivery of power to the grid, including providing a number of case-studies.
Finally the WP has been working on grid integration issues, both from an electrical and market perspective. Work included e.g. review of grid-codes, market strategies, examples of alternative business models, studies of HVDC capabilities etc. 3 case studies were also performed, 2 looking at real examples from UK and Spain, while the third looked at a the Cigré HVDC test system, representing a potential future Northern European HVDC network.

WP9 - Exploitation and Dissemination

The aim of WP9 Exploitation and Dissemination is to coordinate and perform dissemination and exploitation activities addressed to facilitate the use of MARINA results for later market oriented RTD and demonstration projects. Work was focused on three main activities: development of tools for the dissemination (web site www.marina-platform.info project leaflet and dissemination plan), dissemination activities to show the project achievements (workshop, training activities and papers on conferences and peer review journals) and definition of a plan for the use and dissemination of the foreground.

MAIN S&T RESULTS

Below is given a summary of major S&T results and conclusions by Work Package with references to figures in Appendix 1 and to the most relevant Deliverables of the MARINA Platform project.

WP Description	*WP Leader*
WP1 – OVERALL METHODOLOGY AND MANAGEMENT	**Acciona Energía**

WP1 – Overall Methodology and Management

Task 1.1: Methodology

All partners represented in the Steering Group were defining the general methodology and organisation of all work at the start of the project by the release of Handbook of Management procedures that were be approved by the Steering Group.

The project developed an internal reviewing procedure to guarantee the quality of its results. Each WP leader is responsible for the quality of the results, especially of the deliverables, which were subject to a peer review by at least one expert. Wherever possible, work done by primarily academic & research partners was reviewed by an Industry representative, and vice versa.

Task 1.2: Management.

The project was managed according to the logical succession of the phases of the project during its full duration and the communication and data flow between partners and work packages was controlled. This was ensured through Project coordination meetings, circulating information (reports, minutes of meetings etc.), establishing and implementing quality assurance procedures.

The methodology of work and the project management were adjusted as needed as the project advanced. Any issue was managed at first by the coordinator, evaluating and considering if further actions were required, meaning escalating up to the upper levels if needed. This would be realised by involving the Steering Committee and starting contingency plans to resolve any issues or adjustments that had to be made due to the assessment of progress. In some cases resulting in communication with the European Commission to implement changes in the DoW related to the scope of work.

The management role was not only control and reporting, it also included and considered in addition technical and administrative assistance to project partners regarding payment management and the organisation of meetings and any other topic relevant to the project.

All information regarding technical progress and financial status of the advance of the project was part of the management of the project that held four large co-ordination meetings (initial, first Periodic Review, Second Periodic Review, and final Review) with the EU Commission Officers. The Commission was invited to all consortium meetings of the project. There were three major Project Reviews with Technical and Financial Reports during the project, supplemented by Executive style brief Progress reports every six months.

Task 1.3: Assess the progress.

All MARINA partners were involved in periodic meetings to assess the progress of Marina towards the objectives and towards the aspired results. Reports of the progress and the assessment were prepared. Additionally progress meetings with the presence of the WP leaders were held at a minimum half yearly as a way to follow up the progress of the project.

WP Description	WP Leader
WP 2 – SITE ASSESSMENT AND MONITORING	**UEdin**

WP2 – Site Assessment Monitoring

Work-package 2 was divided into a number of tasks, with the key aim of defining, testing and implementing the criteria required in the search for suitable sites for offshore renewable energy platforms around Europe. A protocol for measuring and quantifying the suitability of a site was developed and tested at a set of pre-defined locations. An entirely unique resource atlas was created using bespoke meso-scale atmospheric and oceanographic models. The atlas consists of a 10-year hourly hind-cast of co-located, co-temporal wind, wave and tidal current energy resources for European waters at a spatial resolution of 0.05 degree latitude/ longitude. The fundamental resource information was then incorporated within a Geographic Information System to apply both resource and other constraints, in order to provide bespoke decision support tools for site selection. Alongside the issue of planning considerations, the real-time prediction of the accessibility of platforms for maintenance purposes was also investigated. The same resource models as used in the site-selection process were used to generate forecasts of weather-windows for accessibility purposes. An important part of the WP included detailed consideration of the environmental monitoring requirements, including both baseline and periodic surveys and real-time monitoring during operation.

Task 2.1: Assessment Protocol

The first task in the WP required the development of a protocol to define the specific requirements for the assessment of proposed sites for deep offshore renewable energy platforms. The assessment process included consideration of wind, wave and current energy resources, and also any other potentially relevant constraints related to the physical environment.

Methods for carrying out the assessment and characterisation of renewable energy resources are generally well-established, and in some cases, attempts have already been made to standardise procedures. The EquiMar project (FP7 No. 213380) developed a set of protocols for marine energy resource assessment, and D2.1 incorporates these methods alongside widely-accepted standards for wind energy. Additionally, however, D2.1 includes a method specifically for understanding and parameterising the correlations between wind and wave energy resources, as relevant to the design of platforms incorporating both technologies. The identification of the pattern of generation using combinations of wind and wave technologies was highlighted as being of particular interest. If the relationship between wind and wave has particular characteristics, there are potential benefits to the combination in terms of power smoothing and asset utilisation. The protocol also considers a number of important environmental and physical constraints that may require consideration in site selection for offshore platforms, depending on the chosen designs. These include factors such as areas of environmental sensitivity and bathymetry.

Task 2.2: Site Assessment

In order to illustrate the use of the protocols developed in the previous task and described in D2.1, a set of three existing European marine energy test facilities were used as ‘test’ cases: EMEC, at Orkney in Scotland; Bimep, on the Basque coast in Spain; and SEM-REV on the west coast of France. These sites are all considered to be suitable candidates for development of wind and wave energy, and EMEC is also a potential tidal energy site. The individual resources were each characterised for the sites, but more specifically, the task investigated the potential for combining wind and wave energy at these three locations. The nature of the combined power outputs – assuming the characteristics of existing single technologies – was considered (see Annex ***Figure 1***), and the potential advantages of different scales of combinations were illustrated in D2.2 (see Annex ***Figure 2***). The differences between the combined outputs at the sites were also presented. Design requirements were considered, and survivability of devices was assessed based on estimates of extreme conditions at the sites.

Task 2.3: Resource and Constraint Mapping

The development of a unique resource model was a major outcome of this WP. The task aimed to combine meso-scale atmospheric output with an oceanographic model to provide a co-located co-temporal wind and wave energy resource hind-cast, which represents an exceptional facility for the project. The state-of-the-art regional atmospheric model SKIRON and the ocean wave model WAM are employed and configured to run jointly at high-resolution over extended geographical domains in order to produce the gridded data needed for the wind and wave energy resource assessments. An extensive testing and validation program was carried out to optimise the model set-up and verify the accuracy of the output. The addition of a combination of output from an ocean current model (HYCOM) and a tidal model (TMD) completes the full marine energy resource assessment capability of the WP.

The full extent of these resource models has been exploited in order to analyse the wind-wave correlations at a range of sites, and to analyse design conditions for device survivability under extreme conditions. Furthermore, the historical availability of weather windows for site access can be considered along routes from port to site, by analysing the conditions in sequential order through the model domain (see Annex ***Figure 3***).

The summarised output of the resource models (annual and monthly mean resource statistics) has been combined with other constraint information as detailed in D2.1 and D2.2 to form the basis of a Geographic Information System (GIS) for the project. Within this, bespoke decision-support tools have been developed to allow users to fix a set of required criteria – as per the design of the offshore renewable energy platform – and identify the specific sites or areas which would be suitable for installation of the particular platform design. Annex ***Figure 4*** shows the graphical user interface (GUI) for the main tool; a second tool allows the plotting of routes from site to nearby ports with required facilities and a third tool analyses the levelised cost of energy produced at the different selected sites. An example of output from the tool is given in Annex ***Figure 5***, based on a set of criteria for one of the platform designs chosen in WP3 – a wind speed requirement of 6m/s, a wave power density of 30kW/m and a depth range of 70-250m. The sites have been ranked according to their overall suitability against the preferences of the user.

Task 2.4: Environmental Monitoring

D2.6 develops a framework for assessing the environmental impact of offshore renewable energy platforms in five ‘stressor’ categories: physical, dynamic, chemical, noise and electro-magnetic. These are considered with respect to six ‘receptors’: the physical environment, marine mammals and sea turtles, pelagic communities, benthic communities, birds and water. Under this framework, the potential impacts of a subset of the Marina Platform combined wind-wave concepts are considered. A number of critical parameters to be monitored throughout the development and operation of a platform are presented, along with the required instrumentation and quality control procedures.

Given the floating designs of most Marina Platform concept structures, their impact is generally lower than fixed platform designs. The spar buoy (ID 2) was found to have the lowest impact overall, potentially due to its overall smaller footprint and lower noise potential. There are, however, deemed to be gaps in the knowledge of the effects of many stressors on the different receptors. Further research and the acceptance of long-term monitoring plans adhering to set frameworks are essential to fill this gap.

Task 2.5: Real-time Operations

Task 2.5 considered the issue of weather windows based on historical risk as presented in the 10-year wind, wave and current hind-cast. This task aimed to look at this issue in real-time, by using the same models as those used to create the hind-cast, but run in forecasting mode. The tools and methodologies developed provide support for operation of offshore renewable energy devices with up to 5-day predictions of hourly met-ocean conditions. This allows consideration of accessibility based on thresholds for critical parameters, and with the concurrent estimation of device power output, also offers the potential to account for lost production.

The ongoing forecast information can be found at http://forecast.uoa.gr/marina.php. The parameters available from the atmospheric forecast include 2m temperature, mean sea-level pressure, 6-hour accumulated precipitation, cloud cover, wind speed, direction and power production potential at a number of heights above sea-level. The wave forecast includes significant wave height and direction, maximum wave height and direction, swell height and direction and wave power potential. The forecast information can also be visualised for individual points using a Google Maps interface (see Annex ***Figure 6***).

WP Description	*WP Leader*
WP3 - Concepts identification	**Acciona Energía**

WP3- Concepts identification

WP3 has established criteria for the viability of concepts that integrate conversion of wind and wave/current energy, and applied these in the identification of a small number of novel concepts based on previously known ideas and new ideas. WP3 also included development and assessment of a range of novel concepts of wave and wind energy converters.

There was no known existing methodology for assessing multiple combined renewable energy concepts, so this work provided a number of major challenges to the MARINA Platform partners. These challenges primarily arose due to a lack of knowledge in the industry regarding these novel combined technologies and therefore it required innovative and effective solutions to be developed and implemented. These solutions included several ad-hoc technical studies which drew on vital partner experience and expertise; and the economic assessment tool produced in conjunction with WP6, which for the first time provides an economic value to these combined concepts. In combination, the technical studies and economic assessment tool enabled critical decisions to be made on the potential viability of a number of concepts.

One major aim of the MARINA project was the development of procedures for generation and selection of combined wind/ocean energy converters. The level of detailed design during the first round of selection was far too low to allow making a fair comparison in between all the designs investigated. Therefore the selection also needed to take into consideration for which systems detailed design was available and use concepts for evaluation and for the development of the tools that did have a certain level of details available that permitted to use different kinds of evaluation tools. Therefore the choice of concepts was partially also made with a view to having a wide variety of different designs that allow for the development of the procedures for concept generation and selection. The selection of the concepts should NOT be misunderstood as a final evaluation of the "best" or most suitable concepts.

Task 3.1 Criteria and synergies identification for combined Marine Energy converters

Five eligibility criteria and the TRL (technology readiness level) were defined and documented in the deliverable "D3.1: Basic evaluation criteria and technology applicability maps" and later on used for screening and eliminating the unsuitable combinations. An initial screening was required to perform a quick appraisal and to assess the various concepts and to discount concepts which obviously lacked potential. This process allowed 60% of the initially around 100 concepts to be discarded however a more technical assessment was deemed necessary to further screen the remaining concepts in order to reach the objective of a critical number of viable concepts i.e. 10 in the first phases of the project.

Task 3.2 Concepts generation

To this aim the WP3 did an extensive collection of concepts in the beginning and performed the subsequent labeling and tabulation. An extensive collection of concepts was done based on literature study, brainstorming, ideas and proposals from MARINA partners as well as 3rd parties. Approximately 100 concepts were generated. A technology group matrix was filled with all the concepts grouped whether they were "combined" or "segregated" layouts and next sub-grouped according to their foundation types whether fixed or floating. (see Annex ***Figure 7***) The segregated concepts were not prioritised in WP3. The focus in the MARINA project was on the combined concepts in one platform.

The basic grouping of concepts was developed further distinguishing the energy source, whether tidal or wave, the number of WTs, and also the segregated concepts were grouped according their foundation concept. Finally the concepts were sorted accordingly into 7 corresponding categories and presented in the deliverable "D3.2: Summary of generated concepts and ideas".

Task 3.3 Concepts screening

Within the Task 3.3 a more detailed analysis was performed on the remaining concepts (see Annex ***Figure 8***) and this resulted in the deliverables "D3.3: Methodologies for analysis and assessment of wind-ocean combined concepts" and "D3.4: Recommended concepts for further documentation and analysis"

It was not possible to provide detailed designs of all remaining concepts and therefore the initial first phase was aimed at reducing the number to 10 concepts. In a second phase the number of concepts was reduced down to 3 concepts. In both phases the five criteria for techno-economic feasibility assessment protocol that had been developed was applied.

The five criteria were: the Cost of Energy (CoE), install-ability, constructability, operation and maintenance and survivability.

A suitable site selection was a pre-requisite to be able to apply the evaluation criteria under comparable circumstances. To be able to calculate several of these criteria the environmental conditions on several sites needed to be known. Those were chosen from the European Wind and Wave Atlas that was developed in WP2. A statistical analysis on the environmental data of 18 sites provided was performed and 5 of them were found representative from geographical location, available wind and wave energy and severity of wind and wave conditions point of view. The sites were evaluated considering the Wind and Wave Energy resource. Wind, Wave and Wave period data were undergoing a model check to verify that the models were accurate. Finally the 5 sites where investigated more closely for the implementation of the concepts and for the final evaluation two sites off the Norwegian and off the Portuguese coast were selected. (See Annex ***Figure 9***)

The first evaluation criterion was the anticipated Cost of Energy. To be able to calculate the CoE a tool was developed by WP6 that was used for the economical evaluation. This model did include as well the site data to be able to estimate the production as a vast number of economical values for a series of parameters influencing in the final CoE. The model was run for a series of concepts. Rankings evaluating the distribution depending on CoE and wave to wind energy ratio and on basis of the COE estimation were performed in parallel.

To be able to do the evaluation for one concept a large amount of work had to be done for each concept to get to the level of detail required for a more detailed design selection. The main characteristics such as the material and weight summary of structural components, the response analysis results for extreme conditions and the power production results etc. all needed to be determined.

Then after the CoE the other remaining criteria of install-ability, constructability, operation and maintenance and survivability were evaluated in big part on engineering experience.

The install-ability criterion considered is related to the installation of the floating structure and its mooring system, including the following three aspects, platform load out, departure port and mooring line dimension.

The features that are included in the constructability criterion are the available location to build, special facilities needed, material, complexity of fabrication and ease of mass production.

The operability and maintainability criteria has considered the following aspects, the Power Take-Off (PTO) type and its reliability, access to platform for maintenance and repair, access to components for maintenance and repair, multiplicity/independence of the sub-systems (WECs, WTs, PTOs, etc.) on the platform as well as the PTO, WEC or tidal turbine connection with the platform (which is identified also by the developers for many concepts as being a potentially weak part because of its complexity).

The survivability has considered the following aspects, of the survivability of components as well as system to "normal" environmental conditions and loads, survivability of wind turbine, survivability of wave energy converter or tidal turbine, survivability of floater and mooring system if applicable, the survivability to "abnormal" or accidental events and loads, the survivability against ship collision, the survivability under wind turbine faults; the survivability under wave energy converter faults and the survivability under floater subsystem failure or mooring line failure.

Finally, for each device the rankings according to each criterion were weighted in order to find a final result, giving priority to the CoE result since it would determine the economic feasibility of the concept. The chosen weightings were 0.4 (CoE), 0.15 (Constructability), 0.10 (Install-ability), 0.10 (O&M) and 0.25 (Survivability), (see Annex ***Figure 10***) the weighting of the criteria is based on subjective judgments from the partners in the MARINA project which contribute to the inevitable uncertainty in the assessment. A final assessment of the combined concepts with overall scores was created.

As a consequence the basic group with the 10 selected concepts was defined (see Annex ***Figure 11***) and further analysed to be reduced to 3 concepts in the final phase of evaluation. The 10 concepts were therefore investigated in more detail with the same 5 criteria applied again this time on a more detailed data base that unfortunately was still very limited for certain concepts.

