Article, Published Version

Gao, Yan; Collu, Maurizio; Lagasco, Fabrizio; Brizzi, Giulio; Arena, Felice; Ruzzo, Carlo; Santoro, Anita

An innovative multi-purpose offshore platform concept for the blue economy proposed by the Blue Growth Farm Project

Hydrolink

An innovative multi-purpose offshore platform concept for the blue economy proposed by the Blue Growth Farm Project

By Yan Gao, Maurizio Collu, Fabrizio Lagasco, Giulio Brizzi, Felice Arena, Carlo Ruzzo and Anita Santoro

The combination of energy generation devices and aquacultural systems is a smart way to improve the economic efficiency of integrated renewable energy systems and enlarge the application field of offshore platforms. An environmentally friendly multi-purpose offshore platform is proposed by the EU H2020 funded project 'the Blue Growth Farm' (www.thebluegrowthfarm.eu), which accommodates an aquaculture system within a rectangular-shaped concrete-caissons-based platform, which includes a wind turbine and a set of wave energy converters, producing renewable energy for its own operations. By integrating and engineering the aquaculture and renewable energy production systems, this efficient, cost-competitive and environmentally friendly multi-purpose offshore platform design is well suited for applications in the open sea.

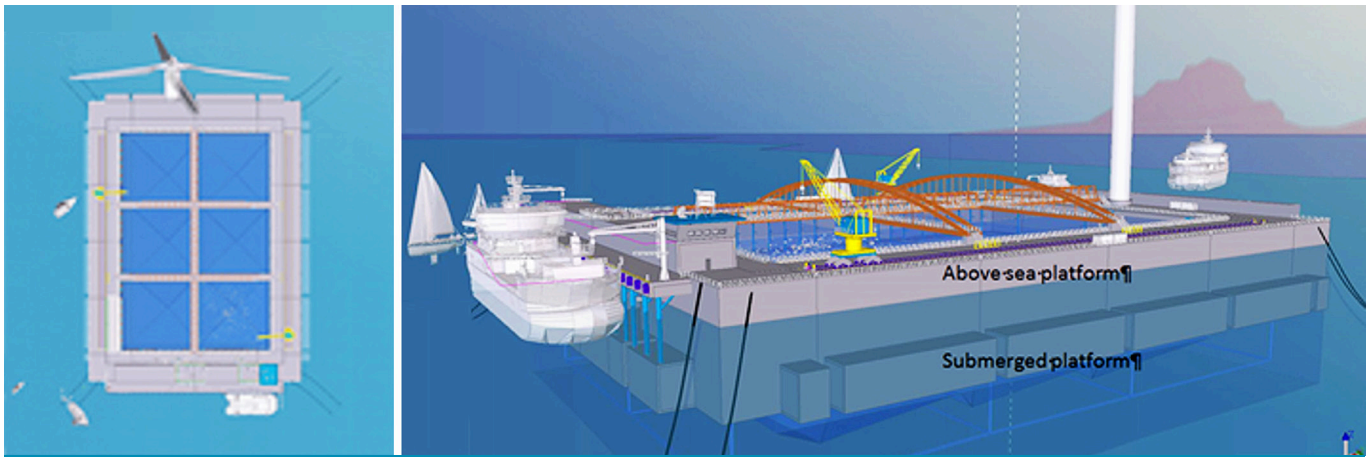

Figure 1 | The Design of the full-scale multi-purpose offshore platform 'The Blue Growth Farm'.

The background and targets of the Blue Growth Farm Project

The 2016 Paris agreement and the following related initiatives have pushed countries worldwide to set ambitious targets in terms of cutting greenhouse emissions (in terms of CO_2 equivalent tonnes). To achieve these targets, countries are largely relying on the use of renewable energy sources, transitioning from fossil fuels to these sustainable energy resources. Offshore renewable energy such as offshore wind, wave, current and tidal, is a favourable green energy resource that is plentiful, predictable, and environmentally friendly. The development of wind energy has been a hot topic in the realm of the blue economy field, especially after the successful operation of Hywind[1], which is the first full-scale floating offshore wind turbine in the North Sea in 2009. Wave energy is another kind of ocean renewable energy and much research has been conducted to convert the wave energy into reliable power via wave energy converters (WECs) such as oscillating-water-column (OWC) WEC[2].

