Ocean Energy exploitation in Italy: ongoing R&D activities

Position Paper/September 2017

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ISBN: 978-88-8286-355-5

ENEA

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ISBN: 978-88-8286-355-5

Copy editing:
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Graphic design scheme and cover design:
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Printing:
Laboratorio Tecnografico ENEA – Frascati

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EXECUTIVE SUMMARY

Marine renewable energy – in particular wave and tidal generated electricity – is exiting the research and development stage and stably entering the operational, pre-commercial phase, the deployment of full-scale prototypes in real-sea environment being already underway. Although in Europe the availability of marine energy resources is highest along the Atlantic coast, it has been recognized that the Mediterranean Sea offers substantial opportunities for both significant energy production and technological development. The latter is mainly favoured by the specific characteristics of such basin, where milder climatic conditions allow the affordable testing of devices and stimulate the design of particularly efficient technologies for energy harvesting. Moreover, the accentuated vulnerability of the Mediterranean environment demands consequential efforts to be undertaken in order to promote the development of innovative technologies capable of supporting the energy independence and sustainability of particularly exposed habitats, ecosystems and social communities, such as those located in small isolated islands, thus providing new adaptation/mitigation options to the Earth's changing climate as well as new solution for pollution reduction. In the ocean energy sector, Italy has made great steps forward in both research and device implementation, and it has by now acquired a prominent position among the international insiders. Targeted policy interventions and investment would now fully disclose the potential offered by the ocean energy sector in terms of economic growth, high-skilled job creation and strategic positioning of the Italian industry in the competitive global market. By leveraging on the vitality and creativity of a well-established community of actors from the public and the private sectors, such policies would support the upscaling of a variety of connected enterprises, sustaining product diversification and opening access to international visibility.

Support to the deployment of ocean energy would also meet the recommendations and directives from the European Union, which established a common framework for Member States as to the promotion of the use of energy from renewable sources (EU 2009/28/CE Directive), as well as a framework for the implementation of maritime spatial planning and integrated coastal management by Member States, aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources (Directive 2014/89/EU).

This Position Paper outlines the current state of ocean energy research and development in Italy, describes the expected positive impacts of its further growth on a wider range of connected economic sectors, and highlights the export opportunities for the most mature technologies and devices. It finally seeks to provide guidelines to policy makers in order to improve the sector's ability to attract both domestic and international investments and to unlock cost-reduction mechanisms, thus boosting its growth, strengthening the expertise of the national industry and its role in the global market, and accelerating the deployment of energy from marine generators.

Introduction

Research, innovation and competitiveness are at the core of the European Commission's EU strategy, which designed a new European energy Research & Innovation (R&I) approach in order to accelerate the transformation of the EU's energy system and to bring promising innovative zero-emissions energy technologies to market. The European Strategic Energy Technology Plan recently prioritized the Key Actions for the ocean energy sector, aiming at confirming the EU global leadership in the field, and at filling the residual gap between research or prototype demonstration projects and their commercial deployment. Substantial reduction of costs is essential, as well as further demonstration of technology reliability and survivability in aggressive sea conditions. The Plan recommends to concentrate efforts on a limited number of promising technologies for energy conversion from tidal streams and waves, targeting a reduction in the LCoE for tidal stream energy converters to at least 15 ct€/kWh by 2025 and 10 ct€/kWh by 2030, and a similar, although slower, reduction in the LCoE for wave energy converters to 20 ct€/kWh by 2025, 15 ct€/kWh by 2030 and 10 ct€/kWh by 2035.
(https://setis.ec.europa.eu/system/files/integrated_setplan/declaration_of_intent_ocean_0.pdf)
Such detailed objectives were agreed between representatives of the European Commission services, representatives of the EU Member States, Iceland, Norway, Switzerland and Turkey (i.e. the SET Plan Steering Group), and representatives from research and industry, after consulting relevant stakeholders from the academy and the enterprise, and based on the available knowledge on the current status of technology development in Europe.
However, although the latest documents provided by experts to the EU Commission in support to the European policymaking process in Ocean Energy matters (JRC Ocean Energy Status Reports 2014 and 2016) recognize the considerable technological progresses made in recent years, and give an accurate overall description of the current technology portfolio in Europe, they only report a non-exhaustive list of European Original Equipment Manufacturers (OEMs) that largely underrepresents the consolidated Italian efforts in this sector. The reason for this also resides in the still too low level of coordination and networking among the Italian OEMs, R&D institutions and private enterprises of the sector in drawing public attention to open critical issues, and in putting forward common proposals for gaining the essential sustained support from large enterprises, administrative authorities and governing bodies, that could finally help Italian technologies complete the technology readiness level (TRL) path, and enhance Italy's visibility on the international stage. Both Reports, in fact, as well as the Ocean Energy Strategic Roadmap 2016, pay special attention to the barriers that are still hindering the industrial roll-out and the final commercialisation of ocean energy technologies (technology development, finance, consenting and environmental issues, and the availability of grid infrastructure), and they explicitly relate the timeline for further development to the level of public support offered in the short- and medium-term by the EU, Member States, and regional authorities. The elimination of current barriers to project deployment is indeed a priority, together with access provision to significant stable and predictable funding, in order to prevent the loss of accumulated knowledge just when it is close to repay the initial investments, and the consequent jeopardy of Italy's prospective position in this sector. This is all the truer for the Italian case, where the lack of national investments impairs the participation of Italian actors in co-funded EU programmes and their access to co-funded financial instruments.
An effective coordinated action at national level would definitely sustain the mutual improvement of new technologies, bring down costs, facilitate project financ-

ing and enhance the design of an effective regulatory framework. By incorporating the objectives of the SET Plan, such an effort would reinforce the implementation of specific actions beyond EU funded projects, strengthen the financial commitment from the public and the private sectors, broaden the participation of stakeholders along the innovation chain, and improve the reporting required by the EU on national research and innovation priorities and investments, thus gaining international visibility for the Italian R&D and business community. In the medium run, it would support technology transfer and knowledge sharing, and stimulate the development of high-tech and sustainable infrastructures in cohesive investment areas, thus concurring to generate economic growth, to enhance the security of energy supply, to foster competitiveness, and to increase the demand of high-quality professionals in new sea careers. Coherent government intervention would enable access to the ERA-Net Ocean Energy co-fund instrument in Horizon 2020, which is to launch transnational calls on demonstration activities involving industry and leveraging private funds, and to a new type of Public-Public Partnership, based on the European Strategic Forum for Research Infrastructure (ESFRI), for the implementation of large scale demonstration facilities of European interest.

This Position Paper originates from the need to gain visibility for the work and experience of an already existing network of Research and Technology Organizations (RTOs), highlighting possibilities for cooperation with Small and Medium Enterprises (SMEs), large enterprises in the energy sector and other key players across the whole innovation chain, from product and process development to prototyping and demonstration, and finally to full-scale implementation. Its ambition is to provide support to decision making, by helping identify effective public support policies for the early stage development of devices, and for the upscaling of innovative SMEs in the Ocean Energy sector, which often lack the necessary financial and organizational resources to fully deploy their prototypes and transit from the proof of concept to the field test phase.

Supporting policies for ocean energy

National dynamism and International positioning

The Italian increasing interest in the exploitation of wave and tidal technology to produce clean and renewable energy can be recognized both in Government intervention (e.g. high incentives were set for ocean renewables in the Italian Renewable Energy Action Plan) and in the research and development activities carried out by public and private players. The main actors involved in R&D in this field are Universities, Spin-offs, SMEs and large Enterprises; thanks to their efforts, Italy is indeed at the forefront of research in developing and testing prototypal and pre-commercial devices for ocean energy conversion. This is confirmed by the number of international partnerships in which Italian actors are actively involved.

Several Italian Universities and the CNR-INSEAN are partners of the largest EU co-funded projects in the field of ocean energy technology. The Politecnico of Turin and ENEA participated in the FP7 Project SINGULAR, whose objective was the large-scale integration and exploitation of renewables in insular electricity networks, through the development of novel models and tools and the adoption of new electricity network and market designs. The University of Florence, the University of Tuscia and CNR-INSEAN participated in the EU FP7 project MaRINET1, which was followed by the EU H2020 project MaRINET2 (www.marinet2.eu), still counting the University of Florence and CNR-INSEAN among its partners. The objective of the MaRINET Infrastructures Network is to facilitate access to marine research facilities, and to streamline the testing process of innovative devices for the exploitation of marine renewables – wave, tidal and offshore wind – in order to accelerate their development and commercial deployment. The network consists of the most representative partners at EU and global level, and Italy is providing an outstanding contribution as to both the rich portfolio of testing infrastructures and the number of marine energy technology developers that applies for access to testing facilities.

Capitalizing on its international visibility, CNR-INSEAN has established research and technology cooperation agreements with leading industries like SABELLA SaS in France, Schottel Hydro Gmbh in Germany, SAFREMA Energy L.L.C. in USA, and participates to several international research projects (EU-FP7 MaRINET, H2020 MaRINET-2, H2020 MARINERGI) and industrial projects (TTT3, funded by Invest North Ireland).

The Italian leading role in the blue energy sector has been recently recognized by the Corporación de Fomento de la Producción (CORFO), the economic development organization appointed by the Chilean Government; Enel Green Power (EGP) from Italy and DCNS from France have been selected to set up a ground-breaking global centre of marine energy R&D excellence in Chile, named Marine Energy Research and Innovation Centre (MERIC). MERIC's applied research and development work will focus on key sources of marine renewable energy such as tidal power and wave power.

Regulatory Framework and Market Incentives

Italy prioritized and incentivized the deployment of renewable energies by adopting a set of rules and regulations, which transposed the EU 2009/28/CE Directive into the Italian national legislation. As anticipated, the principles and the objectives of such regulatory framework are summarized in the National Action Plan for Renewable Energies of 2010, followed in 2013 by the National Energy Strategy, which was recently updated - NES 2017. The former also reports the relevant Italian legislation already in force at the time, and clas-

sifies legislative acts as to their compliance to specific indications of the transposed Directive, according to the following categories:

- Measures in compliance to Articles 13, 14, 16 and 17 to 21 of the cited Directive (Administrative procedures, regulations and codes);
- Measures favouring the production of electrical power from renewable sources;
- Measures favouring the utilization of renewable energies in heating/cooling systems;
- Measures favouring the utilization of renewable energies in the transport sector;
- Specific measures aimed at promoting energy uses of biomass;
- Statistical transfers between Member States and joint projects between member states and Member States and third countries.

The latest indications and regulatory measures for the operative implementation of the National Strategy and Plan have been issued in D.M. 23/06/2016. The Decree updated the support scheme previously regulated by DM 6 July 2012. The latter reviewed the preceding framework based on Feed-in Tariffs and Green Certificates, for renewable plants (other than Photovoltaic) in operation starting from 1 January 2013.

The most recent DM identifies four different ways of access to incentives: direct access, bid auctions (Dutch Auctions), registries for new power plants, for fully reconstructed power plants, for reactivated, empowered and hybrid power plants and registries for rebuilding intervention. The Decree defines the criteria to access the registries and the Dutch Auctions and establishes specific limits for the annual capacity eligible to incentives. These limits are set up differently for each kind of renewable energy source and for all the different ways of access to incentives (registries or bid auctions).

In general, the Decree grants a fixed tariff plus, in some cases, a specific premium, to provide incentives to net electricity fed into the grid. The fixed tariff is different according to each source, technology, and capacity range considered. Power plants with a capacity > 500 kW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 500 kW can alternatively receive a Feed-in Tariff composed by the fixed tariff plus, in some cases, a specific premium.

In the Dutch Auctions the maximum requested value of the tariff cannot be higher than a 2% discount of the reference value and the minimum value cannot be lower than a 40% discount of the reference value. The incentives last for the average conventional plant life of each typology of power plant. All the support schemes are managed by the Italian Energy Service Operator (Gestore Servizi Energetici - GSE), the body in charge of managing all the incentives to renewable energy.

New, fully reconstructed, reactivated or empowered wave and tidal energy power plants can access directly to incentives if their capacity is not greater than 60 kW, otherwise they must apply for access to registries.