Task 3.4 Future viability prospects for a restricted selection of concepts

In this Task 3.4 the deliverable D3.5 "Executive recommendations on integrated solutions for ocean energy development" has been created.

Based on the overall assessment, the following concepts were then selected for further study in the third phase of the MARINA Platform Project based on the additional inputs from WP4 for the specific concepts. With the data fed into WP3 at a later stage that contained far more detailed design analysis with more detailed data about the concepts, the following concepts were chosen after the application of the 5 criteria.

- The STC (spar-torus-combination) concept.
- Semi-submersible wind turbine(s) with several point absorbers. Here 2 systems were investigated: the W2Power based concept with two wind turbines and the single turbine SFC concept with rotating flaps.
- Large floater with OWC array and one wind turbine, which also allowed applying the procedures, tools and cost models to a very large concrete structure.

The **STC (spar-torus-combination) concept** (see Annex, ***Figure 12***) 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.

The Semi-submersible wind turbine with several point absorbers in the form of flaps or rotating buoys is called the SFC concept (Semi-submersible Flap Combination) and the W2Power based concept were chosen for further analysis.

The **W2Power based concept** (see Annex, ***Figure 13***) 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.

The SFC (Semi-submersible Flap Combination) concept (see Annex, ***Figure 14***) 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.

A large floater with **OWC (Oscillating Water Columns) array** (see Annex, ***Figure 15***) with one wind turbine was also selected. This concept allows the tools to be checked for very large structures that furthermore also are realised 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).

The concepts STC, SFC and OWC Array were passed to the other WPs for further studies.

In WP3 also the public report "D3.6 Overview of offshore wind and ocean energy technologies" was created. The deliverable gives an overview on the main technologies currently used in wind and ocean energy conversion. It gives an outline of some existing combined wind and ocean energy combined concepts and considers the potential synergies and constraints in combining the technologies based on the information gathered.

WP Description	*WP Leader*
WP4 – SYNTHESIS – MODELING AND TESTING	**NTNU**

WP4 Synthesis – modeling and testing

The aims of WP4 have been to develop numerical models and methods for dynamic analysis of combined concepts in stochastic wind and waves, to conduct model tests of selected concepts and to validate the developed numerical methods, and also to study the performance of these concepts with respect to functionality (power production) and survivability (structural integrity). The ultimate goal is to develop methods that can be applied to estimate power production and to perform structural and component design, which can be further used to assess the cost of energy of combined concepts. The following three tasks are defined in WP4,

- Task 4.1: Mathematical modelling and numerical simulation (deliverables D4.1 and D4.2)
- Task 4.2: Control strategies (deliverable D4.3)
- Task 4.3: Laboratory testing (deliverable D4.5)

In addition comparisons between model test and numerical results to validate numerical methods are reported in D4.4, and the activities in WP4 are summarised in D4.6.

In the first part of the project – until end 2012 – the focus of WP4 was given to the simplified methods for modelling and analysis of combined concepts for concept assessment and selection (D4.1). Analyses of some 10 different concepts were considered. In the last 18 months the main research efforts were related to numerical analysis of three selected floating facilities using refined numerical methods and their validation against model test results. These three concepts are: a spar wind turbine (WT) combined with a torus wave energy converter (WEC), the Spar-Torus Combination or STC, a semi-submersible WT combined with three flap WECs, the SFC, and a large floater with multiple oscillating water columns and one wind turbine, termed the OWC Array.

The STC concept served as a main example in methodological studies of simplified methods focused on the possible synergy determining aerodynamic loads, extreme values by using the contour surface method as well as long-term fatigue load effects. Model test of the STC in extreme conditions were conducted in two laboratories – with additional funding - considering two survival modes: the torus locked to spar at the mean water level (MWL mode) and the torus locked to spar at a submerged position (SUB mode). The numerical model was then validated against model test measurements for both modes.

Design and analyses of the SFC concept were carried out in a joint effort between WP3 and WP4. Numerical analyses of the SFC concept were done both in full and model scale. The experiments carried out for this concept addressed both functionality and survivability. Particular efforts were devoted to the numerical analysis to the multi-body hydrodynamics and to experimental techniques for measuring the internal forces/moments in the structural component (flap arms and semi-submersible pontoons). The results from the experiments and numerical analyses of operational and survival conditions in regular waves were compared.

While the STC and SFC concepts could be considered as wind turbines equipped with wave energy converters, the OWC Array concept essentially is a very large floater with multiple WECs - for which the hydrodynamic loads are dominant. The complexity of the geometry of the floater with 20 air chambers makes the analysis of wave loads and the motion behaviour, challenging. Therefore, the comparison between the numerical analysis and the model test is focused on the hydrodynamic aspects – i.e. WEC performance.

Analysis and Design

In general, two different ways of combining wind turbines with wave energy converters were investigated, namely a floating WT with add-on WECs (such as the STC and the SFC concepts) and a WEC-dominated large floater concept with WT on it (such as the OWC Array concept). In the first combined concepts, the WEC represents a very small contribution to the displacement and also to power production. 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, see D6.4.

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, see D6.4.

The principle of designing a WEC to have resonant motions in waves as a means of maximizing power production has led to a challenging situation for the survivability of a combined concept in extreme conditions due to excessive motions and associated nonlinear wave slamming loads. A different survival mode should be considered to reduce structural responses and therefore to achieve a cheap design. For example, 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.

Experimental methods and observations from model tests:

Model tests of combined wind and wave power concepts are challenging, in particular to represent the WT and WEC PTO systems for functionality testing and to perform tests in extreme wind and wave conditions in which strongly nonlinear hydrodynamic phenomena were observed. Functionality and survivability model tests of the SFC concept were performed in the ocean basin at ECN, France. The functionality and survivability tests of the OWC array were carried out in the ocean basin at HMRC/UCC, Ireland and at ECN, respectively. Test models of both the SFC and OWC Array concepts in the ocean basin at ECN are shown in Annex, ***Figure 16***. The motion behaviour, structural responses and power performance of the combined concepts in turbulent wind and random waves were studied. Survivability tests of the STC concept in two draft conditions were carried out in the towing tank of Marintek, Norway and the towing tank of INSEAN, Italy, with financial support from CeSOS/NTNU and the MARINET projects, respectively. However, the numerical analyses of the STC concept, as well as the comparison between the numerical and experimental results were reported in the MARINA project.

A scale factor of 1:50 was considered for all of the model tests. WT was modelled as a disc in the STC test, a thruster in the OWC Array test at HMRC, and a redesigned rotor for the SFC and OWC Array tests at ECN. The main issue was to model the thrust force correctly so that rigid-body motion of the floater due to wind turbine loads could be correctly represented in the model test. The Froude law for hydrodynamic load similarity was considered for all of the model tests together with geometrical and kinematic similarities. The obtained Reynolds number is then very small in such model test condition, as compared to the full scale value. This lead to a redesign of the WT blade for the model tests at ECN.

The PTO system of the SFC WEC concept was modelled using a rotary viscous damper attached to the shaft of the flaps, while orifices with adjustable diameter were used to represent the OWC PTO.

Significant efforts were also spent on the instrumentation of the test models, in particular to measure motions of multi-bodies (SFC), contact force between two bodies (STC), internal structural loads (SFC and OWC Array), free surface elevation and pressure in the air chambers (OWC Array), and mooring line tension.

Regular and irregular wave tests show that the motion behaviour of the SFC and OWC Array concepts in operational conditions is reasonable and the power production is as expected. The flap-type WECs do not change the motion behaviour of the SFC significantly, while adding a WT on the OWC Array floater does not influence the global motions of the floater.

In view of the motion characteristics in extreme wind and wave conditions, the SFC exhibits the best behaviour with no strongly nonlinear hydrodynamic loads (which could potentially cause severe structural damage). The STC experienced severe wave slamming on the torus in extreme waves when it is locked to the spar at the mean water level, while the wave loads are significantly reduced when the torus is submerged. The critical issue observed for the OWC Array in extreme conditions is related to the water jet in air chamber with open orifice due to large waves and excessive platform motions. This indicates possible severe water impact force on the air turbines for a full scale facility. One possible solution is to close the air chamber and the effectiveness was demonstrated by the model tests with orifice fully closed.

Results from the model tests of the three combined concepts were reported in D4.5. Moreover, the model testing has led to the development of experimental techniques as well as providing a basis for validating numerical methods and tools, which could be used for design analysis of generic floating combined concepts.

Numerical tools and validation against model test measurements:

The main challenge in numerical analysis is to address both aerodynamic and hydrodynamic loads as well as the coupling effect of wind- and wave-induced responses. Due to nonlinear aerodynamic loads on wind turbines and application of automatic control, as well as nonlinear hydrodynamic loads on floater and WECs, time-domain numerical simulation methods are preferred. There are no tailor-made methods (software) available for combined WT and WEC concepts. The basic approach has therefore been to combine and extend existing methods to this application. As an example, the numerical tool Simo-Riflex-AeroDyn was introduced and applied to the analyses of the STC and SFC concepts. The numerical model of the SFC concept in Simo-Riflex-AeroDyn is shown in Annex, ***Figure 17***. A particular issue has been to address refined as well as simplified methods – the latter being necessary to reduce computational efforts in conceptual design, especially in optimisation studies, and control. Refinement and simplification relates to both mechanics and probabilistic models. Simplified methods for dealing with aerodynamics and hydrodynamics were considered. Use of the so-called contour surface method to deal with the long-term variability of environmental conditions in connection with extreme value predictions, is considered.

D4.1 deals with analysis methods for design check with respect to stability and motion characteristics of a floating structure, power production as well as ultimate and fatigue limit states. The focus was given to the numerical methods in order to obtain global responses under both wind and wave loads. In particular, simplified methods for aerodynamic and hydrodynamic load analysis as well as motion and structural response analysis were presented and applied to conceptual study of a floating combined concept. D4.2 deals with refined methods for coupled dynamic response analysis of the three selected concepts were discussed and presented. Normally, the automatic control of a WT with respect to power maximisation for below-rated wind speeds and load reduction for above-rated wind speeds is considered in time-domain analysis tools. A numerical model of the WEC PTO system and the control strategy for different sea states should also be modelled in the global response analysis of a WEC. These issues related to automatic control of combined concepts are discussed in D4.3 and in particular, a model-based controller was developed for the STC concept.

Numerical models and tools for global dynamic response analysis were developed and applied to analysis of the full scale version of the three combined concepts by partners in WP4. Results of power production and structural responses were used for design check and assessment of cost of energy in WP6 (see D6.4).

In order to validate the numerical tools, numerical models mainly of the three selected concepts but also other concepts, were developed considering the actual models that were tested in the laboratories and simulation results were compared directly to the model test measurements. Comparison of the regular and irregular wave cases indicates that as long as there are no strongly nonlinear hydrodynamic loads, the motion responses predicted by the current numerical tools (e.g. Simo-Riflex-AeroDyn, including 1st and 2nd order wave loads and coupled with wind turbine aerodynamics) compare well with the model test results. Comparisons of the selected internal structural loads are also reasonable. For resonant motions, a better viscous model is necessary to achieve a good agreement. The current numerical tools cannot model the strongly nonlinear wave loads such as slamming loads. Further development of such tools taking into account the specific nonlinear wave loads should be considered. CFD approaches may be necessary to apply towards this aim.

For the STC concept, when the torus is in the survival mode with full submergence, the current numerical tool (Simo) can well predict most of the responses both in regular and irregular waves, including motions and internal force between the torus and the spar. The time-domain analysis tool can also capture well the time series of responses when the wave elevation measured in the test was used as input to the numerical model. When the torus is locked to the spar at mean water level, the numerical tool can also predict the responses well for operational conditions in which wave slamming does not occur. When wave slamming on the torus occurs, predicted vertical forces between the torus and the spar are underestimated.

For the SFC concept, only a more limited number of comparisons have been made. The comparison of RAOs of semi-submersible motions and flap rotations for both the functionality and survivability models shows an overall good agreement between the numerical and experimental results for regular wave cases. However, the numerical model (Simo-Riflex-

AeroDyn) predicts higher platform pitch motions and WEC rotations around the natural periods of WEC rotation motions, indicating a smaller viscous or PTO damping effect in the numerical model. The RAOs of platform motions and WEC rotations were found to be similar for both the functionality and survivability models.

Closer inspection of the OWC Array concept indicates that the frequency-domain hydrodynamic analysis based on the potential theory code NEMOH can also be used to some extent to predict the platform motions reasonably well except the resonant motions, for which a better viscous model should be considered in the numerical analysis.

WP Description	*WP Leader*
WP5 – Technology Risk Assessment	**NTNU**

WP5 Technology Risk Assessment

WP5 has aimed to develop/review risk analysis methods and apply them in assessing risks associated with installation, O&M and survivability of wind and ocean energy facilities. Risk reduction measures involve site selection, system design, inspection/monitoring and maintenance.

Task 5.1 - Protocols for risk related assessment

The objective of Task 5.1 was to define the methodology for risk assessments of combined deep offshore structures to be used in WP5 as a basis for the assessments of the ensuing tasks. The work in the task has resulted in the following deliverables:

- **Deliverable D5.1** - Overall methodology for risk assessments
- **Deliverable D5.2** - Case study (confidential) - Recommendations for development of guidelines and standards on integrated MRE systems

In D5.1 relevant methods have been reviewed in the context of marine operations. Two case studies are presented to demonstrate some of the methods applied on combined offshore energy converters. The methods presented are relevant for traditional HSE risk (health, safety and environment), as well as for events that are threatening the possibility to install a combined offshore energy converter, events that causes long term interruption of energy production and other events that are threatening the development of offshore energy utilisation. The report covers (i) Hazard and operability study (HAZOP), (ii) Failure mode and effect analysis (FMEA), (iii) Fault tree analysis (FTA), (iv) Event tree analysis (ETA), (v) Human reliability analysis techniques (HRA), (vi) Markov Analysis, (vii) Risk based inspection (RBI) and (viii) Reliability centred maintenance (RCM).

In contrast to the detailed methods listed above, a very rough assessment approach to be used to rank concepts in an early stage with respect to risk contribution was also developed and tested. The method does not aim at a detailed modelling of risk scenarios, but rather structuring the uncertainties for each concept. This was accomplished by identifying a set of generic undesired events with rough assessment of probabilities and consequences. The source of the undesired events was related to the *life cycle phase* for which they become most critical. The following life cycle phases were used: (i) ***Design/manufacturing*** – This phase included the process to design the concepts, and manufacturing them ready for transportation, (ii) ***Installation*** – This phase included the process to transport the installations to the field, and complete the installation, (iii) ***Operation*** – This phase included the normal operation of the converters, including shutting down in case of bad weather, optimizing pitching etc., and (iv) ***Maintenance*** – This phase included the activities of preventive and corrective maintenance. Here is also included outage due to failures (reliability).

In D5.2 recommendations for the development of guidelines and standards on integrated multi-renewable energy systems have been provided. The first part of this work was to present an overview of the potentially applicable standards for MRE and relevant standards in related sectors (shipping, offshore oil & gas, wind energy…) that could be extrapolated to multi-purpose platforms. The last part of the work was to propose a risk-based approach presented in a prospect of application to the most innovative and unknown parts of the platform, and for a global review of the system. The main elements of this approach are shown in Annex ***Figure 18***.

Task 5.2. Deployability

The objective of Task 5.2 was to develop methodologies for assessing the deployability of deep offshore combined platforms. Depending on the design of the platform there will be constraints on installation resulting from needs for installation infrastructure (e.g. high capacity tugs, anchor handling ships, piling & heavy lifting barges), from construction and port facilities as well as weather windows based on environmental data. The work in the task has resulted in the following deliverable:

- **Deliverable 5.3 –** Report on risk assessment of deployment

The principal content of D5.3 is a list of deployment methods for fixed foundations and floating foundations. Then a preliminary hazard analysis (PAH) is conducted for each phase of each deployment method followed by identified mitigation measures for the hazards.