The further expansion of marine fish farming in coastal waters is limited by a lack of suitable sites, as well as by concerns about pollution, sustainability and, in many cases, missing regulatory issues, and local community opposition. The integration of the different sub-systems into one complex infrastructure, the shared use of assets, and the combination of various offshore energy generation resources make the multi-purpose offshore platform an economic and efficient solution for both the offshore renewable energy and the marine fish farming industry.

For these reasons, the Blue Growth Farm (BGF) project's aim is to propose an efficient multi-functional offshore platform that 1 | combines fish production with the generation of renewable energy from wind and waves, 2 | operates with advanced automation and remote control capabilities, 3 | provides extra produced electric energy to the grid and sea electric station service to platform shipping operations[3].

The design of the BGF multi-purpose offshore platform

Given the nature of the problem it is addressing, key platform design requirements are that it must be able to withstand offshore conditions, including wave significant heights of up to 6m, whilst offering the highest standards of fish welfare, efficient

use of resources, minimal environmental footprint and visual impact and, at the same time be commercially viable. If all these goals are met, the system should be an attractive option for commercial investors, and much less likely to attract opposition for its deployment from regulators or local communities.

Whilst various designs for offshore fish farming systems have been proposed over the years, so far none has had widespread uptake due to various concerns including their real ability to withstand harsh offshore conditions, insufficient technology maturity, the inherent difficulties in managing units to which access may be limited in adverse conditions, security and, not the least, cost. All these concerns have been taken into account in the design of the BGF platform.

The fish will be grown in floating net pens, much as currently practiced, so fish farming technology used is well proven. However rather than being exposed to the open sea, the net pens will be held within rectangular open-bottomed "pool" formed by floating, prefabricated concrete caissons joined together on site. The caissons, which also act as the collar for the pens, have a draught of 20m, thereby affording the cages protection from most of the incident wave energy and currents. Water exchange within the pool is facilitated by surface openings at the aft of the platform, which allows the outflow of water upwelling from the bottom of the pool due to the motion of the platform and the effects of sub-surface currents. The large open areas over and within the caissons will be used to house the feed silos, automatic feeding system, and other infrastructures such as a net store, ensiling system and workshop. The design of all these facilities is based on requirements dictated by the fish production programmes which have been developed for three different species (salmon, sea bream and sea bass) at three selected sites within territorial waters in Europe. Each programme has been tailored to give maximal production from the cage volume available, whilst ensuring all environmental parameters remain within set limits for best stock welfare.

The renewable energy systems comprise a 10MW wind turbine on the forward deck of the platform, and an array of wave energy converters (WECs) devices which form an integral part of the structure of the forward caissons. The energy produced will be used to power all the on-board equipment, and the excess energy may be dispatched to the local grid via umbilical cable. All systems on the platform, which include an automated feeding system, biomass estimator, under water and deck cameras, water quality sensors, security/surveillance systems, meteorological sensors, and structural health monitoring systems, will be managed and supervised by a central control room on the platform which will in turn be linked wirelessly to an onshore remote control room, allowing the system to be operated and monitored remotely when sea conditions are not suitable or safe to access the platform.

Scaled model tests at the Ecole Centrale de Nantes and NOEL

Various designs for the platform have been studied by means of computational analysis to determine its behaviour under a wide range of sea conditions. The selected configuration was planned to be studied also via experimental testing. A 1:40 scale model of the selected design was then built and tested in a wave tank trial at the Ecole Centrale de Nantes (FR), as shown in **Figure 2**, in order to validate the computer model assumptions and the coupled dynamics[4,5].

A higher scale 1:15 scale prototype, called 'AURORA', was built and is now in place at the Natural Ocean Engineering Laboratory (NOEL) open sea test site at Reggio Calabria in Italy, as shown in Figure 3. This prototype is fitted with an array of sensors to monitor its performance and behaviour for the entire duration of the experimental campaign (7 months) before its decommission by the end of 2021. This 1:15 scale model is constructed by categorizing the building blocks, such as the steel caissons-based platform assembly and its technology components, the ballasting system, the aquaculture prototype, the scaled energy harvesting devices, and the automation and control prototype, etc. For the installation of the aforementioned sub-assemblies, the wind turbine and WECs are both installed on the front side of the floater platform. An offshore camera is located in the mid aft side with the purpose to provide the remote-control station with the information for the entire duration of the experimental campaign. The experimental data collected will provide valuable information on the aero-hydrodynamic behaviour of the platform, the net pens and the wind and WEC systems, and will be used to optimise the models for predicting the behaviour of all sys-tems at full scale, thus enabling reliable virtual testing before any investment being mobilised.