Typology of power plant	Capacity	
	≥ 1 kW and ≤ 60 kW	> 60 kW and ≤ 5 MW
Wave and tidal power plants	Direct Access[1]	Registry

[1] If the power plant is built by the Public Administration the maximum capacity eligible to direct access is doubled (120 kW)

From 2013 to 2015, the total annual capacity (MW) eligible for access to registries, and therefore for the granting of incentives, amounted to 6 MW.

In 2016, a single initiative, with capacity of 49.5 kW entered into operation and requested direct access to incentives.

The Decree does not provide for Dutch Auctions in the case of wave and tidal energy power plants.

For new wave and tidal energy power plants, DM 23/6/2016 has confirmed the previous tariff, as follows:

Source	Typology	Capacity (kW)	Conventional Plant's Life (years)	Fixed Tariff €/MWh
Oceanic (tides and waves)		1< P ≤ 5000	15	300

This FIT will be in force up to the end of 2017.
The Directive 2014/89/EU on Marine Spatial Planning is also relevant for the specific blue energy sector, as it establishes a framework for the implementation of maritime spatial planning and integrated coastal management by Member States, aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The Directive has been recently transposed into the Italian legislation via the D. Lgs 201/2016.

Public Funding Programs

Italy relies on a public research programme aimed at maintaining and improving the national energy system, including the still limited marine energy sector. Such programme, named Ricerca di Sistema (System Research), purses as its main objective the promotion, organization and management, of basic and industrial research, and of the related technological development, finally ensuring maximum fruition of results to all citizens and end users.
The Committee of Research Experts for the Electricity Sector (Comitato di Esperti di Ricerca per il Settore Elettrico - CERSE) plays a strategic role in orienteering R&D activities towards the innovation of the electrical system, through funding under the EU principles that regulate State aid for Research and Development and Innovation (Communication from the Commission 2014/C 198/01). The CERSE is composed of five members, appointed by the Minister of Economic Development, and is responsible for regulating public funding for research projects of general interest in the electricity sector.

The Ministry of Education, University and Research (Ministero dell'Istruzione, dell'Università e della Ricerca – MIUR) has launched two calls for proposals to grant funding for strategic research activities, including the blue energy sector. In particular, two Directorial Decrees were recently issued:

- Decree N. 1610/3 August 2016, for the recognition and the subsequent development of four national technology clusters aimed at coordinating public and private research initiatives, as well as national governance and territorial policies, in accordance with the representatives of major national enterprises. One of the clusters is dedicated to the Economy of the Sea, with specific reference to blue energy as one of the fields of interest. Among these, potentially connected sectors are also explicitly mentioned, such as shipbuilding, environmental monitoring and protection, aquaculture and blue biotechnologies. Applicants, constituted as competing consortiums, were requested to formally authorise a representative selected among their members, in the form of an individual authorisation, and to further substantiate their initiative by presenting an Action Plan and two original industrial research projects. Applications were assessed according to the quality of the proposed Action Plan and projects, and the evaluation results published in the Directorial Decree N.1853/26-07-2017. The cluster "Blue Italian Growth" (BIG), led by the Italian National Research Council (Consiglio Nazionale delle Ricerche – CNR), has been granted access to financial support, while the blue energy project TEOREMA (Technological Solutions for Multi-Objective Off-Shore Energy Platforms), ranked first in its category, is to enter into negotiation.
- Decree N. 1735/13 July 2017, a call for proposals

targeted at projects focused on industrial research and experimental development in the 12 areas of specialization individuated by the Italian National Research Programme (Programma Nazionale per la Ricerca – PNR) 2015-2020. The strategic areas include Blue Growth, and Blue Energy (BE) is explicitly mentioned as a relevant sector.

Such initiatives are expected to contribute to the rationalization of the Italian activities in the blue energy field, and to systematically support the so far isolated efforts of the national actors, amplifying their collective impact by connecting different economic sectors, as well as relevant stakeholders from the business community, the government and civil society, thus also helping create a systematic framework of rules and incentives. As a matter of fact, the Italian research community has so far resorted to a variety of independent public funding sources, either national or international, which, albeit significant in terms of prestige, do not guarantee the constant, coherent and predictable support required to fully exploit the Italian potential and to consolidate Italy's position in the international market.

Permitting and Licensing Process for ocean energy projects

It is the prerogative of the National Government to establish the fundamental principles in the subject of national production and distribution of energy through the national legislative acts, and that of the Regions to exert their legislative power in the constraining framework of such principles, as explicitly determined by the National Government. Additional constraints are represented by EU Directives, and by the National Government having sole competence on transversal subjects, such as the protection of the environment and of competition. Regions are responsible for the regulative and administrative functions that are not explicitly attributed to local authorities or to the National Government. For offshore energy production from renewable sources, D. Lgs. 387/2003 constitutes the main reference, in particular Art. 12 and its subsequent amendments. In accordance with the current repartition of functions, each Region proceeded to legislate and regulate energy through specific acts, which are listed, together with the relevant national legislation, in Appendix 4.2.1.A to the National Action Plan.

Authorization procedure

The simplified authorization procedure for energy production from renewable sources currently in force was introduced via D. Lgs. 387/2003, which transposed EC Directive 2001/77/EC. In particular, Art. 12 of D. Lgs. 387/2003 and its subsequent amendments prescribe that the construction and operation of such plants, as well as their modification, upgrade, total or partial restoration, reactivation, and necessary works and/or infrastructures and interconnection facilities, are subject to a single authorization *(autorizzazione unica)*, which is issued by a single responsible authority. Nevertheless, such authorization must comply with the legislation in force as to the protection of the environment, of the landscape, and of cultural heritage, and it must undergo a complex administrative procedure designed to ensure the involvement and coordination of all the authorities and administrative bodies that represent and protect the different and diverse public interests involved. Therefore, the authority responsible for the authorization is to convene the *Conferenza dei Servizi* (Conference of Services), an assembly introduced via L. 241/1990, where the potentially concerned institutions, administrations and representative bodies are summoned in order to jointly examine and evaluate the proposed project. A motivated final resolution is then taken, according to the prevailing position, within 180 days from the application.

The juridical expression prevailing position can be a matter of interpretation, as the single position of each

participant in the Conference needs to be weighed by the authority each possesses to condition or bind the authorization procedure, according to the legislation in force. Once issued, the single authorization replaces the several permits and licences required under the old regulatory regime.

In the case of offshore installations, the single authorization is issued by the Ministry of Transport and Infrastructures *(Ministero delle Infrastrutture e dei Trasporti)*, upon approval by the Ministy of Economic Development *(Ministero dello Sviluppo Economico)* and by the Ministry of *Enviroment (Ministero dell'Ambiente e della Tutela del Territorio e del Mare)*, having been granted rights to the use of state owned maritime properties and sea waters (according to the provisions of Art. 36 of the *Codice della Navigazione* – Marine Traffic Regulations), and having been examined and passed by the *Conferenza dei Servizi*.

The authorization permits sponsors to proceed with the works and operate the plants according to the project approved, in compliance with the prescribed requirements and reporting obligations that guarantee the safety and consistence of the national power system and the protection of the environment. The single authorization also determines the decommissioning and site restoration requirements, and the deadlines for the initiation and completion of the works, whose expiration will cause the same authorization to lapse.

Due to the nature and the complexity of the matter, a variety of public bodies, administrations and stakeholders are liable to be concerned, and therefore participate in the authorization process, ranging from Regions to municipalities, to the Ufficio del Genio Civile per le Opere Marittime (Marine Civil Engineering Department), to the Circoscrizione doganale (District Customs Bureau), to any other concerned administrative body or authority, that in force of legislation and/or regulation is entitled to represent specific public interests. The reason for such broad engagement is that the interests and values at stake are multifaceted, possibly intertwined although often competing, so that the decision process must be fully participatory, achieving the best balance between all the goals and constraints. Therefore, the total duration of the authorization process can be well over a year (at least), a timeline that is hardly compatible with the necessities of research projects and small scale testing activities, although affordable by large-scale commercial implementation projects.

Research coordination

In the framework of the agreement between ENEA and the Ministry of Economic Development (MISE), under the Ricerca di Sistema - Ocean Energy Programme, ENEA has been long carrying out an intense coordination activity aimed at bringing together the major Italian actors in the ocean energy sector. The national workshops on ocean energy that are periodically hosted on ENEA premises in Rome constitute important milestones in the progress of the connected scientific and business community towards coordinated action. The first Workhop – "*Prospettive di sviluppo dell'energia dal mare per la produzione elettrica in Italia*" - was held in June 2011, followed by a second in July 2014 – "*Energia dal mare: le nuove tecnologie per i mari italiani*" - and by a final conference – "Energia elettrica dal mare" - in July 2015. A great effort was made to interrelate and standardize the scientific and technological expertise of the involved partners, and to set up an unprecedented synergic effort for the technological innovation of marine energy plants, on which the recent National Research Action Plan 2015-2020 was able to draw for the constitution of the Blue Growth Technology Cluster.
In May 2017, ENEA also hosted the meeting "Italian contribution to the SET Plan on Ocean Energy", in accordance with the guidelines of the European Strategic Energy Technology Plan (SET-Plan). The meeting aimed to bring together the Italian R&D activities in the blue energy sector, in order to design a common strategy for the acceleration of their development and for the deployment of innovative technologies in the transition to a low-carbon energy system. During the meeting, opportunities for fruitful coopetition were envisaged by the different actors from academy and industry, in a horizontally integrated approach.
Similar initiatives are being promoted by CNR in the framework of the H2020 project "MARINERGI" (2017-19). The project aims to create a Consortium of European partners for the establishment of the first distributed and integrated European research infrastructure on marine renewable energy. The ambition is to candidate the MARINERGI Consortium for the ESFRI 2020 Roadmap. CNR has been invited to represent Italy in the Consortium and to promote a network of national stakeholders with expertise, capabilities and interests in marine renewables technologies.

Technological advancement

Devices for the conversion of blue energy

The most promising ocean energy technologies are:

- Converters extracting kinetic energy from tidal currents;
- Converters exploiting the difference in potential energy arising from the rise and fall of sea levels between high tide and low tide (tidal range);
- Wave energy converters, extracting kinetic energy from wind-driven waves;
- Ocean Thermal Energy Converters, exploiting temperature differences between deep and surface ocean waters;
- Salinity gradient converters, harnessing the chemical potential of differences in salt concentration in ocean waters.

For each of these resources, different technical solutions were developed, either by adapting existing technology or by designing innovative devices. Parallel technological innovations aim at enhancing the efficiency in energy conversion and/or in storage and distribution, and transversally affect all the ocean energy technologies.
In Italy there is an increasing interest in the exploitation of wave and tidal energy converters.
Devices integrated into conventional breakwaters represent an interesting category of wave converters, as they offer the advantage of a limited increase in the cost of the breakwater in conjunction with ease of maintenance.