D5.3 has elaborated on the following steps for *fixed foundations*:

1. Geotechnical investigations
2. Jack-up positioning
3. Piling
4. Transition piece installation: a) Lifting of the TP, b) Landing and levelling/fastening of the TP by means of hydraulic jacks and/or temporary brackets, c) Grouting of the space between the TP and the monopile, and parallel levelling of the TP, d) Removal of hydraulic jacks
5. Tower and wind turbine assembly
6. Jacket installation: a) Jacket positioning, b) Fixation methods with post-piling and pre-piling
7. Scour protection installation
8. Cable installation

For *floating marine renewable energy devices* the following steps are considered:

1) Anchor installation a) Installation Procedure for Drag Anchors, b) Installation Procedure for suction piles
2) Towing
3) Mooring connection: a) Preparation, b) First connection stage, c) Final connection stage
4) Cable installation: a) Dynamic cable, b) Connecting dynamic and static cable, c) Introducing cable in structure

Task 5.3. Operability – Surveillance and Condition monitoring

The objective of Task 5.3 was to investigate condition monitoring methods and tools relevant for maintenance of offshore combined platforms, and secondarily to look at condition monitoring methods together with classical preventive and corrective maintenance in a broader context. The work in the task has resulted in the following deliverable:

- **Deliverable D5.4** Methods for optimal operability: focus on surveillance & condition monitoring

Condition monitoring is considered to be one of the most significant technology developments as part of the so-called Third Generation of Maintenance. D5.4 presents the idea behind condition monitoring. Next the ISO13374-1 phases of condition monitoring are introduced: (i) Data Acquisition, (ii) Data Manipulation, (iii), State Detection (iv), Health

Assessment, (v) Prognostic Assessment and (vi) Advisory Generation. Each phase is then discussed and examples given. D5.4 presents theoretical results (e.g., mathematical models) regarding condition monitoring applicable for maintenance optimisation. D5.4 also presents the following condition monitoring techniques: (i) Vibration Measurements (ii) Structural Health Measurements, (iii) Oil Measurements, (iv) Generator Measurements, (v) Metrological Measurements, and (vi) Remote Visual Inspection.

Task 5.4. Maintainability and maintenance strategies

The objective of Task 5.4 was to use the developed framework in previous tasks of WP5 to develop the maintenance strategies on component and system level. The work in the task has resulted in the following deliverable:

- **Deliverable D5.5** - Methods for optimal maintainability and maintenance strategies
- **Deliverable D5.6** - Reliability data

D5.5 reviews relevant maintenance optimisation models relevant for marine renewable energy devices. First analytical models are presented. These models are rather simple, but are fast and effective to implement. A case study is performed where three maintenance strategies are compared: (i) Age based replacement, (ii) Online condition monitoring, and (iii) offline condition monitoring. With the assumptions made, condition based maintenance does pay off. Further the case study shows that offline monitoring is better than online due to the assumed rate of false alarms of online condition monitoring.
A weakness of the analytical methods is that they are not flexible in the modelling of the influence of the weather, the number of vessels, the capabilities of the vessels etc. Therefore the MARINA_RAMS_Executor has been developed as part of the work in WP5. The MARINA_RAMS_Executor is a discrete event simulator prototype written in MS Access. Case studies were preformed to assess the influence of environmental limitation of vessels (limit on wave heights), number of vessels and maintenance interval of critical components.

In order to assess the reliability of multi-purpose platforms for marine renewable energy it is required to have reliability figures like failure rates for the components and systems of such platforms. D5.6 reviews some literature on publically available reliability figures for onshore wind turbines. Since the reliability data only exist for the wind turbine elements of a multi-purpose platform, methods and data are required to assess the reliability of other components than those of the wind turbine. To accomplish this, a method is proposed where each sub-system of the multi-renewable energy platform is analysed in terms of “generic” entities. Next, overall relevant data from the offshore oil and gas industry is presented where it is possible to judge and validate this data for the entities being analysed. The failure rates assessed by the proposed method were used both in WP5 and WP7.

WP Description	*WP Leader*
WP6 - Economic Feasibility Assessment	**Technip**

WP6 - Economic Feasibility Assessment

The aim of this Work package is to assess, on the “validated concept” level of detail, the cost and energy benefit of integrating wind and ocean energy technologies including non-energy uses.

The analysis of cost of electricity has been carried out in a first step using generic parameter. A detailed analysis has been performed later on the selected concepts. Synergies between ocean energy technologies and non-energy uses have been analysed separately, for the 3 concepts selected.

The flowchart (see Annex ***Figure 19***) presents the methodology applied for the different tasks in WP6 with their interface with other Work packages.

The conclusions of the studies performed within the Work package are given below, following task results.

TASK 6.1 Analysis of the different life-cycle cost influencing parameters

In Task 6.1, life cycle cost contours were established. Parameters for the different steps in the life-cycle of an offshore energy system were evaluated on a conceptual level, including key parameters that will influence the cost of the life-cycle stages. The risk assessment and the cost estimate over the life-cycle include all the phases of a project: development and prototype, manufacturing, logistics, harbour and facilities, site construction, installation, commissioning, O&M and decommissioning.

The relevant cost parameters were divided into their important cost driving factors. The factors were weighted according to their influence onto the cost parameters. A separation of weighting factors into different categories was performed to allow visualisation of the influence onto the different cost categories like CAPEX and OPEX. Two further categories for weighting Yield and Risk were added to allow also to judge about the possible influence on revenue and risk for the project tied to these factors. A dependency matrix was generated to show the influence of the different parameters onto each other. Interdependencies were added in a descriptive way to each of the parameters. To illustrate the actual impact on the overall Life Cycle Cost, cost breakdowns for the involved technologies were added to allow a direct view on how much the parameters actually influence in the overall project.

TASK 6.2 Value of Identified Cost Reducing and Energy Saving Synergies

The objective of this task in WP6 was to identify potential cost-reducing and energy-saving synergies that might be obtained through the combination of energy systems and non-energy applications, seen as potential sources of revenue, in the context of offshore renewable energy development.

Possible non-energy sources of revenue were identified based on the comprehensive catalogue of possible uses created in D7.5; a selection was made to assign economic value to the “additional use” of platforms and offshore farms and compare costs.

A new, replicable methodology was developed to identify synergies in offshore systems combining wind & ocean energy with alternative (non-energy) sea uses.

This methodology compares CAPEX and OPEX of the offshore energy installation, of the non-energy application, and of the hybrid solution that comprises both. In doing so, the technologies are considered separately as well as together. See Annex ***Figure 20.***

After a screening of the many theoretically conceivable combinations (by simple “traffic-light” diagrams), the methodology was applied to three specific illustrative case studies, each combining farms of one MRE 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.

CAPEX and OPEX for the energy platforms was calculated by the Excel cost model using the same parameter set as in previous WP6 work, with modified assumptions to avoid assessing projects that would be entirely uninteresting from an economic point of view. (In fact, the three cases considered only as wind/wave sites were marginal, *i.e.* displaying near-zero IRR using the Task 6.2 assumptions). Next, CAPEX and OPEX for the alternative activities at each site were calculated from mainly literature data.

In an attempt of mitigating these large uncertainties, a sensitivity study was adopted that takes into consideration “good” effects (when savings are maximum and added cost minimum added costs) and “poor” effects (maximum added costs, minimum savings) resulting from the combination of the two economic activities. This sensitivity analysis was accompanied by a sensitivity analysis of the revenue from generated power (by using different levels of FiT) *vs.* that from the alternative sea use (using different but market-relevant salmon, algae and desalinated water prices).

Some findings are summarised in the Table below. Whereas cost analyses were made on a farm level (normalised to 400 MW rated power) numbers given are per platform.

CASE	base CoE [€/kWh]	Energy production [GWh/y]	Added revenue from alternative sea use [million €/y]	Added cost [million €]
W2Power with salmon farming	0,130	32.6	1,048	~ 0
STC with Laminaria algae culture	0.160	17.9	0,525	+4.6 million €
WaveDragon with wind turbine and RO desalination	0.163	11.2	0,772	-0.5 million €

The cases studied thus display one positive synergy (little or negative added cost, with a significant added revenue from the non-energy activity), one with neutral synergy but still substantial added revenue, and one with negative synergy *i.e.* high added cost but little added revenue. Obviously, these numbers are associated with large error margins especially for the non-energy uses and it is important not to decouple the results from the assumptions used.

Nevertheless the cases show clearly the inherent power of the new methodology. Some other interesting observations were:

1. The revenue from an additional use can reach significant amounts compared to that from power sales (though in all cases clearly less). Considering the likely different profit margins, this indicates that there might be options to develop new “clever” business models resulting in profitable combinations where the added use can pay back the added cost in a short time.
2. Location influences heavily the chance of finding positive synergy: What might be a positive synergy in one location might not be in another. Hence, the location for this new kind of combined system must be critically decided to satisfy the requirements of both the systems in the best way.
3. Neither a large difference in CAPEX and OPEX between the energy use and the non-energy use, nor having few overlapping functions or components for the two uses, are indicative of negative synergy.

Despite the high level of uncertainties, it does appear from these results that seaweed farming combined with offshore energy production may lack interesting cost synergies: the added cost of combining a farm of STC’s with *Laminaria* cultivation between spar buoys is clearly too high, and potential added revenue clearly too small. Fish farming and desalination do offer more promising opportunities. In particular, it emerges that in both cases of salmon farming combined with W2Power and seawater desalination with (wind-enabled) WaveDragon, the additional use could potentially bring a hypothetical development from yielding near-zero returns (i.e. with no chance of ever being built) to become a potentially viable business. Hence, the subject would deserve closer study.

Task 6.3 - Develop life-cycle cost model defining cost drivers for all the phases influencing life cycle

The life cycle cost model was developed in response to remarks and improvement proposed by WP6 industrial partners. Continuing from the work within Task 6.5, a model was developed allowing the user to calculate, in a few steps, the expected Cost of Energy of a device at a specific location. This Excel based tool was later transformed into Java based software allowing statistical cost analysis and with a user-friendly interface. Later the Java model was extended with the introduction of probabilistic and statistics and access to more detailed information about the resource characteristics.

The transfer from the deterministic to a probabilistic model was carried out on a phased basis. Initially, the transfer included re-coding of all elements of the deterministic model described in D6.5. Additional inputs, including a model to calculate the mooring cost by one partner and a concept-specific method to calculate power output from combined devices through the WEC power matrix and the wind turbine power curve, have been included in the model.

The software that has been Java coded is defined as modular software divided into 5 different modules: software parameters, environmental conditions, economic costs, the platform data (fixed or floating) and the analysis of results. See Annex ***Figure 21***.

- **Software parameters:** Input parameters to execute the software.
- **Environmental Conditions.** A specific site is chosen in which to assess the performance each concept. A number of pre-defined options are available to choose from. These sites were chosen through WP4 for the structural design and extreme response analysis for the concepts. These sites are detailed in “Environmental Data at Five Selected Sites for Concept Comparison”.
- **Economic costs.** In this module, data concerning unit costs such as the cost of steel, concrete, etc. are set as inputs. To reduce the uncertainty regarding these parameters, they can be defined as values of probabilistic distributions.
- **Platform data.** In this module, users input data relating to the structure used. The data must be fixed values according to the analysis performed in WP4.
- **Analysis of the results.** With the data that has been input in all of the previous modules the software computes the cost of the structure given specified environmental conditions producing results including COE, NPV and IRR. This module also presents different breakdown charts of the costs of the structure.

Further refinement includes, from WP2, the statistical analysis of the ten-year hindcast wind/wave data (2001-2010) focusing on methodologies for local adaptation of results and an accurate representation of the micro-climate of areas of interest. This analysis includes conventional statistical measures and probability distribution fitting tools to support the risk assessment concerning operations and maintenance with emphasis to possible extreme conditions.

Moreover, a detailed evaluation of hindcasted data against available observations and the selection of representative model grid points for areas with increased wind/wave power potential have been done. Appropriate statistical measures and methodologies are applied for integrated wave parameters such as the significant wave height, wave directions, mean and peak period as well as the full wave energy spectrum.

TASK 6.4 Detailed Life Cycle analyses for 3 selected concepts

The primary objective of this study was to collate results from all WPs to assess the energy balances, risk figures and life-cycle costs for the three concepts, and provide a basis for the final evaluations.
The economic evaluation highlights the differences between the STC and SFC on the one hand, and the OWC Array on the other hand. Whereas direct comparison of the results is difficult, the common test is whether the three concepts studied here have achieved the project objective of producing an effective multi-purpose MRE platform concept that can be taken to the next stage of development.
For this study, effectiveness is determined as adding value with the ultimate aim of producing, or having the potential to produce, a cost effective combined MRE platform.
This final energy, risk and cost analysis has illustrated some of the primary advantages and disadvantages of each concept. The OWC array produces a significant amount of wave power contributing almost 50% of the platform production potential at sites 03 and 14 (see Annex *Figure 9*). Yet the CAPEX and OPEX costs due to the size of the structure and the multiple devices comprising the WEC ultimately result in a high CoE.
The STC and SFC naturally prove cheaper in both CAPEX and OPEX considering they comprise quite small WEC devices per platform. However, their WEC contribution to the power production is relatively nominal while adding complexity to the platform in terms of the risk and cost when compared with a single WT.
The overall assessment of the three concepts analysed is summarised below:

Energy analysis

- OWC Array energy balance is almost 50% wind and 50% wave contribution at both sites
- STC & SFC show 3 to 6% contribution from WECs (and the STC some added production from wind due to the presence of the torus WEC).

Risk/reliability analysis

- OWC array – higher risk and more maintenance but redundancy in design to optimize power production.
- STC & SFC – increases risk and maintenance for a single turbine without any major additional production.

Cost analysis

- OWC array – High platform CAPEX and OPEX costs, resulting in high CoE.
- STC & SFC – 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.
While a significant amount of analysis has been done, there are a number of limitations highlighted throughout the study that need to be considered when reviewing results and before reliable conclusions can be drawn. These include:

- Different levels of concept analysis and lack of detailed information
- Uncertainties in inputs and assumptions for risk and costs assessments
- Inadequate cost information
- Inadequate reliability data for offshore wind and particularly wave energy
- Site dependency of analysis

However, the general trends outlined in this study may provide the basis for future work and analysis.

It is evident that all three concepts have advantages which offer valuable lessons for the future development of multi-purpose as well as single MRE devices. For example, the single WT and WEC comparisons indicate that concepts contributing nominal wave energy to wind power do not provide significant benefits, while adding wind power to a large WEC could make a significant impact on the overall cost of the energy produced. Therefore, the three concepts studied imply that there are synergies in combined platforms for wave energy but further work would be needed to demonstrate any potential added value for wind power.

WP Description	*WP Leader*
WP7 – Critical Component Engineering	**HMRC University of Cork**

WP7 – Critical Component Engineering

Introduction

The aims of this work package were to identify the critical components for wind and wave energy integrated platforms; to develop risk assessment methodologies for these critical components; and to produce a toolbox to support the design and evaluation of system components.
WP7 was divided into a series of tasks according to the component systems of a combined wind and wave energy platform i.e. the platform and moorings (task 1), the wind turbine (task 2), wave energy device (task 3) and the integrated electrical components (task 4), with two additional tasks dedicated to the reliability of the components (task 6) and looking at the

feasibility of introducing other uses to the platform (task 5) e.g. aquaculture or hydrogen storage.
A number of outputs have been produced by WP7, some of which are public (denoted by "PU"). The following is a description of some of the key outputs and findings.

Tasks 7.1- Platform Components and Moorings / 7.2 - Wind Energy System Components / 7.3 - Ocean Energy System Components

The deliverable **D7.1: Critical assessment of platform and mooring components** identifies critical aspects of platform integrity and stability, mooring system and dynamic power cabling and gives an outline of the relevant state-of-the-art design methods, components and software used in the offshore oil and gas industry. Only selected critical components are discussed which were identified through a HAZID analysis.
During the preparation of D7.1 it became clear that a more detailed report later in the project would be useful to document the design work and findings. The deliverable **D7.9: Detailed platform and mooring design for concepts** describes the specific mooring design and analysis for the 3 final selected MARINA Platform project concepts. These are each very different in terms of platform type and required mooring style with 1) a barge platform, 2) a semi-submersible platform and 3) a spar platform.

The purpose of the deliverable **D7.2: Critical wind and ocean energy components** was to provide the options for wind and wave energy power take-off (PTO) components and to evaluate the criticality of these. The criticality of a component is not only related to its failure frequency and impact but also related to overall mass, efficiency, and cost. The report represents an introductory outline for different technologies used for wind turbine blades, wind turbine drive trains and ocean energy system components and is structured in two parts: wind turbine components (materials, failure modes, and condition monitoring for blades and PTO systems) and ocean energy PTO systems (including air turbines, hydraulics systems and direct drive). This report includes a description of tools designed to calculate cost-mass ratio for blades and to estimate the mass and efficiency of different PTO systems.

The deliverable **D7.3: Power take-off and integration components** was an internal deliverable and summarised the power take-off systems and power aggregation options specific to the final three concepts. It reviews the power aggregation methods for wave and wind energy components and the effect of a floating wind turbine on a direct-drive permanent magnet generator was investigated. Marinisation options for bearings and permanent magnet generators are discussed.