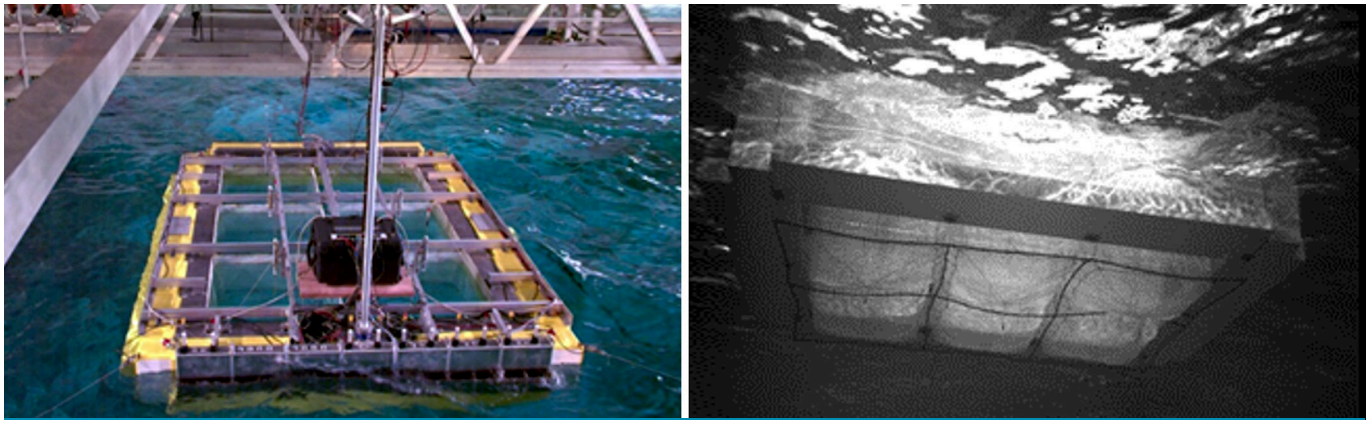

Figure 2 | 1:40 scale model test at the Ecole Centrale de Nantes (FR).

Figure 3 | The 1:15 scale model 'Aurora' at Reggio Calabria in Italy.

Social Impact, economy and business planning

Parallel to the engineering design work on the platform, the project has also looked at the social acceptance of multi-use platforms by holding workshops and meetings with stakeholders and local communities in two selected locations, Reggio Calabria (Italy), and Islay (on the west coast of Scotland). This interaction has provided valuable information on the key factors that most strongly influence public perception of such offshore systems which could be helpful in guiding potential investors on how best to win local approval and support for their proposed activities. Regulatory aspects related to Marine Strategy Framework Directive (MSFD) and compatibility with Marine Spatial Planning Directive (MSPD) of BGF Multipurpose Offshore Installations (MOI) have been investigated and the BGF contribution to best practise for the management of sea space multiple uses is expected to be delivered by the end of March 2022, thus contributing to the implementation of the EU Integrated Maritime Strategy, as well as to the Marine Strategy Framework Directive.

Conclusion and outlook

The EU H2020 funded project 'the Blue Growth Farm' aims to develop a multi-purpose offshore platform design which provides both green energy and fish farming. By combining different offshore energy generation devices such as the wind turbine and wave energy converters, this multi-purpose offshore platform meets the increasing demand of renewable energy production and at the same time decreases the environmental pressure on oceans exerted from fishing. Besides, the internal pool is used for a number of efficiently managed aquaculture fish cages, which also demonstrates its commercial feasibility. The aim of the Blue Growth Farm project of producing advanced industrial knowledge with a fully integrated and efficient offshore multi-purpose floating platform can be thus achieved, providing a practical solution for the blue economy.

Yan Gao
Dr. Yan Gao is a research associate at the University of Strathclyde, UK, at the Department of Naval Architecture, Ocean & Marine Engineering. Her research interests are ocean engineering with a focus on offshore platforms, computational mechanics on nonlocal material modelling, fluid-structure simulation with structural failure.

Maurizio Collu
Dr. Maurizio Collu is a reader in Offshore Renewable Energy Systems, and he joined the Naval Architecture, Ocean & Marine Engineering Department of the University of Strathclyde in 2018. His area of expertise is applied mechanics, focusing in particular on multidisciplinary, coupled model of dynamics for offshore renewable energy systems. He applies this expertise to develop conceptual and preliminary design methodologies for offshore renewable energy systems.