Wave converters

The Università Mediterranea of Reggio Calabria has been developing the REsonant Wave Energy Converter (REWEC3 – at present TRL 7), which is a particular type of Oscillating Water Column (OWC) incorporated into a traditional vertical breakwater of monolithic reinforced concrete structure type (Fig. 1). This activity is being carried out in cooperation with Wavenergy.it – an Academic Spin-Off of the Università Mediterranea. The new device was conceived and patented by Professor Paolo Boccotti, and Wavenergy.it Ltd is the exclusive licensee of the patent.
It consists of a vertical pneumatic chamber connected to the open wave field by a U-duct. This device is composed of a chamber containing a water column in its lower part and an air pocket in its upper part. The air pocket is connected to the atmosphere via a small duct hosting a self-rectifying turbine. In addition, a REWEC3 also includes a small vertical U-shaped duct for connecting the water column to the open sea. The working principle of the system is quite simple: by the action of the incident waves, the water inside the U-shaped duct is subject to a reciprocating motion. This motion alternately induces the compression and the expansion of the air pocket, generating airflow in the air duct. A turbine coupled to an electrical generator, installed into the air duct, is thus driven to produce electrical energy. The dimensions of the device are designed to reach resonance under the more energetic sea wave conditions of the specific site. A small-scale device has been installed at the Natural Laboratory of the University in 2005. The first full-scale prototype is under construction in the port of Civitavecchia (Rome, Italy), as the Port Authority of Civitavecchia recently decided to upgrade its infrastructure and adopted the REWEC3 technology for the realization of 17 new caisson breakwaters. Each REWEC3 caisson is 33.94 m long and includes 6-8 independent absorbing chambers. The total length of REWEC3 caissons is 578 m. A first Wells turbine of 20 kW, without any optimization, has been installed, while the total installed power will be of 2.5 MW. The characteristic of the Wells turbine was determined by the Università Mediterranea

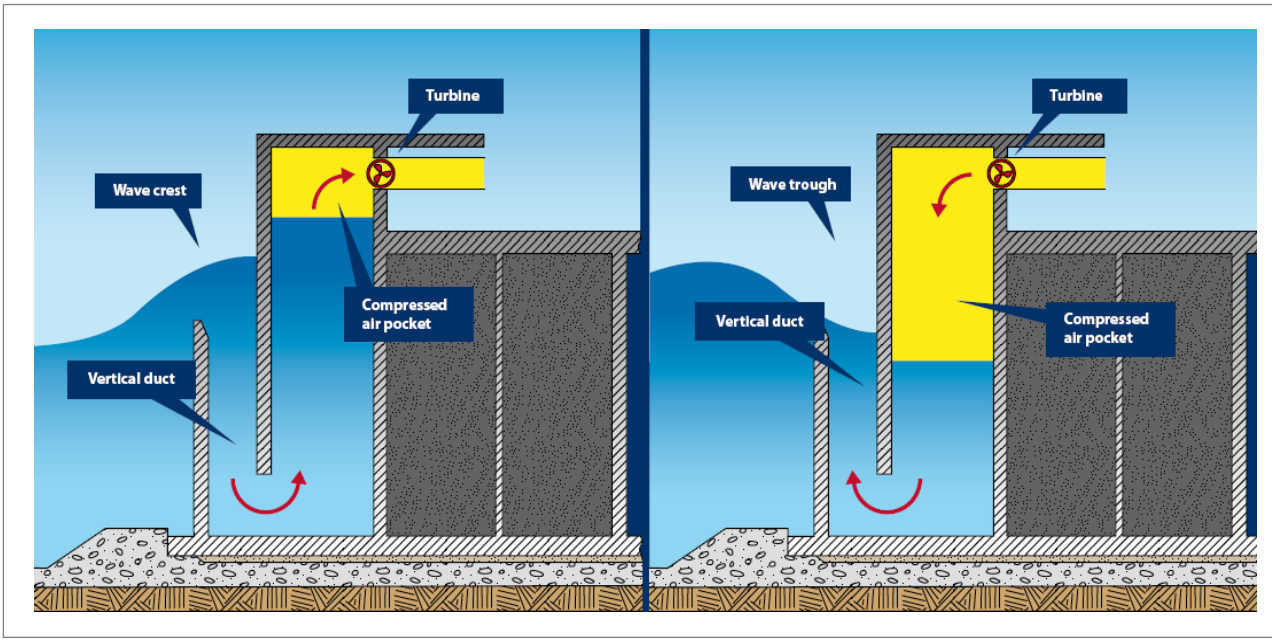

Figure 1 - Scheme of a REWEC3. Left panel: plant behaviour during a wave crest, right panel: plant behaviour during a wave through

of Reggio Calabria, in collaboration with Wavenergy.it; it was realized by Faggiolati Pumps SpA. Theoretical and experimental analyses of the device are reported in many journal papers, in the book "Wave Mechanics and Wave Loads on Marine Structures" by Boccotti P. (2014, Elsevier Science, Oxford, UK), and in the proceedings of several international conferences.

The Università degli studi della Campania "Luigi Vanvitelli" developed a device denominated OBREC (Overtopping BReakwater for Energy Conversion), embedded into a breakwater and based on the wave overtopping process. The device consists of a rubble mound breakwater with a frontal reservoir designed to capture the wave overtopping a sloping ramp in order to convert wave energy into potential energy. Water stored in the reservoir produces energy by flowing through low head hydraulic turbines, as a consequence of the difference in water level between the reservoir and the main sea water level (Fig. 2).

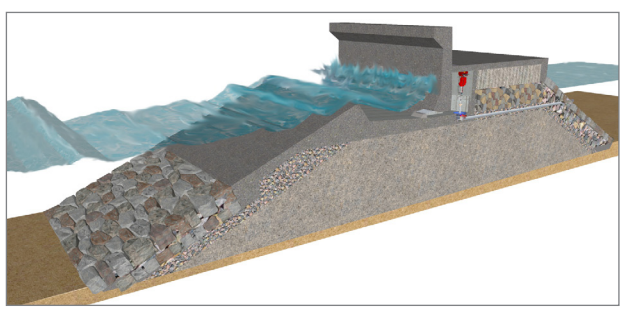

Figure 2 - Innovative rubble mound breakwater with frontal reservoir for energy production

A small-scale (1:30) prototype of the OBREC was tested at Aalborg University (Denmark) during two complementary experimental test campaigns in 2012 and 2014, in order to optimize its geometrical parameters and to assess its hydraulic performances and loadings. The potential wave energy obtainable was estimated as a function of the mean water discharge entering the frontal tank, for different geometries and wave conditions.

Tests have shown that the integration of an OBREC into a breakwater improves its overall performances. A full-scale, 6 metres long prototype has been installed in the port of Naples in 2015, along the San Vincenzo rubble mound breakwater, where sea depth is about 25 m and available wave power is estimated to be

Figure 3 - Breakwater equipped with the OBREC prototype in the port of Naples

around 2.5 kW/m (Fig. 3). The overall performance of the device is being monitored.

The Politecnico of Turin developed ISWEC (Inertial Sea Wave Energy Converter, TRL 7), a point-absorber wave converter suitable for mild climate seas such as the Mediterranean (Fig. 4). It is based on the gyroscopic technology already used in marine applications for roll stabilization, except that the direction of energy transfer is reversed, with the gyroscopic torque induced by the incoming waves being exploited by the electrical PTO. The main characteristic of ISWEC is the possibility of controlling the flywheel spinning velocity so as to match the sea state and increase the productivity of the device. An advantage of ISWEC is the absence of submerged parts in relative motion, as the whole conversion group is allocated inside the hull. Its implementation is not limited by constraints on the seabed, as it requires only a slack mooring, thus guaranteeing an extremely reduced environmental impact. Research activities started 10 years ago and led to the development of the technology industrialized by Wave for Energy, a spin-off of the Politecnico of Turin. On August 2016, the first full-scale ISWEC prototype, with a nominal power of 100 kW, was moored 800 m from the coast of Pantelleria.

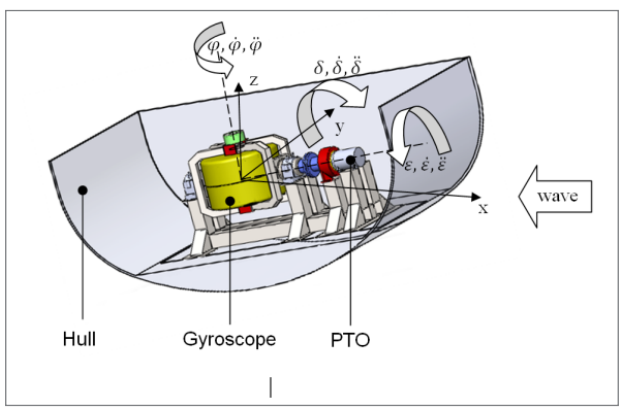

Figure 4 - The layout of ISWEC

The Politecnico of Turin, in collaboration with ENEA, also developed the point-absorber denominated PEWEC (PEndulum Wave Energy Converter, TRL 5). PEWEC is a passive system based on a pendulum positioned inside a hull, whose oscillation is converted into electrical energy via a power take off. A 1:12 prototype has been tested in the towing tank managed at CNR-INSEAN in Rome (Fig. 5).

Figure 5 - The PEWEC prototype at INSEAN

Among the converters developed by 40South Energy, the H24-50kW was the first machine to reach commercial stage. The H24-50kW is a small device, with a Guiding Member which sits on the sea floor or on a small support structure (depending on water depth and on tidal range), and a Moving Member above it which moves under the action of waves or tides. This device works seamlessly as wave and tidal units. In grid-connected situations these machines are being used in Wave and Tidal Energy Parks consisting

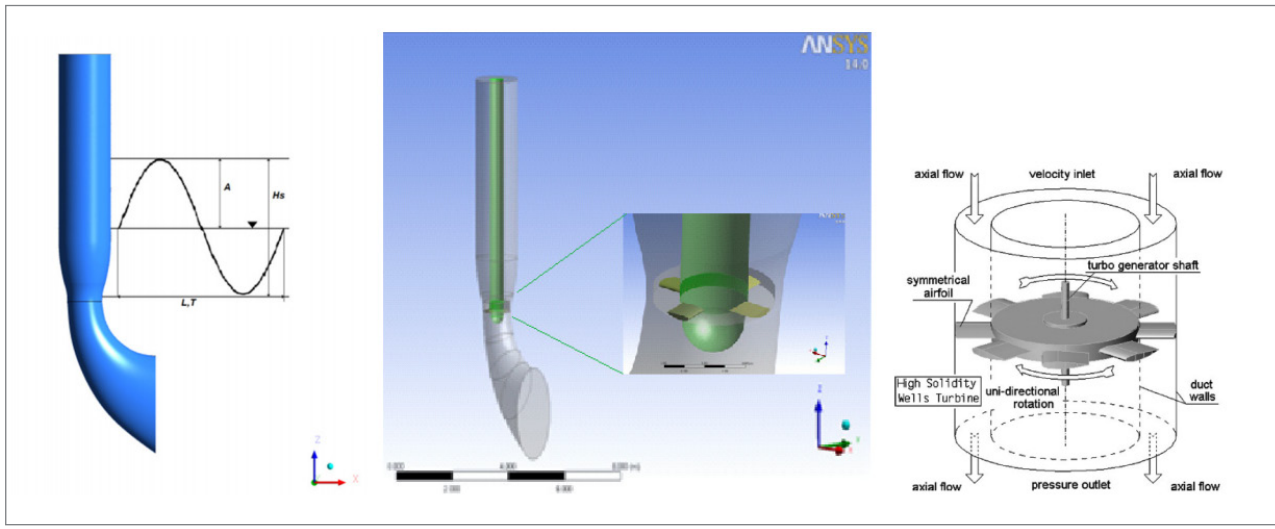

Figure 6 - WAVESAX scheme: fixed body (left), rotational body (centre) and type of turbine (right)

of several units in arrays, typically disposed parallel to the shore. The ideal situation is when coastal protection structures are already present or in need, like when there are harbours or airports. The production with these machines is significantly more stable than that of wind turbines and in case that the site is energetic both in tidal and wave energy they can achieve very high capacity factors. H24 was first deployed off the coast of Marina di Pisa, Italy, and is operated and managed by Enel Green Power.

RSE (Ricerca sul Sistema Energetico - Research on the Energy System) SpA developed WAVESAX (TRL 5/6), an innovative wave converter within the OWC category, registered before the European Patent Office (Patent Document n. 2 848 802 B1, European Patent Bulletin 2016/23). This device (Fig. 6) has been conceived for its integration in coastal structures (e.g. harbours and ports). It consists of a vertical pipe in which water moves upward and downward, following the wave motion. Inside the pipe a hydraulic turbine is positioned, that transforms the energy of the moving water into electricity. The turbine is of a bi-directional type (i.e. the rotor rotates in the same direction during both the ascending and the descending phase of water motion). The main advantages of the device are its low cost and its modularity, as it can be installed individually or in batteries of several elements. Laboratory test studies have been performed on a scale model (1:20) in the ocean wave basin of the HMRC - Hydraulic Marine Research Centre (Cork, Ireland).

A second 1:5 scale prototype (Fig. 7) has been tested

Figure 7 - The WAVESAX 1:5 scale prototype

at the ECN Hydrodynamic and Ocean Engineering Tank (Nantes, France), in order to study different rotor configurations under regular and irregular wave conditions, while the facilities provided by CNR-INSEAN permitted the assessment of device performance for different turbine configurations and control strategies.