Task 7.4 - System Integrated Components and Control

In **D7.4: Wind/ocean environment input to wire output modelling toolbox** a complete pneumatic power to wire model was developed in Simulink for the Multi-Oscillating Water Column Platform (also known as the "OWC Array") concept to investigate the various interactions between the coupled components; wind and marine resources, energy conversion devices, drive train, generator, and power converters. A MARINA Platform Design Toolbox was also developed which guides the user through the design process for the OWC concept. The outputs from this toolbox were then used to populate the Simulink model. This document provides background information on the design process implemented in the toolbox, including characteristic curves and equations normally used to describe the various components. Full instructions for using the toolbox are provided in addition to an overview of the wave to wire Simulink model. This is the first tool to model the power flow through a combined wind and wave energy device from resource to grid in detailed time series using input from physical and numerical model testing.

The deliverable **D7.8: Power quality of combined wind-wave collection systems** considers the power smoothing effect of combining wind and wave energy generation devices with a comprehensive review of the power converter technologies relevant to these concepts. It focuses on the conversion stages required offshore, prior to the power transmission to shore (HVAC, HVDC); grid connection and long-distance power transmission are covered by other WPs within the project.

Harvesting energy from the wind and from ocean waves is quite a complex task, involving several stages of energy conversion and conditioning. One of the problems is that power from natural energy sources is intermittent, variable and normally does not match the actual requirement of the utility grid. The energy conversion and conditioning system has therefore the primary objective of efficiently conditioning the energy from wind and wave into a form that is readily accepted by the utility grid.

The power collection and conversion system can be selected to achieve one or more (possibly conflicting) design objectives such as; minimum overall collection and conversion losses; minimum total cost, including maintenance costs; maximum reliability; optimal power flow control; or optimal power quality.

The aggregation of multiple wave devices, or of wind and wave devices, in the one platform should provide some measure of smoothing to improve the power quality. However a cost benefit analysis would help to determine the optimum power quality/reliability/cost compromise. Additional smoothing will be achieved through the aggregation of devices in a farm and the optimum spacing of devices would need to be determined to achieve this for a given site resource.

Task 7.5 - Components for other potential platform uses

The deliverables **D7.5 (PU) & D7.10: Components for adaptation of platforms for other uses** addressed the opportunity to add additional uses to a combined wind and ocean energy platform such as those being considered in MARINA. The first report (D7.5) is publically available and provides a list of the additional equipment required to adapt the combined wind / ocean energy platform to other potential uses apart from energy generation. The report considered alternative uses such as hydrogen storage, aquaculture, fisheries, etc. The second version of the report (D7.10) was an additional deliverable which considers some of the findings of the EU funded “Oceans of Tomorrow” projects. The EU 7th framework programme projects TROPOS, MERMAID and H2OCEAN which examine various combinations of uses on a platform were included in the analysis. .

Task 7.6 - Component Reliability

One of the major interests in combining different renewable energy devices on the same platform is to avail of synergies in the maintenance strategy. Reliability will heavily influence cost and revenue. Excessive maintenance costs can be commercially prohibitive to even technologies with very high power conversion efficiencies. The consequence of failures in the harsh marine offshore environment is expensive and requires complex interventions. In addition the downtime due to the component failure will impact the energy production and thus project income. There is therefore a focus on Reliability, Availability and Maintainability (RAM) assessments to develop safe and economically viable technologies.

The deliverable **D7.6: Application of risk analysis to critical components** document presents the methodology, assumptions and results of a RAM assessment conducted on MARINA Platform concepts. The methodology described could also be used to investigate other offshore renewable energy technologies, such as offshore wind turbines, tidal turbines or wave energy devices.

Although necessary for a successful deployment at sea, reliability assessment in the offshore renewable energy sector is still in an early stage. Therefore, few if any RAM studies have been conducted for combined offshore platforms such as those in this project.

Significant components or systems of components associated with each task in WP7 were identified in the **D7.7: Preliminary critical component assessment** deliverable and within these subsets the critical components or subsystems are identified. This investigation was intended to be high level and qualitative, rather than a rigorous FMECA (Failure modes, effects and criticality analysis). It represented an introductory outline forming the basis for more detailed critical component analysis in D7.6 and fed into the risk related work package (WP5) in order to provide a more thorough criticality/risk assessment.

The report provided a brief explanation of the main components or sub-systems within each system as well as the key issues for that system, before providing a risk assessment matrix for each identified component.

Currently there is no available component reliability data for offshore wind and wave energy devices and, as a temporary measure, reliability statistics from other marine industries such as the oil and gas sector were employed. This oil and gas data was not related to the specific environment of offshore renewable energy, however, the data was at least representative of these systems in the marine environment. Due to the qualitative nature of the analysis described in this report it could be considered subjective however, in the absence of detailed reliability data, it provided a useful insight into the expectations and experience of experts in the field. This was a beneficial study due to the input it provided to the detailed analysis in D7.6 and also because it gave an indication of the reliability of such systems in these specific applications.

WP Description	*WP Leader*
WP 8 – GRID CONNECTION AND MACRO SYSTEM INTEGRATION	**DONG Energy WIND**

WP8 – Grid Connection and Macro System Integration

Task 8.1: European Grid Analysis

Task 8.1 of the project focused on transmission capacities and possible challenges that could arise with a large-scale future deployment of MRE platforms. The report of this task summarizes the current status and existing plans of transmission capacity in the European transmission network for the purpose of facilitating the integration of renewable energy sources. This survey was done with the purpose to identify potential locations of existing/planned infrastructure for co-implementation with respect to installing MRE platforms. It highlights the challenges in terms of flow limitations in the system based on possible generation and new load developments and gives an overview of transmission reinforcement plans. The survey contained in this document is based on a number of existing studies identifying the challenges of large scale renewable energy integration in Europe.

The focus of the report was on the west / north-west part of Europe and covers the Iberian Peninsula, the Bay of Biscay and the North Sea.

The major finding from the MARINA project analysis was that there were many plans for transmission system development in Europe due to plans for massive renewable energy integration, to facilitate market integration and for the purpose of security of supply. Many of the studies focused on the required reinforcements were based on estimates of a given number of GWs from new renewable generation in certain regions, and not on firm plans. Therefore these studies were to be considered as rather feasibility studies. Some of the areas where systems studied in MARINA could be a candidate were located within regions already identified as possible offshore wind sites without any firm plans. This suggested that such possible installations were not likely to come on top of existing plans but likely to be a part of such plans.

Task 8.2: Deep offshore Farm layout

An important area which needs to be taken into account is the infrastructure synergies by having wind and wave and power placed at the same site. Different aspects of electrical and physical layouts have been studied, resulting in a set of tools which can be used in the future analysis of synergies in the MARINA Project. The work has been based on generic concepts and may be tailor-made to specific devices by additional work. We have been looking at the layout from 4 different angles.

1. **Spacing guidelines:** Optimal use of the space available is important as this impacts the utilisation of the primary resources and the cost of local electrical infrastructure. Reduced output may become an unwanted side effect of reducing the infrastructure cost. A set of guidelines regarding the spacing of WECs within an array for minimisation of destructive farm effects have been prepared.

2. **Reactive power compensation:** Reactive power generation and consumption are important factors for some of the technologies used within offshore renewable energy farms. The reactive power produced by cables will strongly influence how far from shore such solutions can be applied
3. **Infrastructure and collection system:** An Excel/DigSilent based tool has been developed in this task that calculates the cost of electrical infrastructure as well as the collection system power losses.
4. **Short term MATLAB/Simulink tool:** A simplified short time-step (seconds) MATLAB/Simulink based tool for analysing power output profiles of combined wind/wave power plants has been developed.

Recommendations for electrical collection system:

Based on the investigations conducted in Task 8.2 some recommendations for optimum electrical collection system design for given locations, array configurations, and device technology types have been developed:

- A Radial String layout seems to be the most economical feasible array cable layout solution;
- Marine energy farms of installed power of less than 100-200 MW at a distance beyond 100 km from shore is likely to lead to excessive cost, and should therefore be avoided;
- HVAC connection is preferred for all power capacity levels (at least up to 2 GW), at distances below 100km;
- Very long connection distances (100-200 km) may be economically viable if combined with a very large installed capacity (preferably more than 500 MW);
- Large installations may still be connected through HVAC for distances in the order of 100 km; in those cases the use of midway compensation should be considered, as it may result in reduced overall cost, compared to HVDC;
- HVDC is definitely the best solution where very high capacity (1 GW or more) and long distances (more than 150 km) are combined

Task 8.3

Deliverable D8.4-“Efficient solutions for energy pickup and transport to grid connection point on shore” has been completed and distributed. The report has two parts: I-“State of the Art Analysis” and II-“Specific Site Analysis”.

In Part I, a state of the art analysis of physical components needed for grid-connection of combined wind and wave systems has been performed, including choice between DC and AC, selection of umbilical cables, high-voltage connectors etc. Capabilities of floating and fixed offshore substations have also been described together with potential underwater equipment (See Annex ***Figure 22***).
The main objective has been to define cost-effective solutions for distributing and connecting production units offshore as well as energy transport to shore, taking into consideration major critical issues, such as: location of the farm, farm power output and voltage levels.

In Part II, the objective has been to find a way to optimize the High Voltage infrastructure on selected sites using the knowledge gained in the previous tasks. Two different locations have been selected to make these studies, one in Spain and the other in UK (for both see Annex ***Figure 23***). Both have attempted to simulate the actual requirements for the construction of a 200 MW Marine Energy farm. Depending on the requirements defined in each site, different kind of solutions for distributing and connecting the energy generated have been considered.
The main points developed are: Farm layout (voltage levels, cable cross section), Pre-installation procedures (seabed survey and logistics) and Installation and commissioning procedures (platforms and device installation, cable installation).

The main conclusion of this task is that today, it is technically possible to undertake the electrical transmission that this kind of project entails, although certain aspects need to be further developed.

Task 8.4: Integration of MRE in Power Systems

This task focused on investigating cost-effective power production strategies for integrating power generation from Marine Renewable Energy (MRE) power plants into the existing power systems. The grid integration has been analysed from 3 different perspectives:

a) Grid and Compliance Capabilities of MRE Generation

b) Grid Integration of MRE in Potential Sites

c) Access and Integration with Electricity Markets

Generic analysis of the grid interaction of a combined MRE generation investigated plant-level controllers to be for compliance with most recent grid connection requirements (Grid Codes) in terms of voltage and frequency control. For instance, those under preparation by the European Network of Transmission System Operators for Electricity (ENTSO-E) were specifically considered.

Three specific case studies were undertaken, focusing on in-depth analysis of the implications of the network integration of MRE operating under as realistic as possible grid scenarios and operating conditions in different time-horizons. Case studies in Spain and the UK investigated MRE integration into the onshore high-voltage transmission system and the distribution grid respectively. Thermal and voltage related constraints have been identified as main integration constraints at both transmission and distribution system level. By deploying enabling technologies and advanced control schemes (Smart-grids), the constraints can be mitigated. The use of energy storage system in distribution grids was also investigated and the results showed that, in terms of saving energy otherwise curtailed under high penetrations, wind is exploited more than wave. A third case study focused on HVDC interconnections identified some examples of cases and situation that can cause stability problems in large-scale DC-based transmission schemes, but the system can easily be stabilised by adjusting system parameters or control strategies. As the identified issues are captured by small signal stability analysis of the system, traditional techniques for linearised system analysis can be used to aid the design and controller tuning of the system to ensure stability and improve the dynamic response.

As variable renewable sources, the interaction of MRE generation with energy market and the role of facilitating tools/technologies (incl. energy storage) have been investigated. This includes the role of system flexibility, intelligent grids, information technologies in the power system and visibility and controllability in power plant operations. On the role of resource forecasting tools, the analysis is supported by a practical example of the impact of forecasting in the business processes of a renewable generator. On the role of energy storage, a simplified best practice for integrating energy storage with variable renewables is introduced, based on existing industry practices and experience.

Presently, grid support services markets (Ancillary Services) are visualised as a prospective complementary business model for variable renewable generators, including MRE, to provide the electricity added-value products they can generate. Potential coordinating and balancing strategies for Ancillary Services were field tested, demonstrating that existing variable renewable generators, together with the facilitating tools/technologies for market interaction, have capabilities to participate in these types of markets. Finally, alternative business models for MRE generation were also assessed; specifically the direct supply to offshore users (offshore oil and gas platforms). The results from a number of case studies demonstrated that these applications are theoretically feasible. Thus, offshore users will result in new opportunities for offshore MRE generation industry to grow.

WP Description	WP Leader
WP 9 – Exploitation and Dissemination	**Tecnalia**

WP9 – Exploitation and Dissemination

The aim of WP9 Exploitation and Dissemination has been to coordinate and perform dissemination and exploitation activities addressed to facilitate the use of MARINA results for later market oriented RTD and demonstration projects.
The work was organised in different tasks producing a set of deliverables and information, some of them public and others restricted to MARINA partners.

Task 9.1 Definition of a dissemination plan
Task 9.2 Coordination with other National/International initiatives on Marine Renewable Energy
Task 9.3 Development of dissemination material & Dissemination activities.
Task 9.4 Training seminars
Task 9.5 Exploitation Plan

First activity of WP9 was the development of the web site, as a tool to share information within the consortium, and to share public information like deliverables, papers, etc. A preliminary version was available for the project Kick off Meeting, and a fully functional version was available by the end of March 2010. A screen image of www.marina-platform.info is shown in Annex ***Figure 24***.

In addition to the intranet login for project partners, there are different public sections describing the project partners and WPs, a calendar to show the project activities and a communication section with news, events and milestones. Documents and Publications section on the home page is the repository for the public information of the project, including deliverables, contributions to conferences and peer review papers. There are some links on the home page to the most relevant MARINA dissemination activities. A leaflet was produced as a tool to promote the project and summarize project plan, partners and WPs description. It is publicly available on the web site.

The Project web site was the first deliverable of WP9, *D9.3 Web site*. The second one was *D9.1 Dissemination Plan*. This report outlines the dissemination activities expected for MARINA Platform project, identifying the actions to be carried out during the project, the tools, and short-term activities planning. The document was updated periodically in order to reflect new dissemination opportunities. It was also used as the starting point *for D9.2 Dissemination material* and *D9.4 Material for training seminars* deliverables.

D9.2 collects all the dissemination activities carried out during the project. The first year dissemination activities were focused to present the project objectives and work plan in different conferences and events. Project coordinator and other members of the consortium presented MARINA in different conferences and during other FP7 funded project meetings, e.g. like ORECCA. As technical the WPs moved forward in their work a number of publications were produced, both for international conferences and for peer reviewed journals. As a summary,

- More than 50 contributions, oral and poster presentations, to international conferences such as OMAE, EWTEC, ICOE, EWEA... Most of them are publicly available on the Documents and publications section of the web site.
- Some 20 publications in peer review journals like Science Direct journals and Springer. Some of these publications are still in review stage, but most are already accepted and published. They are referenced on the Documents and publications section of the web site with a link to the publication for those with open access.
- Two papers were published in general audience publications, summarizing the project.

Besides the publications, MARINA partners organised two technical events, targeted to invited companies/institutions potentially interested in MARINA project research: a workshop held in Brussels in May 2013 with technical presentations of MARINA WPs and a training seminar held in Derio (Bilbao) with the tittle 'Assessment of combined Marine Renewable Energy devices: from the resource assessment to the model validation'.

- A MARINA dissemination workshop took place in Brussels, 14th May 2013, taking advantage of the 3rd General Assembly meeting and the 2nd period EC review of the project. The dissemination activity had a technical scope and was held in the Office at the Delegation of the Basque Country to the EU, in Brussels. All MARINA technical WPs (WP2 to WP8) presented their most relevant results and outlined the work to be done until the end of the project. Presentations contain technical information and procedures and are publicly available on the web site under Documents and Publications section of the home page.

In addition to MARINA partners, representatives from important European companies and organisations attended the event: EC, The Crown Estate, Ecole Centrale de Nantes, Dong Energy, EWEA, Statoil, Aalborg University. The H2OCEAN, MERMAID and TROPOS projects were also represented.

- The training seminar in Bilbao was focused on resource assessment, numerical modeling and model validation. In addition to MARINA partners, representatives from AZTI Tecnalia, Vicinay Cadenas, IH Cantabria and Oceans of Tomorrow projects – MERMAID, H2OCEAN and TROPOS attended the seminar. Technical information presented is publicly available on MARINA web site.