Fabrizio Lagasco
Mr. Fabrizio Lagasco is R&D Corporate Special Projects responsible in RINA Consulting S.p.A. and he acts as the coordinator of the Blue Growth Farm Project. Based on a leading (> 30 years) multidisciplinary experience matured through national and international industrial projects of high technology content applications, Mr. Lagasco is currently heading transversal and added value initiatives in the R&D projects and he is promoting exploitation of company R&D output towards new industrial capabilities to create value for the company and its industrial clients.

Giulio Brizzi
Dr. Giulio Brizzi is a senior aquaculture scientist. He is expert in offshore aquaculture and impact assessment of aquaculture and other human activities on the marine ecosystem, notably on benthos. Within the Blue Growth Farm Project, he participates as Chlamys srl researcher, and has been in charge of platform siting, after establishing the fish welfare criterion for under exposed marine conditions, as well as the assessment of the environmental impacts of platform.

Felice Arena
Felice Arena is professor of Ocean Engineering at the Mediterranea University of Reggio Calabria, where he is director of the Natural Ocean Engineering Laboratory NOEL. Fields of interest of his research activity include: mechanics and statistics of ocean waves, offshore engineering, wave energy converters, wind energy offshore. He is author of more than 250 papers. He is in the Editorial Board of Probabilistic Engineering Mechanics, by Elsevier; an associate editor of ASME Journal of Offshore Mechanics and Arctic Engineering. He has been scientific supervisor (principal investigator) of many R&I projects on offshore engineering and marine energy (including FP7 and H2020 projects).

Carlo Ruzzo
He is a staff member of Natural Ocean Engineering Laboratory (NOEL) and a post-doc in Ocean Engineering at the Mediterranea University of Reggio Calabria. His research topics include wave mechanics, extreme waves, wave-structure interaction, floating offshore wind turbines, multi-purpose floating platforms, etc. In this context, he is involved in numerical studies, and arrangement and management of experimental activities. His contribution within the Blue Growth Farm project mainly involve the study of the coupled dynamics of the structure and the realization of the outdoor experimental campaign at NOEL.

Anita Santoro
Anita Santoro is the CTO of Wavenergy.it limited company. She obtained her Master Degree in Environmental Engineering at the Mediterranea University of Reggio Calabria in 2010. Thanks to a joint program agreed by the Mediterranea University and the Instituto Superior Tecnico of Lisbon (PT), she obtained her PhD in Ocean Engineering at both universities in 2014. Her interests include wave data analysis, wave modelling and coastal engineering. She joined Wavenergy.it in 2018. Since then, she started working at the Blue Growth Farm project, with particular reference to the aspects related to the patented wave energy converters REWEC3.

References

1 | F. Driscoll, J. Jonkman, A. Robertson, S. Sirnivas, B. Skaare, and F. G. Nielsen, "Validation of a FAST model of the statoil-hywind demo floating wind turbine," *Energy Procedia,* vol. 94, no. NREL/JA-5000-66650, 2016.

2 | A.F.O. Falcão and J. C. C. Henriques, "Oscillating-water-column wave energy converters and air turbines: A review," *Renewable Energy,* vol. 85, pp. 1391-1424, 2016/01/01/ 2016, doi: https://doi.org/10.1016/j.renene.2015.07.086.

3 | F. Lagasco et al., "New engineering approach for the development and demonstration of a multi-purpose platform for the blue growth economy," in *International Conference on Offshore Mechanics and Arctic Engineering,* 2019, vol. 58837: American Society of Mechanical Engineers, p. V006T05A023.

4 | L. Li, M. Collu, C. Ruzzo, G. Failla, K. A. Abhinav, and F. Arena, "Analysis of the Coupled Dynamics of an Offshore Floating Multi-Purpose Platform: Part A – Rigid Body Analysis," in *ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering,* 2019, vol. Volume 6: Ocean Space Utilization, V006T05A025, doi: 10.1115/omae2019-96212. [Online]. Available: https://doi.org/10.1115/OMAE2019-96212.

5 | C. Ruzzo, G. Failla, F. Arena, M. Collu, L. Li, and A. Mariotti, "Analysis of the Coupled Dynamics of an Offshore Floating Multi-Purpose Platform: Part B – Hydro-Elastic Analysis With Flexible Support Platform," in *ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering,* 2019, vol. Volume 6: Ocean Space Utilization, V006T05A026, doi: 10.1115/omae2019-96282. [Online]. Available: https://doi.org/10.1115/OMAE2019-96282.