Seapower Scrl (a consortium between private companies and the Department of Engineering of the University of Naples "Federico II"), in collaboration with Umbra Group, developed the GEL system (TRL 5), a wave energy converter designed to be installed near the coast or in shallow waters (Fig. 8).

The device consists of a floating body linked to a fixed frame that is left free to oscillate around a horizontal axis under the action of waves. The permanent magnet elec-tric generator, inte-grated in the Power Take Off (PTO) actua-tor/generator, allows the transformation of linear motion induced by waves into rotary motion of the generator rotor.

A floating body of about 5 m width can produce around 60 kW out of waves of 1.5 m height. In a sufficiently energetic site (e.g. the west coast of Sardinia), the system is expected to produce approximately 150,000 kWh per year. A 1:5 and a full scale prototype have been tested in the wave tank located at the Department of Industrial Engineering (DII) of the University of Naples "Federico II". It has reached TRL 5 and it is ready for testing in real sea conditions.

A new type of wave energy converter based on elastomeric composite materials was developed at the Scuola Universitaria Superiore Sant'Anna (Pisa). Related research is now jointly conducted at the Universities of Trento and Bologna, focusing on the modelling and simulation of its behaviour, on the design and prototyping of its structure, on the primary mover and on PTOs for wave energy converters.

The University of Genoa, in collaboration with RINA Consulting (formerly D'Appolonia), developed a prototypal device named Seaspoon, a wave orbital motion converter, which was installed in the open-sea in front of Genova city in 2015 (nominal capacity 1 kW and 2 m wave front length), after having been tested in the wave tank available at the University campus (nominal capacity 10 W and 0.6 m wave front length). Analyses of its performance confirmed the predictions, showing good sea-state adaptability and storm survivability; current efforts are devoted to its possible integration in a smart grid. The prospect of powering offshore charging stations for autonomous naval systems by using micro-turbines is going to be tested in a new wave energy generator utilising sea water, 5m wave front, being installed in the La Spezia harbour: the Seaspoon prototype at TRL 6 is designed to produce approximately 100-200 W continuous power, depending on the generated waves (max height of 0.7 m). Another concept has been developed by the SME GENERMA Srl. The technology consists of an innovative wave energy conversion system based on the attenuator concept. The device consists of unit elements connected together by hinges in a floating modular structure. The relative rotation of modules under wave motions moves hydraulic pistons that compress fluid in a closed circuit. Energy conversion is obtained by a modified Pelton turbine and an asynchronous generator. A consolidated alternative is to substitute such hydraulic system with reciprocating linear alternators,

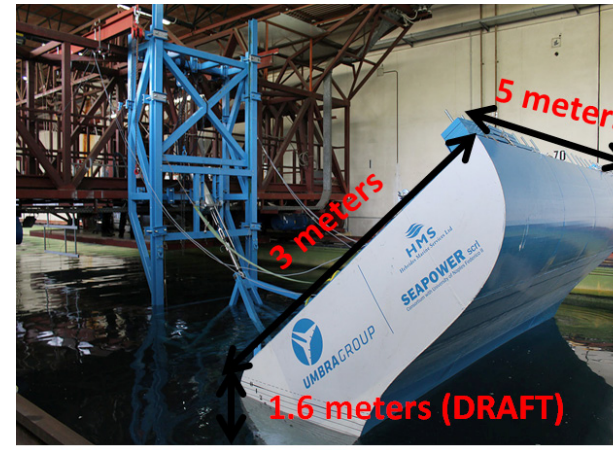

Figure 8 - The GEL prototype

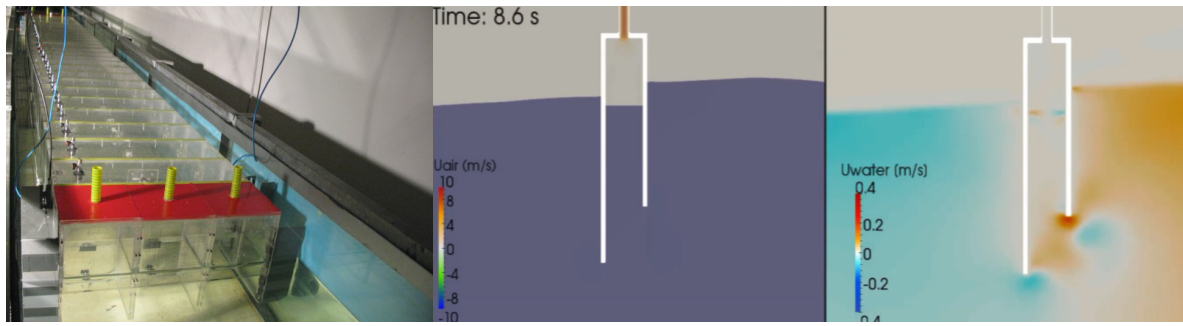

Figure 9 - Left: scale model of the floating platform equipped with the OWC tested at the University of Florence (TRL4). Centre and right: sample results of the CFD study conducted to optimize the efficiency of the OWC device

working on the principle of electromagnetic induction. The latter allow to directly obtain electricity by a less bulky and lighter device, at the same time reducing maintenance costs. After laboratory tests on sub-components and early field tests on a small 5 kW model, in 2016 a near-scale prototype 80 m long and 1.9 wide with nominal power of 150 kW has been realized and field tests in the Adriatic Sea are planned by the end of 2017.

The Laboratory of Maritime Engineering (LAboratorio di Ingegneria MArittima – LABIMA) of the University of Florence (www.labima.unifi.ti), and its spin-off AM3 Spin Off Srl are developing a floating caisson embodying an oscillating water column (OWC) wave energy converter (WEC). The caisson is designed as an anti-motion device for very large floating platforms with the additional benefit of providing an efficient renewable energy source. The device development has reached TRL4, the new technology having been validated and optimized through laboratory experiments and CFD modelling (Fig. 9). Experimental tests proved that the pneumatic efficiency of the developed OWC is around 87% in the wave conditions typical of the Mediterranean. This activity obtained the financial support of Regione Toscana under the project GENOMA. Furthermore, LABIMA provided support to the German enterprise SINN Power GmbH during the development (TRL4 phase) of their point absorber WEC, which has been operating in Crete (Greece) since 2015 (Fig. 10). LABIMA and SINN Power are now negotiating the implementation of similar devices in the Italian seas with Italian Port Authorities and other Italian bodies.

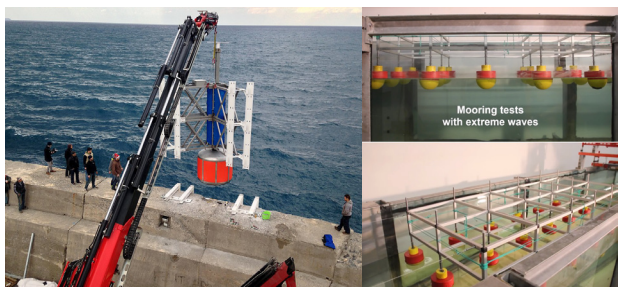

Figure 10 - Left: full scale installation of the SINN Power single module WEC in Crete (2015). Right: SINN Power multi-module WEC under development at LABIMA (TRL4) (2014)

Tidal turbines

The Aircaft Design & AeroflightDynamics Group (ADAG) of the University of Naples “Federico II”, in cooperation with SEAPOWER Scrl, has long been designing systems for the extraction of energy from marine currents.

It developed and patented the KOBOLD turbine (TRL 7), a rotor mounted on a vertical shaft, which produces mechanical energy by exploiting marine currents. A platform equipped with a Kobold turbine of the diameter of 6 m with three blades with a span of 5 m, built by the Ponte di Archimede Company, has been installed in the Strait of Messina in the year 2000 and is still in operation (Fig. 11). The nominal power

output is 30 kW and the device is connected to the distribution grid.

ADAG and Seapower, in cooperation with Ing. Morrone, also designed GEM, the Ocean's Kite (TRL 7), an ocean current energy conversion system that consists of a submerged body with two horizontal axis hydro turbines (Fig. 12). It is tethered to the seabed and free to self-orienting to the current. The device is placed at the desired depth thanks to its self-towing winch and is easily recovered to the surface for maintenance. Patented in 2005 GEM, after the experimental phase in towing tank, a first full-scale prototype has been deployed in Venice lagoon. The nominal power of the device is 100 kW with 5 knots of current speed; in the Venetian lagoon, where the maximum flow current speed is around 3 knots the power that can be produced is about 20 kW. A full-scale prototype of 300 kW will be installed in the Strait of Messina.

Figure 12 - The GEM device

Support technologies

The positive international outlook for ocean energy deployment has induced researchers involved in subsidiary fields and potentially connected industrial players to approach this promising sector. They actively contribute to designing the building blocks of innovative ocean energy converters, either by developing ad hoc technologies or by optimizing existing ones, as well as to enlarge the existing database of environmental and product design constraints.

Figure 11 - The Kobold installation

Environmental modelling: resource availability, environmental impact assessment, optimal design of installations & operative parameter tuning

Prior to planning a renewable energy project it is essential to determine where sufficient resources exist, that guarantee adequate return on investment levels. For this reason, it is essential that reliable and updated maps, data and forecast systems are coupled to the engineering of devices, allowing optimal facility siting and a better understanding of site characteristics. As the size and complexity of the installations under study increase, the tools adopted to project or measure the resource become more and more critical, and need to integrate a variety of modelling and monitoring techniques.

ENEA performs ocean wave modelling activities aiming to both quantify ocean energy availability in the Mediterranean Sea and provide the information necessary to optimize the operational set-up of wave energy converters (Fig. 13). A wave forecast system was developed and validated at ENEA, and is operatively

running since June 2013 (https://giotto.casaccia.enea.it/waves/). Forecasts cover the entire Mediterranean basin, while nested higher resolution projections are provided for ten sub-basins along the Italian coasts. A sample projection for the western coast of Sardinia is shown in Fig. 14. When coupled to real-time measurements, the forecasting system can further support the operation of wave energy generation devices, predict actual electric power generation and give the alert in case of severe sea conditions.

Similar activities, for specific sites or periods, are carried out at the Universities of Bologna, Genoa and Florence and its spin-off AM3 Spin-Off, the University of Tuscia, the Marine Energy Research & Innovation Center (MERIC) and RSE, in some cases also including the assessment of the potential offered by tidal currents.

RINA Consulting routinely performs meteocean modelling, mainly to support the optimization of design parameters of engineering projects in offshore areas (platforms), marine, waterfront (harbours) and coastal (beach protection) environments, and to minimize their environmental impacts. Offshore geotechnics services are carried out for offshore platforms, subsea structures, pipelines, floating structures applications, including non-linear dynamic modelling capacity, highly suited to characterise deep-water soil conditions under earthquake loading.

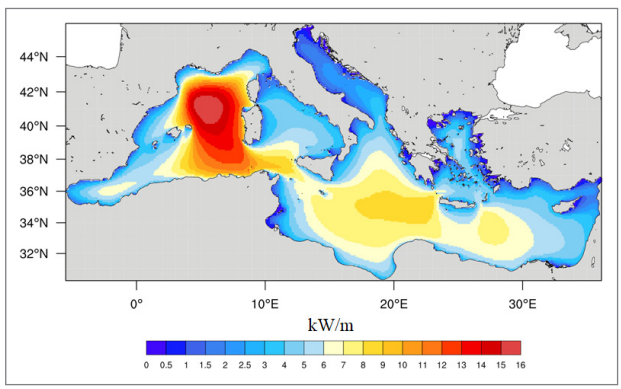

Figure 13 - Mean Energy flux over the Mediterranean for years 2001-2010

RINA Consulting experts are highly experienced in analysing meteorological and oceanographic data, as well as extreme event statistics, and in characterizing the typical environmental conditions and processes at the project site, including longshore/cross-shore sediment transport and contaminant dispersion. Additionally, RINA consulting provides design, installation and management services of monitoring systems to measure meteocean data (winds, waves, water level/velocity/acceleration, salinity, density, atmospheric pressure, and temperature).