The topics addressed and the partners involved in the activity are summarised in the table below:

Resource analysis: met-ocean modelling, resource database and site selection. *NKUA, UEdin*
Numerical models validation and calibration: description of MARINA reference concepts and wave tank testing. *ECN*
Numerical modelling: overview of the numerical methods for modelling and analysis of combined wind and wave concepts; specific analysis results for each concept and the comparison with model test results. *NTNU, UCC*
*S*ummary of the activities carried out in MARINA project and the main outcomes

In addition to the above, other training activities are documented in *D9.4 Material for training seminars*. These activities include Universities training using MARINA project work, technical visits carried out in the framework of WP meetings, including Mutriku OWC wave power plant, Nysted offshore wind farm…- and cooperation with other FP7 projects. A special remark can be made concerning the EU-OEA Annual Conference on Ocean Energy, Edinburgh 29th – 30th of October 2013 where the MARINA project was represented by WP2 leader, The University of Edinburgh. Almost all current EU-funded projects on marine energy were on hand to present their work and raise awareness of their activities. In addition to the networking with other projects, MARINA had a presentation related to WP2 in the session 'QUANTIFYING THE RESOURCE'

The collaboration with other National/International initiatives is addressed also in another WP9 task: *T9.2*. The projects and activities carried out are identified in *D9.6 Plan for the Use and Dissemination of the Foreground*. As an example of this collaboration between FP7 projects, MARINA took part at ORECCA's KoM and the first periodic review of MARINA was held together with the ORECCA final review. A strong link was also established between MARINA and "Oceans of Tomorrow" projects H2OCEAN, MERMAID and TROPOS, which on several occasions were invited to MARINA workshop and training events as potential users of MARINA achievements.

The PUDF report was developed in two stages: a first draft developed during the first quarter of 2012 and the final version by the end of the project. The document describes the actions undertaken within the MARINA Platform project to ensure the use and dissemination of its main results in the future:

- the strategy aimed at protecting the intellectual property, including the procedures for publishing and patenting,
- the procedure for engaging with developers and other projects, and
- the expected impact of the project results.

A summary of the Dissemination plan is also part of the report content, including a list of the main activities carried out and the public deliverables released.
The report includes a section gathering the collaboration with other projects. This cooperation was based on using other projects results (CORES, EQUIMAR, ORECCA, WAVEPLAM, WAVETRAIN2, SUPERGEN, FINO, NOWITECH, RAVE), promoting other projects/initiatives (HiPRWind, INORE, MARINET), looking for future collaborations (ReliaWind, DeepWind, SEEWEC, TROPOS, MERMAID, H2OCEAN and SmartGrids European Technology Platform) and provide information to other EC funded projects (surveys, public results) such as MarineTT info Base, ECOWEB.

Public deliverables are also summarised in the document. After the first period review and following EC suggestions, the MARINA consortium decided to make public more deliverables than those identified as public in the Description of Work. In the last General Assembly held in Derio -Bilbao- it was decided to make public some more deliverables of the project. Public reports are available on the project web site under Documents and publications section.

In addition to increasing the number of public deliverables, it was also decided to make public some tools developed during the project: WP5-Risk Assessment provided an MS Excel file to support analytical calculations, and MARINA_RAMS_Executor for risk analysis; WP2-Resource Assessment developed a GIS tool to support the site selection for combined devices. The GIS and plugin-tools are available for public download via a data-sharing page on the Edinburgh University website, making it possible to continue MARINA work related to WP2 and keeping track of who uses it, stimulating its use and possible follow-up research.

The result of WP9 is explained in detail in the WP deliverables:

D9.1 Dissemination plan	Restricted to the consortium
D9.2 Dissemination material	Public
D9.3 Web site	Public
D9.4 Material for training seminars	Restricted to the consortium
D9.5 Draft – Plan for the Use and Dissemination of the Foreground	Restricted to the consortium
D9.6 Final – Plan for the Use and Dissemination of the Foreground	Restricted to the consortium

IMPACT – DISSEMINATION & EXPLOITATION ACTIVITIES

In the following the most important impacts of the MARINA Platform project are listed and summarised as well as the Dissemination and Exploitation related activities.

Strategic impact

The MARINA Platform project will have strategic impact on several policies of the EU and of those Member States with potentially exploitable marine renewable energy (MRE) resources. Following EU policies on applying RTD and innovation to societally urgent needs such as securing a more sustainable energy supply and climate change, MARINA has *introduced a scientifically funded, methodologically rigorous way of working with novel ideas for combined wind & ocean energy systems* and introducing these into the mainstream of offshore energy. This is a new contribution, which will have a strong impact on all three technological fields in which the project operates.

For *offshore structures,* MARINA significantly merges the excellent, but expensive practices from oil & gas with the focused, *cost-driven thinking* of the wind industry that is essential for the dispersed renewable resources at sea to be commercially exploited. Radical innovations are required, as the allowable cost of a support structure for renewable energy conversion is only a fraction of that conventionally acceptable for an oil & gas platform.

For *deep-water wind farms,* adapting decades of practice in operating at extreme conditions – standard knowledge in oil & gas – is essential to mobilise RTD skills serving the new wind industry to the challenges with a scientific sense and structured way of adapting new ideas – required to sustain technological innovation.

And for *ocean energy conversion,* introducing market pull and possibilities for cost sharing with a widely recognised resource, is a potential game-changing opportunity. Whereas the technological innovation in wave and tidal current energy has been astounding, with dozens of concepts under development, the volume of business investment remains a minor fraction of that flowing into offshore wind; thus wave & tidal technologies on their own still are far from “proven technology” status. MARINA has found that especially wave energy has potentially very large benefits to reap from being seen in a common perspective with offshore wind.

The structured approach in MARINA of stimulating, analysing, and quantitatively assessing – with rigour, method and transparency – ideas for combining these three diverse engineering areas, using a scientific approach, has been key to achieving this impact. Without the active engagement of lead players in all three areas, industrial as well as academic, this would not have been possible. The synergistic cross-fertilisation of ideas and the joint effort driven by a pan-European industry/academic partnership like that mobilised for the MARINA Platform project is an example of how deep offshore renewable energy production can one day be made economically attractive.

Economic and energy policy impact.

MARINA Platform has for the first time investigated in a structured way how to improve the cost/benefit ratio of the marine off-shore technologies through multiple uses of infrastructures. This will bring off-shore renewable energy applications closer to the market. However total economic and energy impacts of a successful multiple uses are both broader and deeper.

The sea plays a major role in European competitiveness; transport and security of energy supply with for example the North Sea contributing large quantities of fossil energy to the EU economies. With a view to the future, key objectives to realise also a sustainable supply of secure energy from the sea have been identified by the Commission and EU Heads of State and Government EU energy and climate policies today recognise that marine resources represent a vast source of renewable energy.

It is essential to access also the deep-water offshore resources and MARINA has contributed to establish an RTD technology base. In shallow seas, multiple competing uses suffer from the natural consequences of being geographically concentrated vs. an intermittent, variable resources: In periods of strong wind, very high grid capacity is needed to transport the power far away – and conversely, more reserve generating capacity (mostly fossil or nuclear) would be needed in periods of low wind. In order for Europe to have a balanced future portfolio of renewable generation, *geo-diversity in utilisation of its marine renewable resources* is critical.

In contrast, deep-water areas with potentially exploitable resources are widely distributed and deep-water offshore wind farms could contribute substantial new supply of electricity in many areas of European coast. The results from the MARINA Platform project enable technologies for deep-water marine energy, contribute to accelerating the rate of technology deployment and to a continued drop in technology costs that should lead to significant reductions in energy related carbon emissions by 2050 and enhanced security of supply much earlier.

Furthermore, whereas the current focus of policy makers and industrial actors is on a sub-set of the marine energy resource base – offshore wind – the MARINA partners see themselves as pioneers in *realising the total available marine renewable energy resource base.* A major impact of the project will result from its showing that wave resources can add new generating capacity in low wind periods, in many areas. This, as well as grid capacity considerations in periods of high wind, makes developing added resource from waves an interesting business proposition compared to adding more wind capacity at a given site. More localised than wave energy, tidal stream energy resources can in certain cases also be an interesting proposition in that they are fully de-coupled from wind resources and predictable over the very long term with great accuracy.

Notably, wave energy and marine/tidal current energy are “young” renewables. In contrast to wind or biomass, these resources have not been exploited by mankind for millennia. With less than 40 years of serious development (less than 20 for tidal streams) it is only natural that these are seen as higher risk than more established technologies.

The approach of MARINA has been to exploit the business and policy drive for offshore wind while at the same time mobilising the creativity in ocean energy, driven by a combination of scientific curiosity, entrepreneurial spirit and sometimes unrivalled optimism from innovators.

All-European aspect and Impact on economic policies of Regions

It is clear that the MARINA Platform project needed to be conducted at a European level and MARINA consortium partners have activities in all seas and coasts of Europe. The MARINA consortium draws on experience from global players, such as Technip and Statoil.

The implementation of a large collaborative high profile project like MARINA has outlined the paths to economic development and job creation in maritime, coastal and peripheral regions of Europe. This is an additional benefit for regions which depend on traditional uses of the sea/ocean: marine energy is a new source of employment, which requires highly qualified staff and offers new perspectives for industrial activities in coastal areas.

Impact of MARINA Platform on maritime clusters

Additional impacts of MARINA’s success can be expected for Maritime Clusters in areas with combined energy resources, creating new maritime jobs and promoting a maritime identity by exploiting synergies between interrelated sectors in the offshore wind and offshore wave/tidal energy sectors, which Europe already leads. Offshore energy requires services from ports and vessels crewed by crews with detailed local knowledge – providing additional employment.

In terms of specific deliverables of the project, D2.3 “European decision support tool for the identification of deployment locations for combined platforms” has provided a unique tool that will integrate with the MSP procedures and directives being developed by the Commission. This tool allows developers, authorities and legislators to make decisions on an informed basis accounting for the needs of a wide range of stakeholders and broader environmental considerations. It is certain that this will lead to a broader diversification of sites for energy extraction increasing the availability of renewable energy under meteorological conditions, for example, when wind speeds in the southern North Sea are too low for wind generation, since combined platforms could be deployed along the Atlantic front. Diversification permits a wider range of end users, providing opportunities for secondary activities such as aquaculture, the production of algae, desalination for potable water production, etc. This will strengthen the local coastal communities and the enhanced development of maritime clusters.

Impact on Export and Global potential

European companies have developed know-how in marine technology, not only in the offshore exploitation of hydrocarbons, but also in renewable marine resources, deep-sea operation, oceanographic research, underwater vehicles and robots, maritime works and coastal engineering. These technologies will be increasingly used and will enhance the growth of the European marine technology sector, particularly in worldwide export markets. Notably, European companies have a lead in many segments of this industry, but like the oceans the market is continuous and completely open to world competition.

Specifically for the US and Japan is that their offshore energy resource is dominated by resources in deep water. Unlike Europe with its shallow North Sea, they have no “stepping stone” to achieve deep water competent solutions. The challenge for European companies is to use actively this competitive advantage in working in parallel with developing world-class competitive solutions for both shallow and deep waters. The MARINA Platform project has been a big step forward in this direction.

Across the world, marine energy platforms can play a major role in the energy economy of developing countries, particularly on remote islands, and the establishment of a protocol for matching available technologies to specific sites will greatly assist the deployment of European marine energy systems in ICPC countries and developing nations. Especially for those developing countries with low lying coastlines, connecting such efforts with related activities *e.g.* coastal engineering and building of coastal defences could be of vital importance.

The knowledge gained in the MARINA platform project will increase the related know-how and enable the growth of export and improve the competitiveness of the European companies on the global market.

Impact on Safety - Enhancing survivability and the predictability of offshore structures

This project has developed, assessed and evaluated new technologies for wind and ocean energy conversion. Omissions and oversights of phenomena have often caused accidents and failures in the oil and gas industry as well as for wave energy and wind turbine facilities and other marine industries. The MARINA project has used extensively benchmark testing to assure that all software used and developed performs as it should. Of particular importance is the provision of independent checking procedures to validate the results from analyses.

Degradation due to dynamic loads: wear, fatigue which often depends on local design had the project team’s particular attention for the facilities of interest. Survivability also was an important aspect, especially for some wave energy facilities due to their very nature of extracting energy by amplified effects of waves.

An important part of developments and assessments carried out in MARINA was to identify issues that may cause unexpected behaviour and subject such issues to scrutiny by analysis or experimental investigation, this extended across most WP’s and subjects. From a safety point of view the most important issue was to identify new phenomena that represent a new or altered hazard. In the developments of concepts, a critical part was to assess survivability, which would normally represent a non-operational condition (i.e. a parked wind turbine, or a shut-off wave energy device). When identified, the uncertainties associated with a hazard are commonly accounted for by conservative design approach. There has been a strong drive to reduce uncertainties to limit design conservatism for economic reasons. In view of possible unknown phenomena or effects, robust design is a measure of interest. Key questions are:

What is the safety level required for integrated deep water devices? Based on the risk analyses performed and requirements in the shipping and offshore oil & gas sector there was a structured approach to defining the required safety level.

Specific design requirements to be used during design and evaluation: Using results from the MARINA project and in permanent exchange, critical parameters can be identified and proposals for their evaluation can be made with focus on safety issues. The findings are directly influencing also the design and engineering of critical components.

Energy yield evaluation. Requirements for equitable energy yield evaluation of the different devices under consideration have been formulated adding to and extending the methodology based on the results and protocols of the FP7 EquiMar project.

Certification procedures. MARINA results will have impact on future certification work for combined systems as well as wind & wave energy conversion devices individually by having systematically evaluated the key risk, technology and component elements.

Impact of the different WPs

In the following the impact of the different WPs of the project are listed with more details to the actual connection of the results to the respective positive impacts of the project.

- **WP2 Site Assessment and Monitoring**. WP2 provides methodologies for site assessment (D2.1 - Site Assessment), of public release and examples of their application to existing test sites (D2.2 - Review of existing test sites). This will definitely help in the definition of the suitability of a given location for harnessing offshore wind or ocean energies. The most remarkable result is the resource mapping of Europe and the related decision support tool, which allows obtaining accurate resource statistics and data of any European offshore location, crucial for assessing the feasibility of any offshore project.

- **WP3 Concept Identification.** WP3 worked on the cost and performance assessment of the different technologies of ocean energy crucial for the real knowledge and future feasibility of solutions combining offshore wind and ocean energies. It provides the methodologies aimed at defining the required steps for the assessment and published the methodologies applied at a set of three feasible combined concepts. WP3 has also had a significant role in identifying gaps of knowledge to be researched by other/future projects.

- **WP4 Synthesis – modelling and testing.** This WP4 developed methodologies for the dynamic analysis of combined concepts integrating wind and ocean energy devices, from their estimation of their production capacity to their structural requirements and sea-keeping behavior. Given that some of the most important entities in the modelling and testing of ocean energy devices participate in the project, it is clear the results of the work on in this WP did strongly contribute to the advance of the research on the technologies involved, as a lot of possibilities of collaboration and validation of the results was possible.

- **WP5 Risk Assessment methodology**. Risk assessment methodologies in ocean energy systems are yet to be developed. Experience from oil and gas and, mainly, the cooperation with other European projects helped in the advance of this WP, which also had a significant impact on the certification, construction and installation aspects of this type of devices.

- **WP6 Economic Feasibility Assessment.** The economic assessment of ocean energy devices is limited by uncertainties. The methodologies for the economic assessment and the cost model developed by WP6 are expected to significantly reduce those uncertainties and thus make it possible to improve the estimated costs for ocean energy developments.

- **WP7 Critical Component Engineering.** The development of novel combinations as the ones pursued by MARINA Platform require an important research on the definition and design of the least reliable components and those of relevant importance in the performance as WT rotor or the WT generator. WP7 identified those components of critical design and created, with the results of other WPs (numerical models, tests, etc.), a generic toolbox aimed at assessing the performance of the combined concepts.

- **WP8 Grid connection and macro-system integration.** The results produced by WP8 allow ensuring that the power produced from Marine Renewable Platforms can be effectively delivered to the grid and distributed to the major consumption centers throughout Europe. The offshore transmission cables are a major cost of establishing offshore power production and the tools and methods developed in this WP will help to reduce these costs. Also the use of sea-space will be optimised through more intelligent farm layout thus increasing the amount of available energy without getting into conflict with other sea-uses.

Impact on standards

MARINA Platform came up with recommendations for development of standards, guidelines and technical specifications related to MRE integrated platforms and more generally to MRE converters. These recommendations can be used by members of international standardization groups such as International Electrotechnical Commission (IEC) Technical Committees TC88 (Wind Energy) and TC114 (Marine Energy), and by certification societies.

This is aided by the participation of many MARINA Platform partners in the development of MRE standards. For instance, UEdin has led the EquiMar Project (FP7-213380, 2008-2011) aimed at delivering protocols and evaluation procedures, leading to the European Marine Energy Center (EMEC) guidelines in 2009. Bureau Veritas is a classification/certification society aimed at developing their own standards and guidelines for marine applications and MRE in particular. Active MARINA partners as DONG, Tecnalia, Statoil, DTU Risø, UCC-HMRC, ECN, UEdin and Bureau Veritas are involved in the technical committees IEC TC 88 and IEC TC 114 for the development of IEC wind and ocean energies standards and NTNU is involved in the IEA Task 33, for the development of recommended practice for reliability data collection.

To give a relevant advice based on experience in these standardization groups, the work conducted in the MARINA Platform Project provides to the MRE community a comprehensive background support needed to develop the guidelines required for integrated platforms. The knowledge developed within the MARINA Platform project in such different areas as design, modelling, testing, electrical connections, site characterisation as well as power production or cost assessment, is a valuable foundation for the IEC working groups.

The fields in which MARINA Platform project did contribute covers the following areas:

- **Estimation of the power production and the cost of energy.** In order to carry out an assessment of the combined devices, MARINA has developed procedures aimed at allowing estimations of the power production capabilities and the cost of the structures involved, with the final aim of estimating the cost of the energy produced. These procedures are supported by numerical simulations, and validated with tank tests. All the results of the EquiMar project were also considered to build up a methodology for an independent and objective evaluation of each concept.

- **Safety required by the combined concepts.** This work was conducted mainly by WP5 where the combined concepts recommended by the project were submitted to a risk assessment. External hazards (ship collision, lightning, leakage…) as well as hazards induced by interactions between the different sub-systems inside the combined platform were considered. The different stages of the platform lifespan were also addressed during the risk analysis. A Preliminary Hazard Analysis (PHA) was conducted for the installation phase in D5.3 *Report on Risk assessment of deployment*, whereas a HAZard IDentification (HAZID) assessment was conducted for the operational phase in D5.2 *Recommendations for development of guidelines and standards on integrated MRE systems*. This risk assessment step was fundamental to identify the appropriate safety level for the design of the structure. Then, this safety level shall be ensured by the application of future MRE design guidelines and standards.

- **Design and evaluation requirements**. The work performed by WPs 4 and 7 does have a strong impact on the design of combined solutions. At this moment the solutions selected for its modelling cover a wide range of technologies: all underwent a deep analysis, which included simulations and/or tank testing. Regarding WP7, the most critical components of the combined device according to reliability, from the wind turbine to the PTO, were looked at in detail, and specific guidelines were provided as far as possible for their design and assessment. Deliverables like D4.6 – "Synthesis – Modelling and Testing: Methodology and Validation (Final)" or D7.4 - "Wind/Ocean environment input to wire output modelling toolbox" play a significant role.

- **Certification**. As there are no specific standards to certify MRE combined platforms, a proposal for the approval of such innovative concepts has been developed by Bureau Veritas in WP5. Developing new standards with the traditional prescriptive approach does not seem to be the appropriate path for MRE combined platforms. Actually, the existing record of in-service information for these concepts is insufficient to provide prescriptive rules, and guidelines or standards should remain highly adaptive to different combinations of MRE devices. In order to ensure safety and system integrity, an alternative to the development of prescriptive rules for combined MRE platforms was proposed by Bureau Veritas in D5.2 *Recommendations for development of guidelines and standards on integrated MRE systems*. The proposed methodology combines the use of existing standards for MRE and related sectors like shipping, wind turbines and oil & gas, with a risk-based approach, relying on the qualification of novel technology, for the most innovative and unknown parts of the platform. Risk assessment is performed in parallel for a global review of the system. This approval scheme proposal is highly adaptive and could address fixed or floating foundations, WECs as well as wind or tidal turbines.

DISSEMINATION & EXPLOITATION

The GIS and plugin-tools will be made available for public download in the near future via a data-sharing page on the Edinburgh University website. A link on the MARINA Platform website will be added to the data-sharing page on the Edinburgh University website. It would require the user to download several files, install some open-source software and set up the system as per a set of provided instructions. There is of course a more detailed version for the partners of the project. The document will also contain contacts to be able to obtain more detailed data for certain areas of special interest from the partners that elaborated the data for the Wind, Wave and Current atlas against remuneration. A counter will be implemented to keep track of the use that is going to be made of the GIS tool, to enable tracking of the interest and to demonstrate the usefulness of the MARINA Platform to the community.

Whereas the GIS tool is an example of software that has direct public utility value, also direct commercial exploitation of MARINA results is expected to grow in the future as the value of MARINA results will begin to be appreciated by participants. Exploitation is governed by the rules of the Consortium agreement. Ownership of results is in most cases shared, with the responsibility for patenting and protecting being assigned by consensus to individual project partners who wish to pursue patent protection. An example is the Spar-Torus combination, for which a decision in the MARINA project was to allow NTNU the right of pursuing a patent, which is now granted in Norway and in the process of being confirmed internationally.

The "List of Scientific publications" and the "List of Dissemination activities" give a comprehensive overview of the detailed catalogue of dissemination of foreground generated. The efforts undertaken to disseminate the results created within the MARINA project are shown in the following. The dissemination events and the fact that apart from representatives from other related projects, from other Universities and the EC commission also members of the industry and members from of the EWEA, The Crown Estate were present demonstrates the effort that was made to cause the required impact that the project should have on the industry and on potential policy makers.

The first **MARINA dissemination workshop** took place in Brussels, 14th May 2013, taking advantage of 3rd General Assembly meeting and 2nd period review. The dissemination activity had a technical scope and was held in the Office of the Delegation of the Basque Country to the EU, in Brussels. At this stage, when about 75% of the results had been reported some project achievements were shown by reviewing the work carried out in the WPs. The by-invitation session was targeted at companies/organisations potentially interested in the MARINA project research. In addition to MARINA partners, representatives from important European companies and organisations attended the event: EC, The Crown Estate, EWEA, Statoil, Aalborg University and others. The H2OCEAN, MERMAID and TROPOS projects were also represented.

MARINA technical WPs – (WP2 to WP8) presented their most relevant results and sketched the work to be done until the end of the project. Presentations contained technical information and procedures and are publicly available on the web site under Documents and Publications section of the home page.

A **second MARINA dissemination workshop** has been planned for Brussels during the second half of 2014 to coincide with the Final Review meeting. A dissemination event will close the project and show the main achievements and conclusions of the 54 months of work. By the release of this document the agenda is still to be defined.

Training seminar during 4th GA in Bilbao, 28th May 2014. This training activity was open for invited institutions. A total of 37 attendees including MARINA partners, H2OCEAN, MERMAID, TROPOS and MARINET FP7 projects, AZTI TECNALIA research center, Vicinay Cadenas and OCEANTEC wave energy converter developer participated.

The universities did offer seminars to achieve the impact to enhance industry-academia cooperation by helping to provide a next generation of MRE researchers and developers by holding 4 annual open workshops and providing specialist training courses. These were meant to create new interest within young researchers and also to educate personnel necessarily required for the future research in the RE market.

University activities based on MARINA project results:

- ECN started the dissemination of public results of the MARINA project during lectures at Master level on wave energy conversion at ECN. In addition to the lectures, practical courses were proposed to Master level students at ECN. 12 groups of three to four students were asked to carry out tank testing activities on the OWC array model between the 10th and 20th January 2014.
- Universidade do Algarve has presented the MARINA project and preliminary results to the students of Renewable Marine Energies from the degree of Marine Sciences (UAlg), and also to the students of Wave, Tidal and Hydro Power from the Master Sciences on Renewable Energy and Energy Management (UAlg). Within the classes of the above mentioned courses students were introduced to the concept of multi-purpose platforms, namely including offshore wind energy and current/wave energy.

Some examples of designs were provided and discussed. The environmental assessment was also part of the course and the approaches defined at WP2 also taught to the students.

- University of Edinburgh carried out MARINA GIS training of IDCORE EngD students at Edinburgh. IDCORE is an Engineering Doctorate (EngD) course that is run via collaboration between several different UK universities, research institutions and industrial partners. The students spend a year on a taught program, mainly in Edinburgh, focusing on the many different aspects of developing offshore renewable energy. The GIS workshop forms part of the taught module on resource analysis and introduces the students to some basic GIS concepts, and also demonstrates how GIS has been used in practice for combined platform assessment in the MARINA Platform project.
- University of Athens carried out several activities in the framework of WP2, resource assessment.
  - The statistical methodology developed for the local adaptation of the wind/wave atmospheric models was presented by NKUA in a training seminar organised by the US-Naval Postgraduate School on August 2011.
  - The resource assessment methodology and models were presented by NKUA in a seminar organised in the Chapman University, Orange, California on August 2011.
  - The main activities and results taken within the framework of WP2, were presented by NKUA in four annual seminars (2011, 2012, 2013 and 2014) to the postgraduate program in Environmental Physics - Meteorology of the Department of Physics of the University of Athens (2 hours each).
  - Specialised seminars were organised at the framework of the Graduate Program “Naval Science and Technology” that is organised by the National Technical University of Athens and NKUA. In total six seminars (2 hours each) were organised to demonstrate findings of MARINA PLATFORM.
  - The models and methodology developed within the framework of WP2 were presented by NKUA to three annual seminars (2012, 2013 and 2014) in the Hellenic Naval Academy.

Training activities and the related material are described in deliverable “D9.4 – Material for Training seminars” in more detail.

The GIS and plugin-tools will be made available for public download in the near future via a data-sharing page on the Edinburgh University website. A link on the MARINA Platform website will be added to the data-sharing page on the Edinburgh University website. It would require the user to download several files, install some open-source software and set up the system as per a set of provided instructions. There is of course a more detailed version for the partners of the project. The document will also contain contacts to be able to obtain more detailed data for certain areas of special interest from the partners that elaborated the data for the Wind, Wave and Current atlas against remuneration. A counter will be implemented to keep track of the use that is going to be made of the GIS tool, to enable tracking of the interest and to demonstrate the usefulness of the MARINA Platform to the community.

Coordination with other European projects

MARINA Platform was cooperating with other projects in order to share useful knowledge and prevent the repetition of works. This cooperation was based in distributing the deliverables generated or sharing any useful information. MARINA partners collaborated in different ways within a variety of European, national and international projects.

Deliverables restricted to 7Th Framework Programme participants

In order to optimize the dissemination activities, MARINA was encouraged to establish links with other projects and developers, which the MARINA Platform successfully did with more than 20 projects. In addition, apart from the knowledge included in the public deliverables, the following deliverables of the MARINA Platform Project are accessible to other projects belonging to the 7^{Th} Framework Programme:

- D2.6 Final – Multipurpose platforms Environmental monitoring protocol.
- D3.5 Executive recommendations: Integrated solutions for ocean energy development.
- D4.6 Synthesis – Modelling and Testing: Methodology and Validation (Final).
- D5.1 Overall methodology for risk assessments (protocol).
- D6.1 Analysis of different life cycle cost influencing parameters.
- D7.1 Critical assessment of Platform and Mooring Components.
- D7.2 Critical Wind and ocean energy components.
- D7.5 Components for adaptation of platforms for other maritime uses.
- D8.1 Transmission Capacity in the European Power System - A survey of existing studies – FINAL.
- D8.2 Transmission Capacity in the European Power System - A survey of existing studies – FINAL.
- D8.5 Power integration of MRE in power system.

APPENDIX

This Appendix contains the Figures corresponding to the WP sections.

WP2

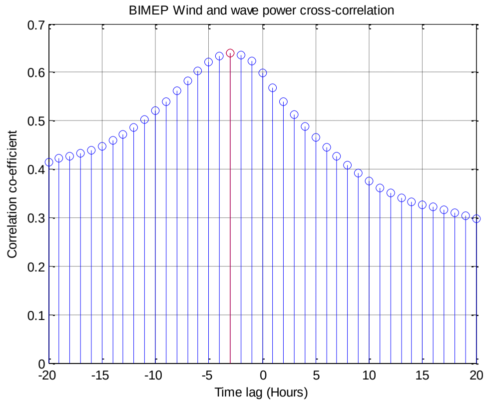


Figure 1: Time lag cross-correlation for wind and wave power at Bimep

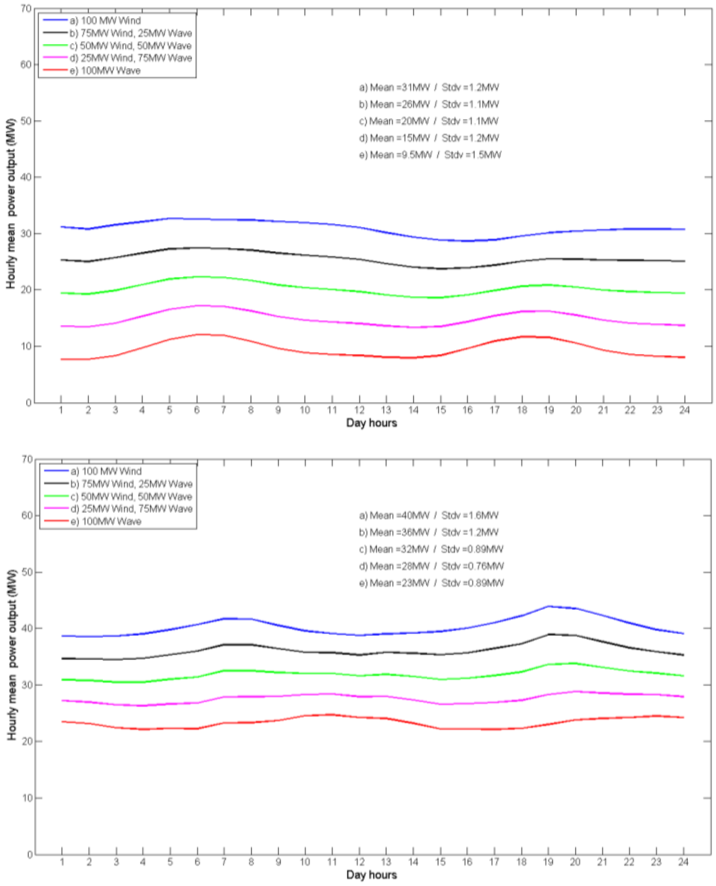


Figure 2: Hourly variation of power production at SEM-REV (top) and EMEC (bottom)

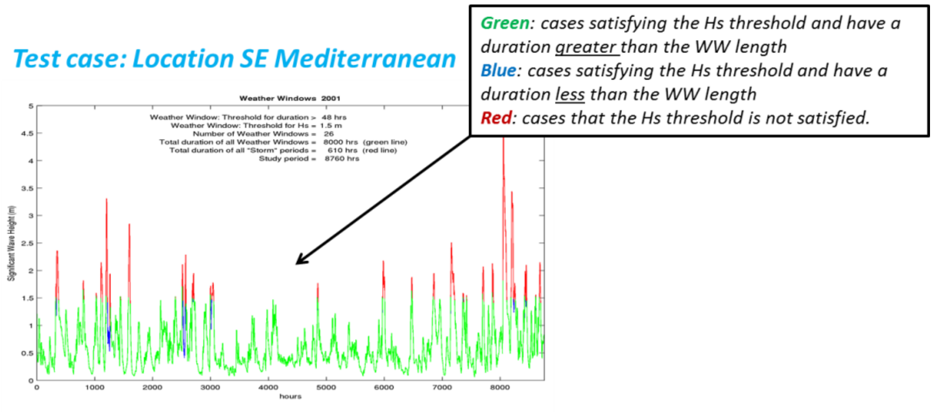


Figure 3: Weather window analysis (2001, SE Mediterranean). The weather window duration is defined to be 48 hours and the significant wave height threshold is 1.5m.