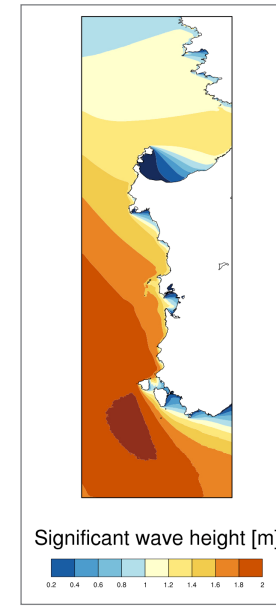

Figure 14 - Sample projection for the western coast of Sardinia

Enel Green Power also carries out strategic activities to identify, predict and classify the potential environmental risks of marine energy plants, from concept to decommissioning, thus supporting the selection of sites that present lowest sensitivity to project characteristics, as well as the redaction of exhaustive Environmental Impact Assessments (EIAs). In addition, it evaluates the associated socio-economic impacts and promotes the early engagement of all concerned stakeholders through iterative consultation in a fully participatory process.

Device optimization

Once the optimal siting of a device for ocean energy conversion has been analysed, its further development requires the careful assessment of its expected performance in realistic operative conditions. All the Italian research institutions and enterprises involved in the development of devices for ocean energy con-

version, design ad hoc numerical model for their most promising concepts, which mimic their behaviour from the mechanical and hydro-dynamical to the electrical aspects, also accounting for the control system, for the characteristics of their industrial components and for the constraints of grid connections. Simulations are carried out in a variety of sea conditions and multiple device arrangements, and finally provide optimal configuration and scaling, geometrical layout and layout orientation, together with the estimate of maintenance requirements and yearly average productivity.

The Politecnico of Turin routinely performs numerical experiments in order to explore a large number of possible configurations for the devices that are being developed, from the first stages of the design process. Device productiveness is first assessed by using linear models that offer speed of execution and acceptable accuracy. After the best overall system layout has been identified and the size of the main components has been decided, the system configuration is refined by using more complex and accurate non-linear numerical models, at a higher computational cost. Both in-house and commercial software tools allow the simulation of array pattern arrangements of devices, assessing the performance and productivity of wave farms as a function of location, mutual hydrodynamic interaction and electric connection. Numerical tests also enable to estimate maintenance requirements and optimal operating conditions.

The University of Bologna and Politecnico of Milan conduct numerical experiments to optimize the scaling and performance of wave power devices to be deployed off the Italian coast and in the Mediterranean environment, where most of the existing wave power technologies are oversized. Their tests demonstrated that several Italian locations and a large part of the Mediterranean coastline could be successfully exploited for marine energy production if properly downscaled devices were employed. They also develop non-linear models of the combined hydro-mechanic and electromagnetic behaviour of WECs, as well as of the hydrodynamic interactions of point absorber arrays (wave farms) in real wave fields. Special attention was given to the modelling of the surge effect in a heaving point absorber, and of its contribution to the expected energy production.

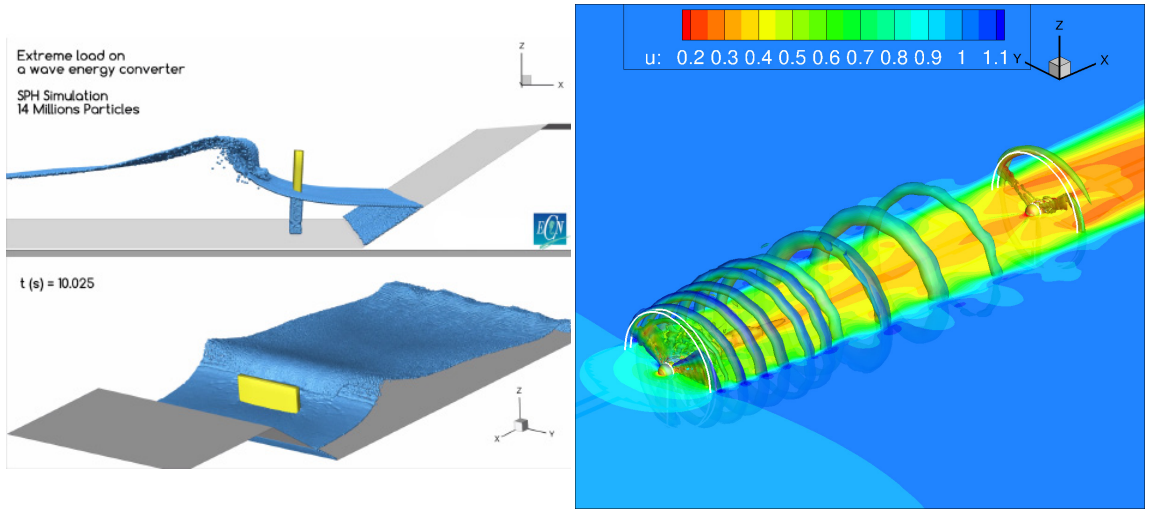

Figure 15 - Computational Fluid Dynamics (CFD) models by CNR-INSEAN for the analysis of marine energy systems. Flapping foil WEC in extreme waves (left), interaction between two turbines in a tidal array (right)

The Sapienza University of Rome recently developed an integrated open source tool, aiming at modelling the behaviour of floating wave energy converters under the ENEA-RSE-MISE agreement.

CNR-INSEAN carries out research activities for the development and validation of advanced Computational Fluid Dynamics (CFD) models to numerically simulate the operation of wave and tidal energy devices. (Fig. 15). These methodologies can be used to analyse system performance and response to environmental conditions, including severe sea states, and provide a complementary approach to standard experimental studies on physical models. Numerical applications on Wave Energy Converters include the characterization of the hydrodynamic response of various types of concepts and the prediction of power output over a range of operating conditions. Computational studies of tidal turbines are performed to predict the hydrodynamic performance of single devices as well as of array of devices. Results are validated against experimental data and are intended as support tools for the design and development of new systems for the generation of energy from waves and currents.

Experimental infrastructures

During the development of any ocean energy converter from its first modelling to its deployment, scale prototyping and testing is crucial to correctly re-direct the design process. Small and medium scale prototypes are used in wave flumes and wave tanks where a specific sea state can be artificially created, and power production and device survival assessed. While scaling down the system, the wave tank/flume features are also to be taken into account, so as to scale the prototype according to the characteristics of the facility that is going to be used.

Figure 16 - CNR-INSEAN tank

- While universities usually offer facilities of limited size that confine their application, the CNR-INSEAN offers research infrastructures that include world-class towing tanks and flume tanks, thus providing a relevant testing environment for wave, tidal, offshore wind energy systems (Fig. 16). The facilities provided are among the largest worldwide, and consist of:
  - a 460 x 13.5 x 6.5 m calm water towing tank
  - a 240 x 9 x 3.5 m wave towing tank
  - a 12 x 3.6 x 2.3 m depressurised circulating water channel.

These infrastructures are used to test large-scale models of concepts with TRL up to 5 and allow the simulation of real operating conditions at sea, accounting for the combined effects of winds, currents and waves. The facilities are equipped with advanced measuring systems in order to provide a complete characterization of device performance and response to simulated operating conditions, including extreme events. Testing activity is supported by in-house laboratories for the design, manufacturing and maintenance of test models and of the related equipment.

Research work in this area includes the development of new equipment specific for MRE systems, and the elaboration of testing protocols and standards in collaboration with other leading international research centers. The facilities are included into the network of MRE testing infrastructures under the EU-FP7 MaRINET and H2020 MaRINET-2 projects. CNR-INSEAN also investigates the hydrodynamic and structural response of offshore floating platforms through numerical modelling.

Although experimental activity at CNR-INSEAN is mainly focused on techniques for laboratory-scale hydrodynamic facilities, equipment to characterise field wave and tidal resource and relevant environmental conditions parameters is under development in the framework of the RES-MARE project. In particular, a moving laboratory to support field site measurements will be available by 2017 for support on site characterization and prototype operation activities. In addition to this, within the Flagship Project Ritmare, a 5 m autonomous vehicle (U-SWATH) for measurements at sea is under development, with an on-board laboratory for the characterization of seawater qualities (e.g. currents, temperature, waves) and for the support to field testing activities.

The University of Naples Federico II offers the largest towing/wave tank in Europe that is hosted at a university. The towing tank is 140 m long, 9 m wide and 4.5 m deep. Maximum towing cart speed is 10 m/s (~20 knots). The installed wave-maker is capable of generating regular and irregular waves from 1 m to 12 m length. The steepness ratio (height/length H/λ) can be varied from 1/100 up to 1/15 for waves of 9 m (Fig. 17).

- The LIDR (Laboratorio di ingegneria IDRaulica – Hydraulic Engineering Laboratory) of the University of Bologna hosts a wave basin where 16 independent wave paddles can generate regular, irregular and multidirectional waves simultaneously with the generation of currents. The basin measures 18 m x 10 m x 1.5 m, while the maximum possible wave height is 0.5 m.
- The Natural Ocean Engineering Laboratory (NOEL) of UNIRC provides a unique testing infrastructure in the marine environment (Fig. 18), where field tests can take advantage of the dedicated sensors and data acquisition centre, and be carried out with the support and assistance of specialized personnel (www.noel.unirc.it).
- Facilities for the measurement of environmental variables are offered by RSE and by the University of Tuscia. In particular, RSE is running two monitoring stations, Capo Granitola, measuring wind and wave parameters (Sicily, Italy – 2013-2016), and Civitavecchia, measuring wave and real-time meteorological

Figure 17 – The towing/wave tank at the University of Naples Federico II

parameters (Latium, Italy – 2013-2017), while at the University of Tuscia, the Laboratory of Experimental Oceanology and Marine Ecology is equipped to carry out field measurements on wave characteristics, sea currents and water and sediment characteristics.

- The University of Genoa owns and operates an offshore elastic beacon for testing sea energy devices at about 1.8 km off the coast of Genoa city, with a depth of 35 m. The beacon, which is self-powered by photovoltaics, is instrumented with wave radar meter and data tele-transmission to the internet. The University of Genoa also owns and operates the first wave energy generator in sea water, installed in the La Spezia harbour at CSSN site. The wave energy generator features a wave front of 5m, wave max height of 0.7 m and period of 4 s. The test section is equipped with support elements to position and operate wave energy converters and their PTO. The test section is designed to include energy storage devices, such as a module for hydrogen generation (PEMFC) and storage (metal hydrates).

Figure 18 - The NOEL at Reggio Calabria

- The University of Florence hosts a wave-current flume in Laboratory of Maritime Engineering (LABIMA) (Fig. 19) and a wind tunnel in the Wind Engineering Laboratory (Centro di Ricerca Interuniversitario di Aerodinamica delle Costruzioni e Ingegneria del Vento - CRIACIV). Such infrastructures are part of the EU network of 39 partners sustained by the MARINET and MARINET2 EU projects. During the last 5 years, several EU research groups have benefited from the financial support provided by MARINET and MARINET2 for accessing LABIMA and CRIACIV infrastructures. Details on how to apply and a list of the projects that were awarded access can be found at www.labima.unifi.it.

Infrastructure design & development of mechanical and electrical elements

In order to support the development of the ocean energy sector, innovative infrastructures and components need to be designed that are capable of enduring the marine environmental stresses they are to suffer, thus making facilities less prone to faults and more cost-efficient and guaranteeing that they can be kept in constant operation. The Italian experience in connected sectors such as marine construction, shipbuilding and electric power system design and operation provides invaluable opportunities for knowledge transfer and for the adaptation of technological solutions that can accelerate the deployment of ocean energy.

Fincantieri Oil & Gas has been long designing and constructing floating structures for the energy sector, including vessels for Oil & Gas operations (drilling platforms, offshore supply vessels), for the renewable energy sector (vessels for installation and maintenance of offshore renewables infrastructure such as wind farms), and for the construction of offshore infrastructure (e.g. cable laying vessels). For such a large enterprise, the development of the ocean energy sector represents not only a business opportunity to expand current activities in the renewable market, but also a chance to acquire new skills and capabilities that will enable them to confirm their capacity of offering innovative, high-value solutions. Fincantieri Oil & Gas can provide support for the assessments of technologies related to floating structures, marine systems, and ship technology. Likewise, the company can deliver the

Fig. 19 - Above: the Wave-Current Flume at LABIMA, University of Florence. Below: scale models of a tidal-current turbine (left) and of an offshore wind tower (right) tested in the LABIMA wave-current flume

economic assessment of the different phases in the lifetime of a floating structure, from construction to deployment. Following a consolidated tradition in creating partnerships with companies and research institutions, they have already started collaborating with the Politecnico of Turin on their WEC, and are active in studying and promoting innovative solutions for combining different technologies on a common offshore platform. In particular, Fincantieri Oil & Gas designed Sea Flower, an innovative floating platform for offshore wind power generation suitable for the latest generation of wind turbines, allowing them to be installed farther from shore, which reduces the visual impact of offshore farms (Fig. 20).