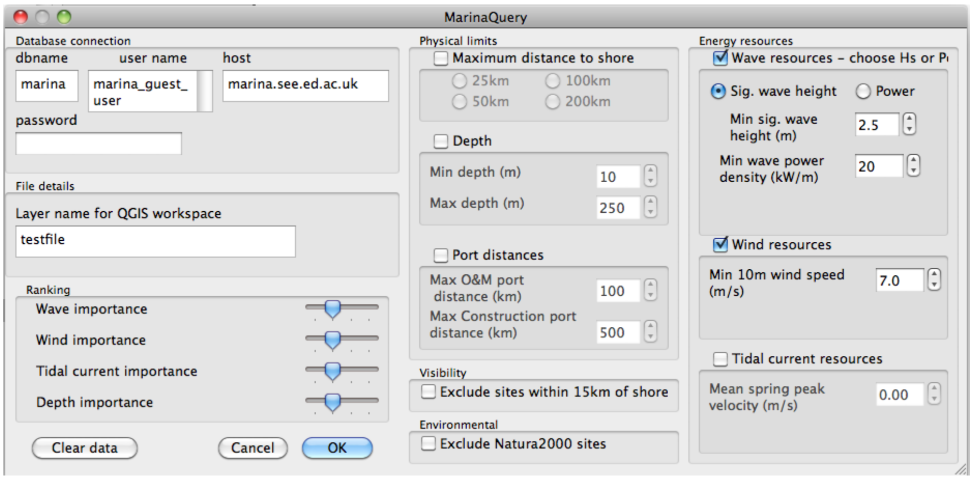


Figure 4: MARINA GIS Site Selection Tool – User Interface

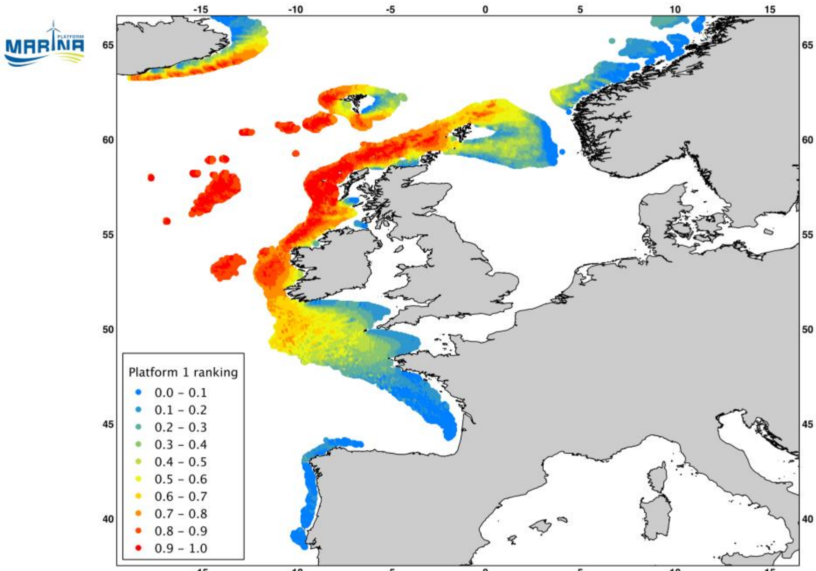


Figure 5: MARINA GIS Site Selection Tool output for sites with a given set of criteria

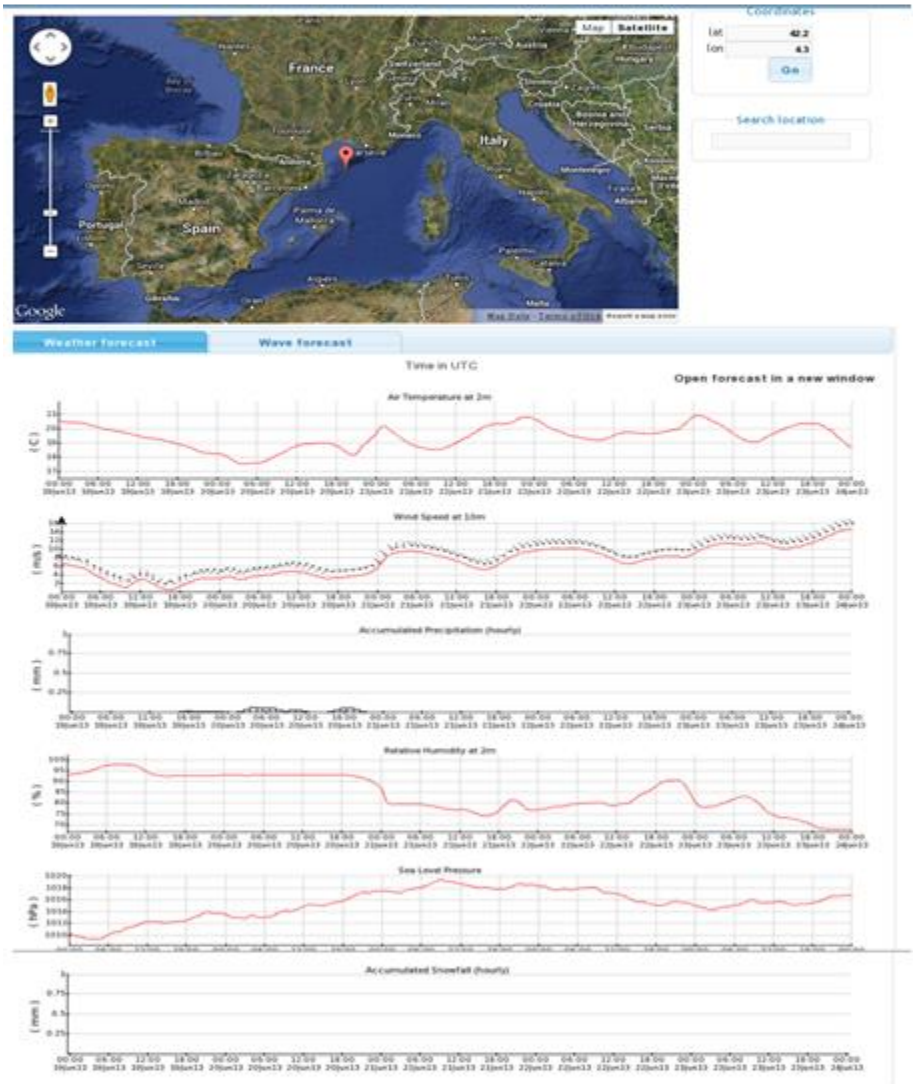


Figure 6: Time series of the main parameters produced by the atmospheric model SKIRON (air temperature at 2m (oC), wind speed at 10m (m/s), hourly accumulated precipitation (mm), relative humidity at 2m (%), sea level pressure (hPa) and hourly accumulated snowfall (mm)) for a site inside the Gulf of Lion during the forecast period:19th of June 2013 at 00 UTC - 24thof June 2013 at 00 UTC.

A	B	C	D	E	F	G
Fixed/Floating Structure + Tidal Energy device + Wind	**Single Fixed WT + WECs**	**Fixed Structure with multiple WTs + WECs**	**Single Floating WT + WECs**	**Floating Structure with multiple WTs + WECs**	**Segregated Fixed WTs + WECs**	**Segregated Floating WTs + WECs**
Any possible combination between tidal devices and WTs, integrated or segregated	Integrated combinations of fixed foundations with a single WT and WECs	Integrated combinations of **fixed** foundations with multiple WTs and WECs	Integrated combinations of floating foundations with a single WT and WECs	Integrated combinations of **floating** foundations with multiple WTs and WECs		

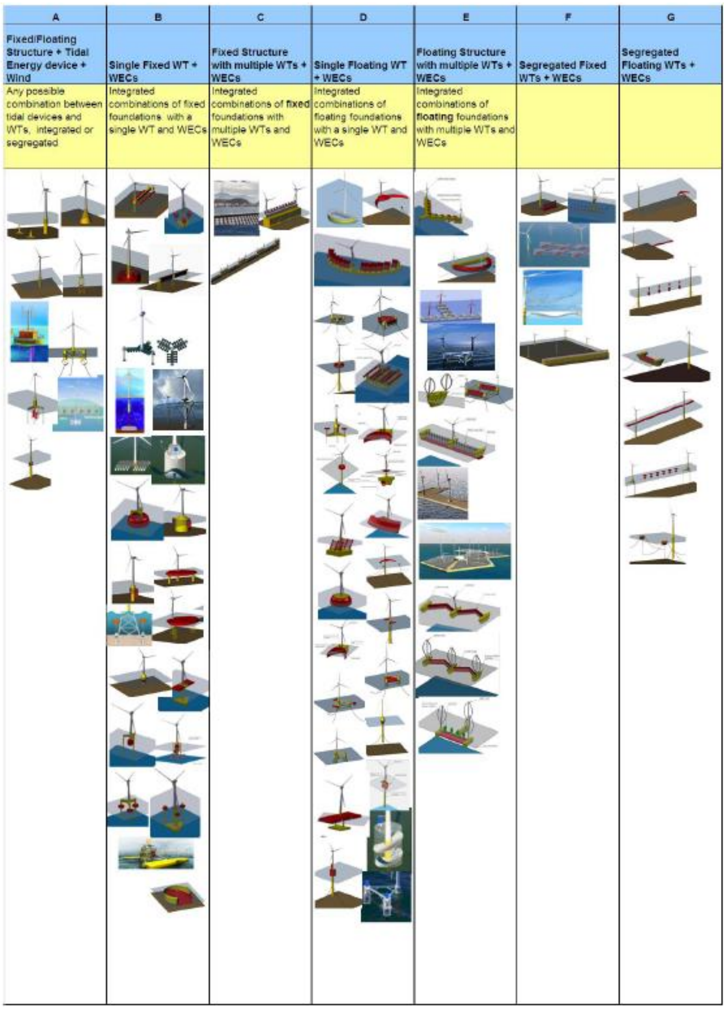


Figure 7: Grouping of concepts according to defined categories

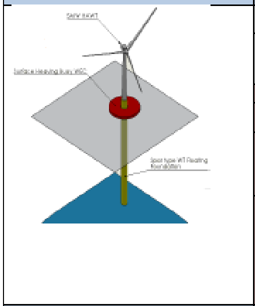
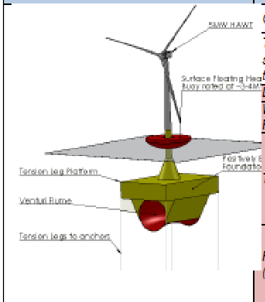
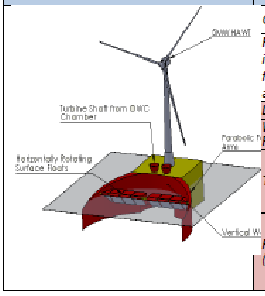
ID 2	Floating Spar Wind Turbine Foundation with point absorber - SEACAP			
	Generated by MARINA / HYDROCAP ENERGY [http://www.hydrocap.com/]			
	Spar provides stable vertical axis and submerged mass for self-reacting heaving point absorber. The point absorber, of 20m radius, is a torus of an inverted dome shape to minimise pitching			
	Layout	INTEGRATED		Advantages
	WT Foundation	SPAR		- Very simple compact combined platform. - TRL of both technologies - Very suitable for deepwater deployment. - Torus buoy independant of wave direction. - Not sensitive to seabed conditions; simple design - WEC components can be protected within the spar.
	Technologies	Wind E.	HAWT	
		Wave E.	POINT ABSORBER	
		Tidal C. E.	-	
	Rated power (MW)	Wind E.	5	
		Wave E.	0,7	
		Tidal C. E.		
		Total Power	5,7	
ID 3	Tension Leg Wind Turbine Platform with Venturi Flume and Point Absorber			
	Generated by MARINA			
	TLP wind turbine with a point absorber attached to the cylindrical structure and a submerged horizontal turbine able to harness energy from the surge motion of the wind turbine.			
	Layout	INTEGRATED		Advantages
	WT Foundation	TLP		.- Use of three components for energy absorption. - Positive interaction effect can be achieved. - Stability expected to be very good due to large buoyancy volume both near free surface and under water. - Stability of the platform may give higher yield from both wave and wind device.
	Technologies	Wind E.	HAWT	
		Wave E.	POINT ABSORBER + VENTURI FLUME	
		Tidal C. E.	-	
	Rated power (MW)	Wind E.	5	
		Wave E.	1	
		Tidal C. E.		
		Total Power	6	
ID 4	Floating Barge Wind Turbine Foundation with OWC Chamber and Surface Floats			
	Generated by MARINA			
	Floating barge hosting OWC chambers. OWC would be located on the wave incident side of platform, helping to reduce the pitching of the platform. Surface floats span between the focussing arms in order to reduce the wave reflection and extract further energy.Overall width of the arms: 200m			
	Layout	INTEGRATED		Advantages
	WT Foundation	BARGE/VESSEL		.- Innovative combination of existing concepts - Damping of surge motion of the WT If platform is stable, this may provide high yield from both wind and wave.
	Technologies	Wind E.	HAWT	
		Wave E.	OWC's and Surface Floats	
		Tidal C. E.	-	
	Rated power (MW)	Wind E.	5	
		Wave E.	4	
		Tidal C. E.		
		Total Power	6,5	

Figure 8: Evaluation at initial stage.

Figure 9: Site selection from initial 18, to 5, to 2 sites for final evaluation.

CoE	Constructability	Installability	Operation & maintenance	Survivability
40%	15%	10%	10%	25%

Figure 10: Weighting of criteria.