Innovative energy storage solutions and batteries for marine offshore applications are currently being developed by H2boat, a spin-off of the University of Genoa which, in collaboration with Fincantieri, participates in the Hydrogen Initiative for Sea Energy Applications (HI-SEA) by designing, constructing and managing a joint laboratory for the investigation and testing of the applicability of fuel cell technologies from the automotive sector to such purposes. In particular, research is focused on the thermal and fluid integration of PEM fuel cells and Metal Hydride hydrogen storage (prototype 1, completed), and on the electric and fluid integration of Electrolyser and RES plus Metal Hydride storage for hydrogen production and storage (small scale prototype 2 – under development). These high quality and long life batteries can be supplied either as part of an integrated marine renewable energy solution or supplied as stand-alone battery packs or individual units.

RINA Consulting also provides cost effective solutions

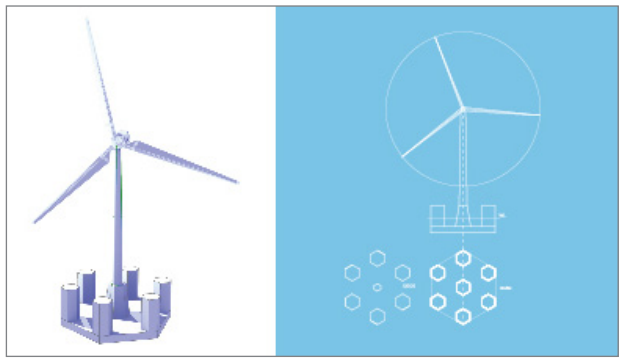

Figure 20 – The Seaflower platform

for onshore construction as well as hands-on experience in all areas of offshore geotechnics. Typical projects include offshore platforms, subsea structures, pipelines, floating structures, and rely on advanced laboratory testing and site response analysis, which include quantitative risk assessment. Investigations are provided for the full range of marine installation, and include the hydrodynamic and seakeeping analysis of floating units, their mooring analysis, ship handling / manoeuvring simulations, and the analysis of mechanical components (e.g. static and dynamic stress analysis, structural thermal coupling, vibration and fatigue analysis). In addition, RINA Consulting, through its RINA Consulting – CSM laboratory infrastructure (formerly Centro Sviluppo Materiali), conducts durability and corrosion testing activities on subsea structures specimens. RINA Consulting - CSM activities cover the entire cycle of innovation, from basic applied research (e.g. physical, chemical and mechanical properties, new alloys, innovative coatings) to functional prototype production, components and structures safety assessments, material and component testing, including environmental and materials recycling issues. RINA Consulting - SEATECH, (formerly SeaTech), also provides engineering services for all types of subsea structures. Services cover the conceptual, FEED, and detail design of subsea structures in shallow, deep and ultra-deep water.

Umbra Group SpA (UMBRA) is a manufacturing company, world leader in the production of bearings, ballscrews and Electro-Mechanical Actuators (EMAs) for the aerospace, industrial and energy sectors. It employs approximately 1,000 people in Italy, Germany and the USA. During the past years, stimulated by wave and tidal energy developers, UMBRA has developed an innovative Power Take-Off (PTO) technology based on a direct-drive Electro-Mechanical Generator (EMG) that converts linear, reciprocating motion into electricity with increased reliability and efficiency with respect to commercial PTOs. UMBRA has further consolidated its technical competences and has contributed to the technological development of the blue energy sector by participating, in collaboration with potential customers, to several regional, national and international research projects (e.g. Umbria regional innovation project 61-2015-RS; projects in the framework of the National Operative Programme (Programma Operativo Nazionale – PON), funded by MISE and MIUR). A consortium formed by UMBRA, Seapower and Scottish HMS, was selected – out of more than 25 participants – and awarded a contract by Wave Energy Scotland (WES) for the development of innovative PTOs and wave devices (stage 2 of the WES programme). Recently, a larger consortium led by UMBRA passed the selection phase for stage 3 of the WES programme, and obtained funding for the deployment of a full-scale device in Scotland's waters.

Besides carriying out R&D activities, UMBRA has been constantly participating in networking and educational activities, e.g. by supporting INORE, the International Network on Offshore Renewable Energy. UMBRA has been an INORE Primary Sponsor since 2015, and contributed to the organization of the INORE European Symposium held in Naples, Italy, counting more than 70 attendees from 17 countries. UMBRA was one of the industrial partners participating in the multinational Initial Training Network (ITN)

OceaNET, funded under the EU FP7 PEOPLE Programme (Marie Curie Actions), and contributed to several conference papers.

Faggiolati Pumps SpA is specialized in the design and production of Electro Submersible Pump, and developed a Wells turbine for a small scale REWEC3 device, carried out in the NOEL laboratory, within the POSEIDONE project, in collaboration with WavEnergy.it Srl, UniRC and UniRoma1. In particular, Faggiolati patented a system to optimize the performance of unidirectional or bidirectional turbines under variable flow conditions, designed to cope with the low-energy wave conditions typical of the Mediterranean Sea.

Potential for growth

The international landscape: opportunities and caveats

The ocean energy sector spans each level of a product development value chain from R&D to final deployment, so that several competitive advantages can arise from the development of the connected technologies, helping the Italian specific competences to establish a strong market position as a technology exporter. Such technologies being still at an early or intermediate stage in potentially competitive countries, the opportunity exists for Italy to occupy market niches that are still to be conquered, provided that adequate, tailored support instruments are designed at both EU and national level. The adoption of global agreements on the reduction of emission from fossil fuels (e.g. the Paris agreement at the conclusion of COP 21) contribute to disclose promising opportunities for high-tech export to developing countries, as well for international cooperation.

To secure competitiveness, all technology components need to be further strengthened for deployment in the severe weather conditions that characterize the global ocean, both onshore and offshore. On the other hand, it is expected that in the future a considerable part of the cost burden will be constituted by operation and maintenance costs, and that the intellectual property of efficient installation, operability and connection, and in general of cost-effective management solutions will therefore represent an asset on the global market. Under this respect, the Italian ocean energy sector can benefit, to a certain extent, from its experiences in offshore oil & gas explorations, which have created specialized knowledge that can be transferred to the blue energy sector. Moreover, the long-term experience in shipbuilding and maritime industry represent an additional resource.

Clusters of specialized suppliers and research institutes can contribute to the success of the Italian blue energy industry, by providing tailor-made solutions to help improve the entire process. Close links to the industry already exists, also through the common involvement in national and international research projects.

However, a national perspective is not sufficient to bring ocean energy technologies to the market, due to the high investment costs. Access to financial resources from international funding bodies needs to be facilitated in order to help the domestic industry players achieve a 'critical mass' that could speed up project roll-out. Italy should strive to make the most of its presence in EU initiatives, by guaranteeing continuous and consistent participation of national experts in their works, and a fruitful representation of national competences and interests. This implies a formal commitment to support co-funding initiatives at EU level with specific funds allocated by Italian ministries.

Strengthening the links with connected economic sectors

Italy's SMEs engaged in the supply chain for WECs and Tidal Energy Converters (TECs) detain long-term experience and innovation capacity, which can support all the specific, high-tech steps of the design and production process. Components range from PTOs and generators, to electrical&automation devices, to bearings, to coating materials, to blades, brakes, shafts, gearboxes and control systems. Italy's opportunities in international competition would greatly benefit not only from the creation and continuous support of the blue energy business and high-tech clusters, but also from enhanced connections to the historic know-how-based industries that can provide specific manufacturing expertise.

Recently, the EU Interreg-MED Programme launched the horizontal project InnoBlueGrowth –"Horizontal

Communication & Capitalization project for Innovation in Blue Growth at Mediterranean level" – with the aim to implement concrete actions (i.e. a communication strategy, community building initiatives and capitalization events), to build cohesive stakeholders communities sharing common interests and issues and to enlarge the spectrum of potentially connected industries. Among the modular projects of InnoBlueGrowth, the PELAGOS project is specifically dedicated to ocean energy and offshore wind energy. National support to such initiatives, as well as the inception of similar efforts at the national/regional level, and the complementary implementation of adequate financial support instruments, would definitely contribute to a more capillary and effective network expansion, help implement solutions tailored for the Italian context, and sustain Italy's competitiveness.

Managing conflict among socio-economic sectors: highlighting potential synergies

Traditional maritime sectors (e.g. shipping, fishing activities, tourism) are not always spatially compatible with the development of new maritime industries. Competition between different sectors for alternative uses of sea space can lead to suboptimal economic development, while their uncontrolled coexistence can induce negative cumulative impacts on the environment. To address such issues, the EU adopted the Directive 2014/89/EU, which establishes a framework for Maritime Spatial Planning (MPS), in which a harmonization is seeked between environmental legislation, legislation on marine renewable energy, fisheries regulations and the Integrated Maritime Policy. In particular, MSP aims to bring stakeholders and authorities together to agree on sustainable spatial management and coherent planning of sea areas, having recognized the potential conflicts between blue energy deployment and maritime transport (e.g. increased potential risks to the safety of navigation due to higher traffic density in transit areas and shipping lanes and visual limitations), fisheries (e.g. fishing restrictions in the security zone around energy farms and gear type restrictions for the protection of submarine cables connecting energy farms to the onshore distribution grid), tourism (e.g. limited access to sea space for leisure purposes and low social acceptance) and environmental protection (e.g. the destruction of marine habitats due to the installation or removal of infrastructures, increased turbidity, noise and vibrations that can affect the distribution of fish populations and marine mammals).

Nevertheless, potential synergies have also been highlighted, in particular as to the capacity of offshore energy infrastructures to create artificial reefs that are beneficial to marine ecosystems, by providing additional hard bottom habitats and increasing biomass in specific areas. Safety zones may also serve as protected areas for the preservation of marine resources and marine communities, especially sedentary and short-lived species. Moreover, energy farms located close to the coast can host aquaculture activities, at the same time providing clean energy for their management. Wave energy farms can also serve as wave breakers, limiting damage to offshore or coastal installations.

Synergies can be also developed between the different types of energy production at sea (wind-tidal-wave), by jointly collecting background data and information in the development and consent phase and by jointly planning the necessary infrastructures and the grid connections, thus sharing the related cost burden. Such practices would also increase the availability of data between stakeholders and the efficient design of Decision Support Systems (DSSs) and information services for connected or parallel uses.

It is, however, essential that all long-term options for multiple potential uses are examined and decided upon at the very beginning of the planning process and that the proactive participation of all the different stakeholders is guaranteed throughout the decision process, as well as cross-border consultation.

Conclusions

The global energy system is changing, due to both an ever increasing demand driven by rising living standards, and to the enhanced environmental awareness of public opinion, reflected in the Paris agreement at the conclusion of COP21. In the power sector, renewables and nuclear capacity additions supply most of demand growth, as the energy mix is being redefined. Affordable, secure and sustainable energy systems will progressively integrate more diverse energy sources and will rely substantially on distributed generation, therefore opening up the market to innovative technologies and smarter renewable power.

The EU Commission and several experts have proposed a long-term vision to tackle the challenges posed by the decarbonization of the European energy system, and a package of binding policies (climate and energy package) has been initiated, decided, implemented and reformed. A combination of instruments to overcome distributional obstacles and enable burden sharing among member states was designed, and synergies were created to mutually reinforce the objectives of the package. Member states, however, still play a crucial role in determining the success of community policies, while national plans represent a potentially valuable innovation allowing for a more coherent harmonization of the reform of European energy governance, policy and regional cooperation, and long-term climate protection goals.

In this context, ocean energy is recognized to hold a great potential, although still requiring significant cost reductions. Larger demonstration projects should be facilitated in order to sustain its development from basic and applied research to final commercial deployment. To this end, the international cooperation between various levels of governments and with the private sector is recommended, that would help envisage new business models and create market opportunities that benefit both manufactures and users of technologies, while contributing to the most cost-effective transition of the global energy systems. As a matter of fact, stakeholders lament their limited involvement in policy design as one of the causes for the weakness of policy penetration into the sector. In addition, a lack of coherence is denounced between community and Member State policies, in particular as to the implemented financial instruments, which are anyway assumed to be of a temporary nature and only necessary until commercial maturity is reached. The creation of enabling conditions still largely being a responsibility of each member state, the perceived risk that local contingencies might limit the opportunities for development is still high.

Despite the prominent position acquired among the international insiders, the progress Italy has made in the Ocean Energy sector is still underrepresented at European level, as to both innovative research and device implementation. Targeted national policy interventions and investment are now crucial for the exploitation of the sector's potential in terms of economic growth, high-skilled job creation and strategic positioning of the Italian industry in the competitive global market. The vitality and commitment of a well-established community of actors from research institutions, SMEs and industry provides a solid basis for effective public policy intervention, in support to both research and to a variety of connected and downstream enterprises, which would be allowed upscaling and access to the international market. As recognized in the EU Ocean Energy Strategic Roadmap, the design and implementation of innovative financing tools to efficiently channel public and private investment is no longer deferrable. Access to capital is, indeed, the main challenge that the Ocean Energy sector is facing, which demands new solutions for capital unlocking to be designed and implemented, and access to EU funding to be enabled.

National support policies are explicitly required in the

EU recommendations and directives, which establish a common framework for Member States as to the promotion of the use of energy from renewable sources (EU 2009/28/CE Directive). National intervention is also needed to fulfil the EU requirements in the matters of maritime spatial planning and integrated coastal management by Member States (Directive 2014/89/EU).

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Description of involved institutions and enterprises

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) – Contact point: gianmaria.sannino@enea.it

ENEA is the Italian government agency responsible for new technologies, energy and sustainable economy. The Agency has a staff of around 3000 employees and operates through nine major research centres and a number of smaller facilities. ENEA has a special technical unit devoted to energy and environmental modelling studies, with a staff of about 90 employees. This unit combines long-standing expertise in the areas of oceanic and atmospheric modelling and impact evaluation in relevant economic sectors.

In particular, the CLIM laboratory is devoted to Climate Modelling and Assessment (15 staff researchers).

Its activities are mainly focused on regional climate modelling and forecast provision, in support to energy and environmental studies. Relevant applications are in the field of renewable energy, for the design and maintainance of devices and infrastructures, as well as for wave energy potential assessment.

The models currently implemented on ENEA computational resources are: POM (Princeton Ocean Model), MITgcm (Massachusetts Institute of Technology general circulation model), WAM (WAve Model), SWAN (Simulating WAves Nearshore).

Natural Ocean Engineering Laboratory (NOEL), Università Mediterranea di Reggio Calabria, www.noel.unirc.it – Contact point: Felice Arena, arena@unirc.it

The NOEL (Natural Ocean Engineering Laboratory) established within the Mediterranea University of Reggio Calabria (Italy) is composed of a highly specialized team working in the field of marine engineering. The team detains 25 years' experience in conducting field experiments on small-scale models of marine infrastructures and wave energy harvesters at the NOEL natural basin. This laboratory represents a unique natural environment were experimentalists can conduct tests with the support of dedicated sensors, of an acquisition data centre, and of the specialized staff permanently working in the laboratory facing the basin (for details see www.noel.unirc.it).

The mission of The NOEL research group is to utilize the knowledge acquired in the field of marine and civil engineering to develop novel methodologies in the analysis of wave phenomena and of wave climatology, in order to improve the characterization of wave interactions with floating of fixed structures. The group also conducts studies on coastal protection structures (e.g. caisson breakwaters) and on innovative onshore structures suitable for hosting REWEC devices, and is developing the experimental framework for field-testing a floating offshore wind turbine.

Dipartimento di Ingegneria Meccanica e Aerospaziale, Sapienza Università di Roma (Sapienza-DIMA) & OWEMES Onlus – Contact point: Domenico Borello, domenico.borello@uniroma1.it

The DIMA is one of the 63 Dept. of Sapienza Università di Roma. Its research and innovation activities are focused on several sectors related to Mechanical and Aerospace Engineering. The group of the Contact Point is focused on Energy themes as: Efficiency, Renewable Energy Sources, Turbomachines and Alternative Engines as well as Environmental Impact of Energy Systems. It has a staff of about 60 professors/senior researchers and 60 Post-Docs/Ph.D. students. DIMA's activities in Ocean Energy focus on: a) development of open source software for prediction of Energy producibility from Floating Wave Energy Converters; b) design of turbomachinery for OWC applications; c) Analysis of sustainable energy systems in small islands distribution grids.

OWEMES Onlus is a not-for-profit association devoted to the promotion of Offshore Wind and Ocean Energy in Mediterranean and other European seas. It promoted and organized several events in the framework of Ocean Energy. Among them: 9 editions of an International Conference on technologies (the next will be in Bari 11-13 October 2017, www.owemes-2017.eu); several workshops and seminars on thematic arguments; EUSEW days on 2016 in Reggio Calabria.

CNR-INSEAN - Istituto Nazionale per Studi ed Esperienze di Architettura Navale – Contact point: claudio.lugni@cnr.it, francesco.salvatore@cnr.it

INSEAN is the Italian centre for research in marine technology. Established in Rome in 1927, since 2011 it has been part of the Italian National Research Council (CNR).

Research activities address the areas of interest of the integrated European maritime policy: eco-sustainable transport, sea transport safety, innovative technologies for the shipbuilding industry, sustainable exploitation of the sea, marine renewable energy systems.

With more than 140 among researchers and engineers, technicians, assistant researchers and administration staff, INSEAN manages world-class hydrodynamic testing infrastructures. The institute is a center for the development of advanced testing equipment and procedures, and for the development of theoretical/computational models for studies in hydrodynamics, hydroacoustics, fluid-structure interaction.

Research work is carried out by participating in collaborative projects under national and international funding programs (H2020, EDA, NICOP) and through commercial projects, in which expertise and capabilities support technology developers and industry.

INSEAN is member of key international R&D networks and organizations in the areas of marine transport (EU Waterborne Platform, ITTC, ISSC) and energy (ETIP Ocean, EERA, OEA). Website: http://www.insean.cnr.it/en/content/cnr-insean.

Università di Genova (UNIGE) – Thermochemical Power Group (TPG) – Contact point: alberto.traverso@unige.it

The Department of Mechanical and Energy Engineering – DIME includes the "Thermochemical Power Group" TPG (www.tpg.unige.it), founded in 1998. Its mission is to carry out theoretical and experimental research in the field of advanced energy systems. Since 2004, the TPG hosts the Rolls-Royce University Technology Centre on Fuel Cell Systems, with the aim to investigate solutions and technologies for fuel cell stationary power generations. The main fields of research of TPG are: development and testing of advanced energy systems; dynamic performance modelling of energy systems; thermoeconomic analysis; monitoring and diagnostic techniques for combined cycles and energy systems; fuel cell technology (PEMFC and SOFC); investigation of thermal processes for biomass conversion. Original software resources are: WECoMP – Web Economic Cogeneration Modular Program for the design and optimisation of CHP networks; WTEMP - Web ThermoEconomic Modular Program, for thermoeconomic analysis and development of energy systems; TRANSEO - Matlab-based tool for dynamic simulation and control system development. TPG has been developing an original WEC technology, the Seaspoon, patented in 2011, for energy generation from orbital motion of sea waves. The state of the art is >1kW prototypes, which need to be downscaled for the application to off-shore meteo-marine monitoring system. UNIGE has fully authorised and installed a full scale prototype offshore of Genova, Italy, in 2015, which is currently under the monitoring phase. TPG manages an elastic beacon 1.8 km off-shore the Genoa coast for real sea testing of wave energy converters, as well as a wave energy generator operating in real sea water in the La Spezia harbour.

Laboratorio di Oceanologia Sperimentale e Ecologia Marina - Dipartimento di Scienze Ecologiche e Biologiche - Università della Tuscia di Viterbo – Contact point: marcomarcell@unitus.it

The Laboratory of Experimental Oceanology and Marine Ecology, of Tuscia University, is located in Civitavecchia's harbour; representing one of the main laboratories of marine experimental research on the Tyrrhenian sea, it focuses its activities both on open sea and coastal processes. The research activities of the Laboratory of Experimental Oceanology and Marine Ecology of Civitavecchia can be, basically, divided into the following main areas: development of new technologies; study of coastal processes, dynamics and pollution; study of marine ecosystems and their dynamics; marine and coastal resources management.

In particular Marine and coastal resources management concerns the study of renewable marine energy with particular reference to the characterization of suitable sites for energy exploitation from different marine sources (currents, waves and tides). In this context, the laboratory was also part of the MARINET project (http://www.fp7-marinet.eu/), an EC-funded initiative which aims to accelerate the development of marine renewable energy (wave, tidal & offshore-wind).

Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali Università di Bologna (UNIBO-DICAM) – Contact point: Renata Archetti, renata.archetti@unibo.it

The Department of Civil, Chemical, Environmental and Materials Engineering (DICAM) is the result of a large aggregation of research skills and laboratory facilities of diverse but interrelated engineering branches traditionally developed at the University of Bologna. The department integrates the scientific expertise of various research groups, such as Structural, Transport, Hydraulic, Survey and Territory Engineering, Applied Chemistry and Materials Science, Chemical, Mining, Petroleum and Environmental Engineering. More than 320 people currently team up to carry out the research activities of the Department: approximately 105 academic staff, 45 technical, administrative and library staff, and 174 Ph.D. students, research assistants and fellows.

DICAM's activities in Ocean Energy focus on: a) the development of numerical codes for the simulation of floating bodies dynamic and for the estimation of energy production efficiency of Wave Energy Converters (WECs); b) open source modelling of wave interaction with fixed structures and floating bodies based on CFD (Computational Fluid Dynamics); c) the design of moorings; c) the assessment of possible environmental impacts of WECs.

In particular, the Hydraulics Laboratory (Laboratorio di idraulica - LIDR) provides expertise, facilities, and equipment for the testing of prototypes and for model calibration, among which a wave and currents tank measuring 18 m x 10 m x 1.5 m, where regular, irregular, focused and 3 dimensional waves can be generated.

Politecnico di Torino (POLITO) – Contact point: giuliana.mattiazzo@polito.it

POLITO is a leading public research university founded 150 years ago and dedicated to theoretical & applied research. It can boast 170,000 teaching hours per year; 26,000 students receiving training in 115 courses, spanning all academic qualifications, from Bachelor's degrees (39), to Master of Sciences (35); to Doctorates (23) and specialisations (18). Research activities are distributed over 11 departments. POLITO has a strong reputation in research and education on sustainable technologies and renewable energies. With more than 800 research contracts with public institutions and industries worldwide, POLITO cooperates with various international research centres, industrial partners, local authorities and utilities. The Offshore Renewable Energy Group started its activities at the Department of Mechanical and Aerospace Engineering (DIMEAS), the main focus of the its research activity being mathematical modeling and experimental testing of Wave Energy Converters (WECs) and Offshore Wind systems. The group offers a broad variety of long-standing skills, including resource assessment, wave-to-wire modeling of the WECs, frequency and time domain modeling, wave tank testing, productivity optimization via innovative control logic development. Research activities also deal with EES (Electric Energy Storage) for power output regulation and optimal grid connection.