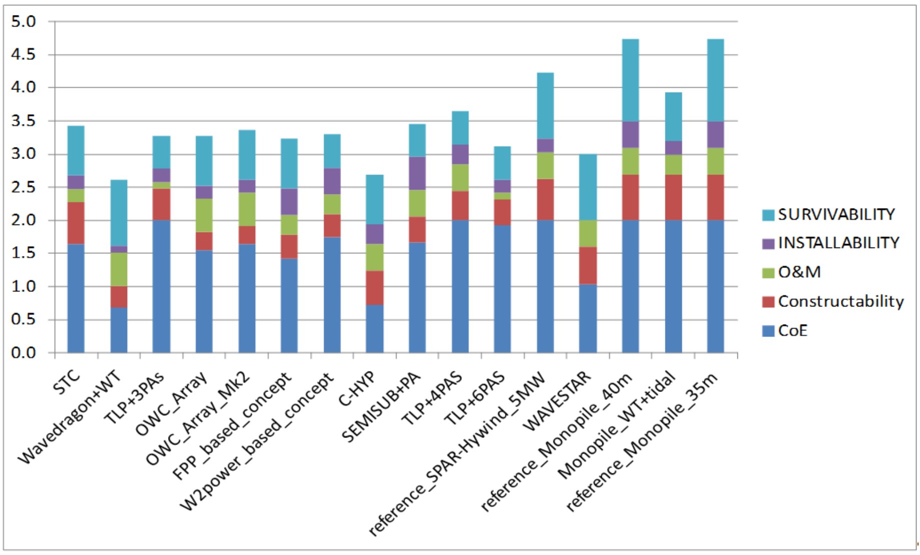


Figure 11: Evaluation of 10 concepts

WP3/4

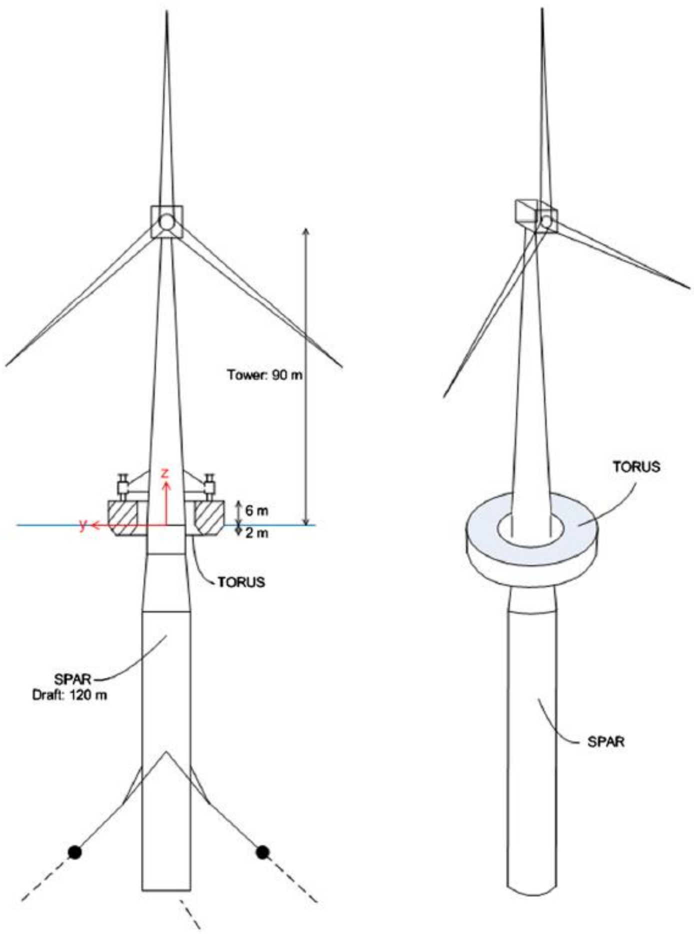


Figure 12: The STC concept

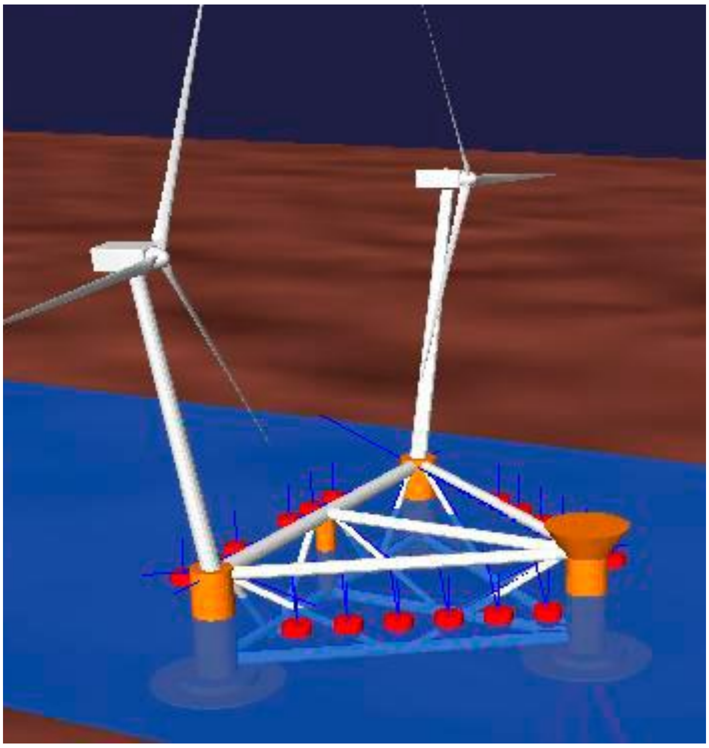


Figure 13: Sketch of the EW2Power based concept

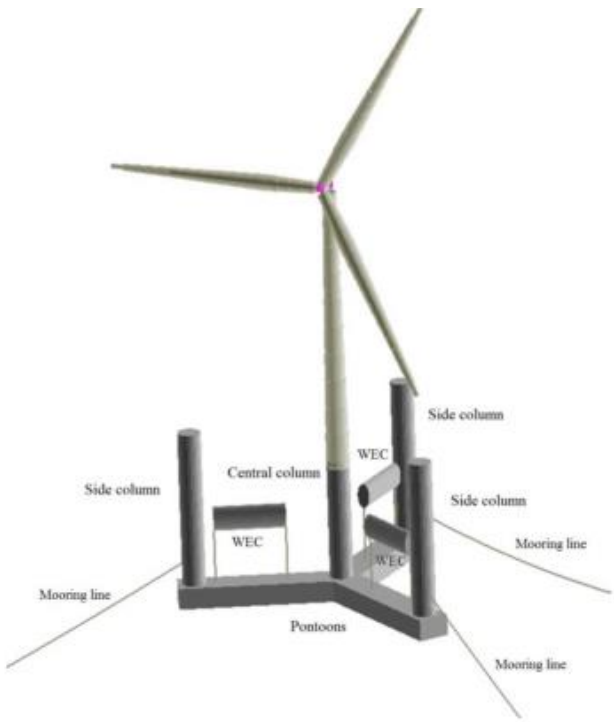


Figure 14: The SFC concept

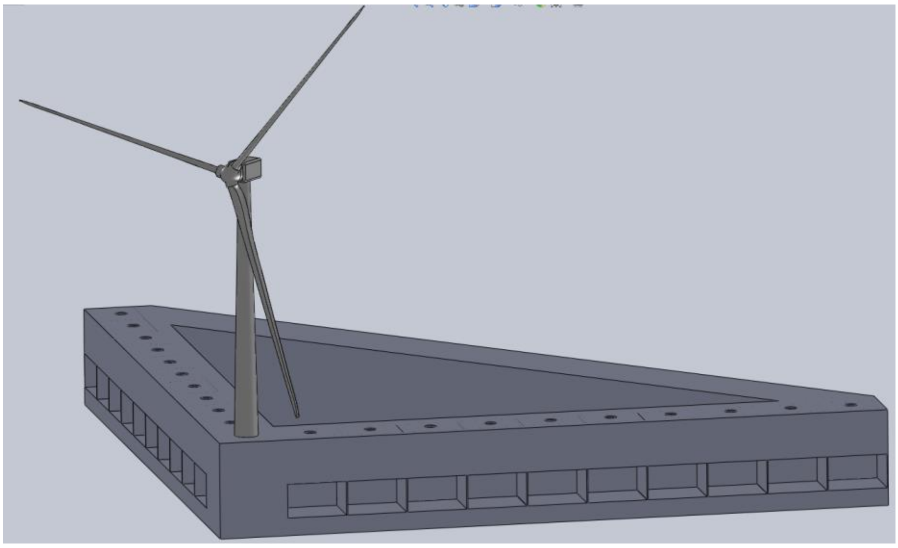


Figure 15: The OWC Array concept

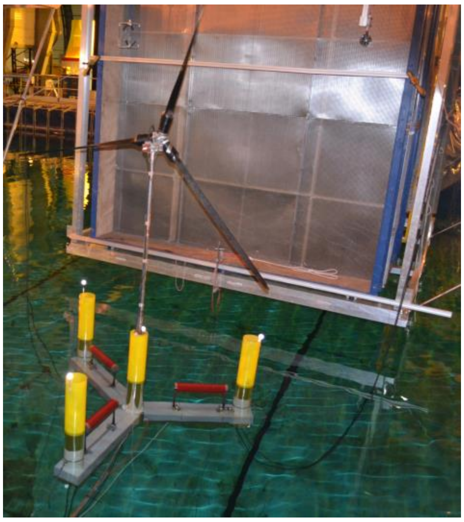


Figure 16: Test models of the SFC (left) and the OWC Array (right) concepts in the ocean basin at ECN

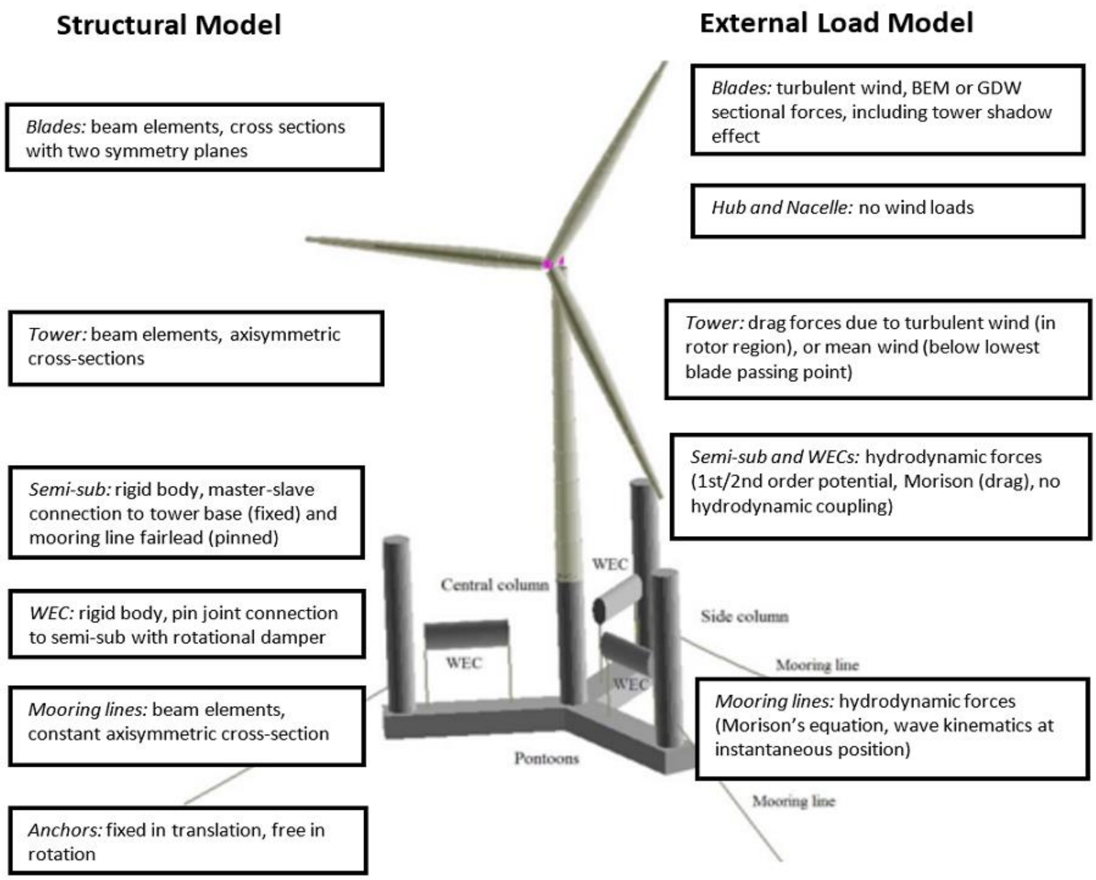


Figure 17: Numerical Model of the SFC concept in the software Simo-Riflex-AeroDyn

WP5

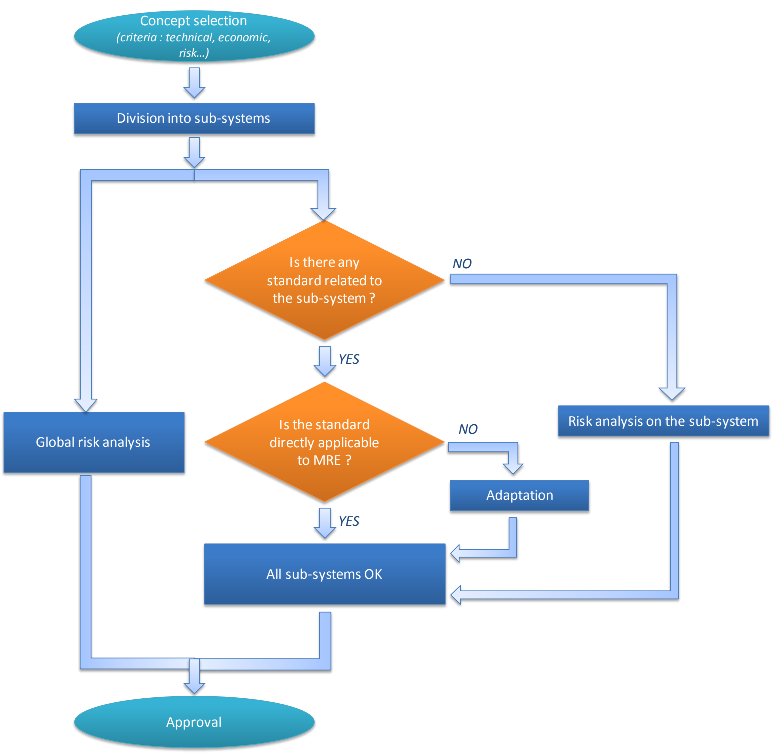


Figure 18 Risk-based approach for the certification of novel system as MRE platform

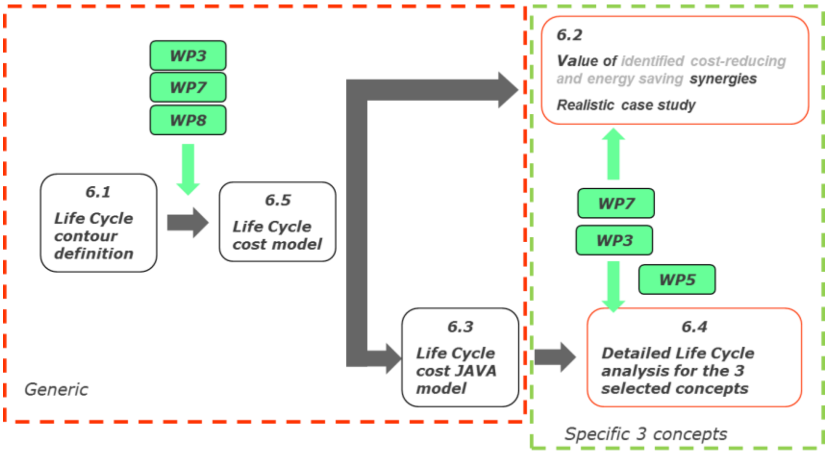


Figure 19: WP6 tasks flowchart

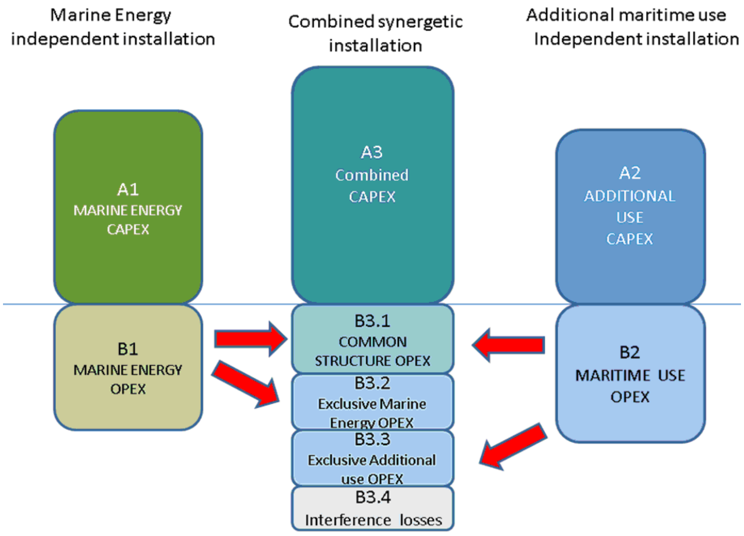


Figure 20: Schematic of the methodology for assessing synergies.

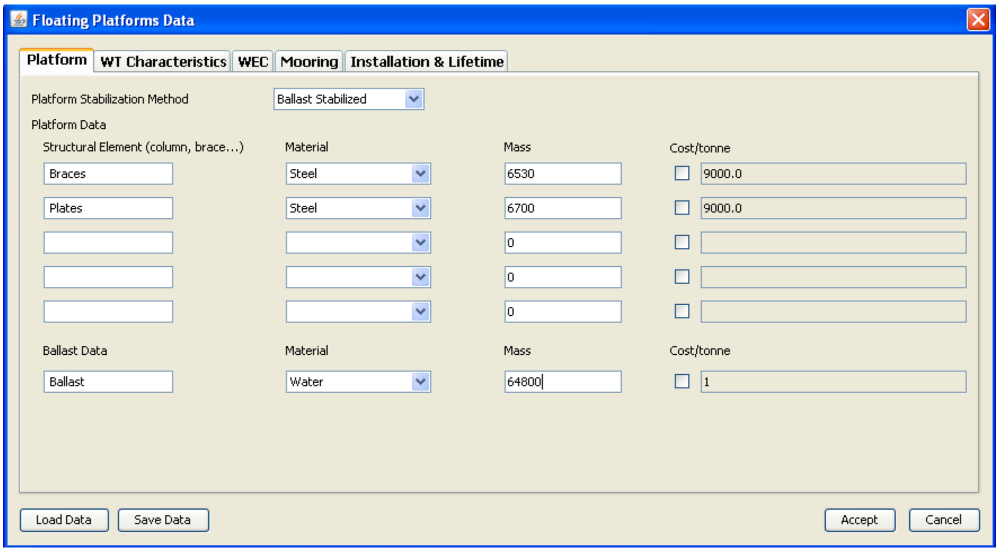


***Figure 21*: Screenshot of the Java user interface**

Figure 22 – Offshore equipment

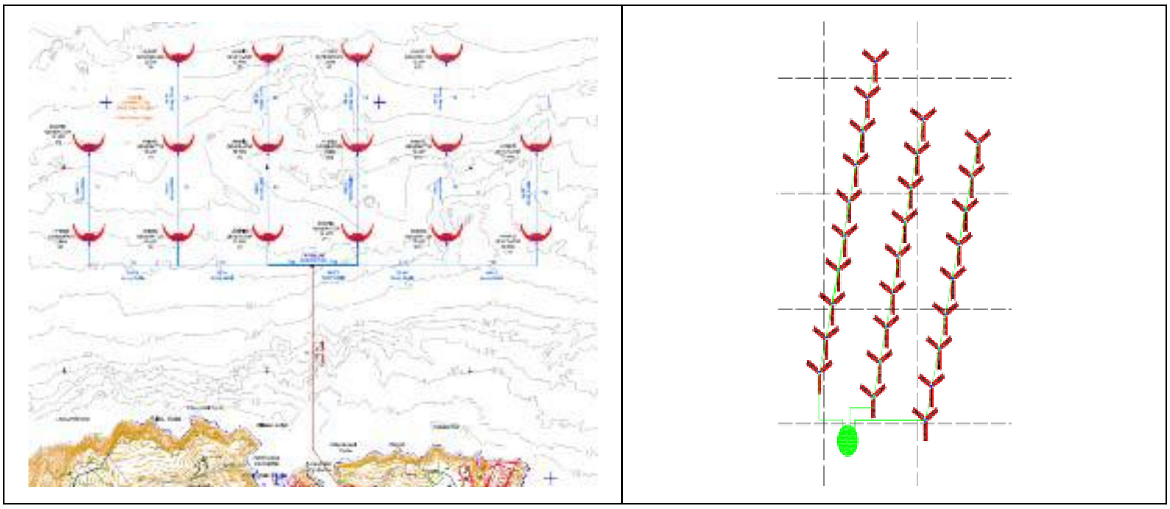


Figure 23 – Spanish study (left) and UK study (right)

www.marina-platform.info

Figure 24: MARINA Website