Università di Firenze (UNIFI) – Contact point: cappietti@dicea.unifi.it

The University of Florence is an important and influential centre for research and higher training in Italy, with 1,800 lecturers and internal research staff, 1,600 technical and administrative staff, and over 1,600 research assistants and doctoral students. It offers a wide range of study programmes: 126 Degree courses (First and Second Cycle, corresponding to Bachelor's and Master's Degrees) organised in 10 Schools, with a population of about 51,000

enrolled students, one-fourth of which come from outside of Tuscany. Over 9,000 degrees are awarded each year in Florence. Researchers at the University of Florence operate within 24 different departments and have approximately 40 research structures at their disposal, comprising inter-departmental and inter-university centres as well as specialised research, knowledge transfer and advanced training centres. LABIMA is the Laboratory of Maritime Engineering of the University of Florence (www.labima.unifi.it). LABIMA has been operating since 1980, when the laboratory was equipped with one of the first wave-flumes in Italy for the simulation of random waves. Since 2009 the LABIMA has started to further develop its research installations, both experimental and numerical, in the field of ocean energy. LABIMA researchers have top-level skills in the use of software for off-shore/near-shore and near-field numerical simulations (e.g. DHI-MIKE21, Veri-tech CEDAS, WW3, SWAN, XBeach, OpenFOAM) and in software development (e.g. Lattice Boltzmann Methods for fluid dynamics and a number of proprietary codes, among which a PMS equation based solver for refraction-diffraction, sea-state generation, short-term and long-term wave analysis). Since 2011 LABIMA has been one of the leading infrastructures participating to the largest EU research projects in the field of Ocean Energy. Services commonly provided at LABIMA are: a) wave and current generation to specified requirements (i.e. site specific wave generation); b) scale-model testing of the hydrodynamic performance of devices in a range of environmental conditions; c) optimization of WECs by means of experimental and numerical parametric studies; d) limited survival tests (based on scale); e) identification of the power map of WECs; f) measurement of the stress exerted on device structural components (e.g. mooring behaviour); g) validation of pre-completed numerical models; h) data acquisition and analysis.

Fincantieri Oil & Gas – Contact point: marko.keber@fincantierioilgas.it

Fincantieri Oil & Gas is a wholly owned subsidiary of Fincantieri SpA. Headquartered in Trieste, Fincantieri is the fourth largest shipbuilder in the world and the first for diversification and innovation. It is a leader in the design and construction of cruise ships and a key player in all areas of high-tech shipbuilding, from offshore to naval vessels, special ships and ferries, to highly complex mega-yachts, as well as in ship repair and conversions, production of systems and components and after-sales services. In offshore the company is specialized in the design and construction of vessels for the Oil & Gas and Renewables sectors ranging from large drillships, multi-purpose platforms and special vessels for marine construction to medium sized offshore support, crew and subsea construction vessels.

RINA Consulting – Contact point: stefano.barberis@rina.org

With a history going back 150 years, the RINA Group is a global corporation that provides engineering and consultancy services, as well as testing, inspection and certification.

RINA Consulting is the engineering consultancy division of the RINA Group, the result of the integration of a number of internationally respected RINA companies including D'Appolonia, Centro Sviluppo Materiali, Edif ERA (ERA Technology), G.E.T., Logmarin Advisors, OST Energy, Polaris, SC Sembenelli Consulting and Seatech. RINA Consulting brings together a rich heritage of engineering consultancy expertise into one unique organisation.

Working alongside Clients, as a trusted technical partner, RINA Consulting provides a wide range of traditional and innovative services to critical industry sectors, including oil & gas, power, renewables, space & defence, transport & infrastructure sectors. Our 1,700 talented professionals give us the depth of experience across engineering disciplines to support Clients at each phase of their project – from initial concepts and design, through to operation, maintenance and decommissioning. We are committed to providing services that are of the highest quality for our Clients, creating added value for their business through our technical advice and support - managing risk, operating safely, in a sustainable way and optimising performance.

Enel Green Power SpA (EGP) – Contact point: armando.giacomi@enel.com

Enel Green Power has been working in the field of Ocean Energy for several years in the framework of its international positioning strategy, and has been paying particular attention to opportunities in emerging countries and markets. It supports the development of the most profitable devices, by collaborating with technology providers right from the beginning of the roll out and industrialization process. Currently it is actively participating in the development and testing of several prototypes.

UmbraGroup – Contact point: LCastellini@umbragroup.com

Umbra Cuscinetti SpA was created in 1972 and it is today the parent company of UmbraGroup. The Group has achieved great success in its 40 years history and currently consists of four subsidiaries in Italy, Germany and the USA. UmbraGroup is a cutting-edge manufacturing company in the aeronautics and industrial sectors. It is the world leader in producing recirculating ballscrews in the aeronautics sector. UmbraGroup has recently strengthened its position in the supply of products aimed at the energy market.

Long-term investments in Research and Development have resulted in considerable growth in Umbra's product portfolio.

WavEnergy.it Srl – Contact point: ceo@wavenergy.it

WavEnergy.it is a limited-liability engineering company, born as an academic Spin-off of the Mediterranea University of Reggio Calabria. The company has been working for the development of the REWEC3 caissons, as the exclusive licensee of the REWEC3 patent by Professor Paolo Boccotti. In particular, WAVENERGY.it was involved: a) in the "Renzo Piano Building Workshop" for the adoption of REWEC3 as a design solution for in the project for the new Genoa waterfront proposed by architect Renzo Piano in the volume "Genoa and its port: the changing city"; b) in the design of REWEC3 for the extension of the breakwater of the Port of Salerno (under construction); c) in the design of the first prototype of caissons REWEC3 in the Port of Civitavecchia; d) in the construction of the first full scale REWEC3 in the Port of Civitavecchia, built as wave energy absorber and completed in 2017; e) in the monitoring activities of two chambers in the Port of Civitavecchia, equipped with a Wells turbine (project TEN-T number 2013-IT-92050-S); f) in the conceptual design of a new REWEC3 breakwater in the Porto delle Grazie of Roccella Ionica (RC); g) in the development of new components for the REWEC3 caissons (including structural and electro mechanical components). WavEnergy.it participates in several collaborative research projects, among which the GreenPorts project, under the Regional Operavtive Programme (Programma Operativo Regionale – POR) of the Calabria Region, for the implementation of REWEC3 devices in two test sites in Calabria (i.e. the ports of Crotone and Vibo Valenzia), and the Poseidone project (in collaboration with Faggiolati Pumps SpA, Mediterranea University and University la Sapienza), for the development of a small scale REWEC3 device equipped with with a reduced size Wells turbine, to be tested in the NOEL lab.

Wave for Energy (W4E) – Contact point: : info@waveforenergy.com

W4E is a dynamic company aiming to create new opportunities for clean and sustainable energy supply from the most powerful and challenging renewable source on the planet: waves. W4E was born in 2010, capitalizing on the several years of research on mechanics and waves interactions carried out by its founders within POLITO. W4E has developed and patented ISWEC (Inertial Sea Wave Energy Converter), an innovative technology for energy conversion from waves, which has been continuously improved over time. The installation of ISWEC requires a huge amount of expertise, ranging from mechanical to electrical engineering, from waves dynamics to multi-body interactions, from legislative to environmental and regulatory aspects, from weather forecasting to the management of offshore operations. W4E hence developed an

integrated approach to simultaneously address all these crucial aspects. The ISWEC technology is therefore designed to be fully compliant with marine environmental protection requirements, while complementarities between wave energy production and different sea-related economic sectors and activities are under study. W4E manages a test site at Pantelleria, a small island in the Mediterranean Sea offering high wave energy resource, where a pre-commercial 100 kW ISWEC prototype is being tested.

SEAPOWER Scarl (SEA) - Contact point: coiro@unina.it

Seapower Scarl is a non-profit consortium founded in 2010 spinning off from ADAG research group belonging to Dept. of Aerospace Engineering, University of Naples "Federico II" which has been developing systems for spreading the generation of renewable energy from fluid sources. Seapower has strong technical skills, know-how, resources, tools and capabilities that the ADAG research group has gained in over twenty years of activities. Seapower has developed several tidal and wave energy projects as well as many projects regarding small/medium wind turbines. It has also coordinated the manufacture and installation of small and full scale prototypes for marine energy sector. Seapower has the capability of developing projects from scratch up to the full scale prototype including final field test. Seapower is also developing a test site for marine current devices located in Messina Strait, in Italy, and the final permits to lease sea areas nearby Villa S. Giovanni will soon be released. Seapower offers advanced technical services for marine energy sector always considering sector-specific rules and design requirements.

Università degli Studi della Campania "Luigi Vanvitelli", Department of Civil Engineering, Design, Building and Environment (DICDEA) – contact point: diego.vicinanza@unicampania.it

Università degli Studi della Campania "Luigi Vanvitelli" (Second University of Naples before the name change) was established in 1991 as after a decree by the President of the Council of Ministers to downsize the "Federico II" University of Naples (http://www.unicampania.it). Department of Civil Engineering, Design, Building and Environment (DICDEA) serves as a center for education, training and research of the UNICAMPANIA (http://www.dicdea.unicampania.it). Strategic areas are: Civil Engineering, Building Engineering, Environmental Engineering and Industrial Design. The Renewable Energies in Civil Engineering Research Group (RECERG) is a research group active inside the DICEDA with the aims to give a practical answer to the problem of mutual integration between energy demand and environmental sustainability, promoting the development of innovative technologies for energy production from wind, sea, river currents and geothermal sources for the environmental sustainability and quality of life in towns and urban areas (http://www.dicdea.unicampania.it/en/ricerca/64-uncategorised/327-energie-rinnovabili-nell-ingegneria-civile2). Key Research Facilities, Infrastructure and Equipment: 1) NAtural Wave Energy Lab (NAWEL) at SUN consist of a full scale prototype of an innovative wave Overtopping Device (OD) totally integrated in a rubble mound breakwater located in Naples harbor; 2) Multidirectional wave basin (16 x 13 m) equipped with 30 piston type wave generators capable of generating both regular (periodic) as irregular (random) long-crested or short-crested waves; 3) Simulation software, Advanced Computational Models: MIKE 21, SHORECIRC/REFDIF, TELEMAC, SWAN. Partner and Coordinator of about 20 national and EU projects in the last 20 years (H2020, FP7, FP6, MAST, Interreg, MED, Hydrolab, RITMARE, POR, PON, PRIN).

Politecnico di Milano (POLIMI) – Contact point: giuseppe.passoni@gmail.com

"Politecnico di Milano" is the largest technical university in Italy, with about 42,000 students, offering undergraduate, graduate and higher education courses in engineering, architecture and design. The university was ranked the best for Engineering and among the top big universities in Italy in the CENSIS-Repubblica Italian University rankings for 2014-2015. According to the QS World University Rankings, it is the 24th best technical university in the world, ranking 7th for Design, 24th for Engineering and Technology, 14th for Civil and Structural Engineer-ing and 14th for Architecture.

The Wave Energy group at “Politecnico di Milano” is deeply involved in simulation of WECs, also taking into account non-linear behavior and coupling with electric machinery. Research is mainly based on numerical modelling by means of the CFDHub@Polimi facility which consists of a mixed cluster with 63 nodes for a total of 884 cores and 3056 GB RAM. The calculation nodes make use of an Infiniband fibre-optic network. The system has a storage unit with a RAW capacity of 60 Tb. The cluster is also equipped with many commercial packages for solid and fluid dynamics, multi-phase flows, multi-physics and post processing tools like: Abaqus, Ansys Fluent, Ansys CFX, Comsol, Lsdyna, OpenFoam, Paraview, Star-CCM. Many numerical codes for wave-structure interaction and wave2wire simulation have been autonomously implemented as well.
Within the Department (DEIB) collaborations are active with Electric Systems and Control Systems groups for further research developments.

Gestore Servizi Energetici (GSE SpA) – Contact point: luca.benedetti@gse.it
GSE is the state-owned company which promotes and supports *renewable energy sources* (RES) in Italy.
In particular, GSE fosters *sustainable development* by providing support for renewable electricity (RES-E) generation and by taking actions to build awareness of environmentally-efficient energy uses.
The sole shareholder of GSE is the Ministry of Economy and Finance, which exercises its rights in consultation with the Ministry of Economic Development. GSE is the *parent company* of three subsidiaries: “Acquirente Unico” (AU), “Gestore dei Mercati Energetici” (GME) and of “Ricerca sul Sistema Energetico (RSE), which is active in research in the electricity and energy sectors and in projects of strategic interest.
GSE manages *support schemes* for renewable energy sources (RES) at central level, with different solutions, which take into account the different technologies of the plants and the level of maturity of the related markets.
The granting of support by GSE requires a careful technical assessment of the plants in order to check their compliance with sector-specific legislation.
In the past few years, GSE’s technical responsibilities for *qualification and verification of plants* have been extended to the assessment of the architectural integration of solar photovoltaic (PV) plants into buildings and to energy efficiency.

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September 2017