REFOS Platform: Integrating Offshore Wind and Wave Energy for a Sustainable Future

Mentored and Supervised by:

Antonios Nikolaos Billis, MEng Mechanical Engineering, University of Thessaly, MSc Marine Engineering, University of Strathclyde

Research & Writing by CLC's students:

Panagiotis Vagias / Jeffrey Shao /

Konstantinos Sougioultzoglou / Odysseas Kontos

Powered by:

Table of Contents

1. Introduction

In the last several decades, the growing need to reduce greenhouse gases and combat climate change has led to a global transformation towards renewable energy. Among these, offshore renewable energy is a virgin territory with vast potential to generate clean electricity by harnessing the natural power of seas and oceans.

By the early twenty-first century, the European Union made the sustainable use of marine and ocean resources as part of its long-term "Blue Economy" focus. Oceans cover more than 70% of Earth's surface and represent the largest biological ecosystem in the world, as well as the most economically underutilized frontier. With growing pressure on coastal zones from increased urbanization, tourism, and offshore industrial endeavors, it becomes increasingly crucial to redirect maritime efforts to deeper waters with fewer shoreline impacts and far greater space. Yet working in these areas requires specialized facilities for safe, sustainable, and efficient operations in more demanding environments.

Offshore conditions are resource-rich, with strong, consistent winds and high waves that can be tapped and converted into usable energy. However, even though abundant in resources, the majority of renewable systems focus on a single resource—wind or wave—and this makes infrastructure more expensive as well as decreasing efficiency. The Renewable Energy Multi-Purpose Floating Offshore System (REFOS) was developed to address these problems by combining various renewable energy technologies into a common floating platform.

2. What is the REFOS Platform

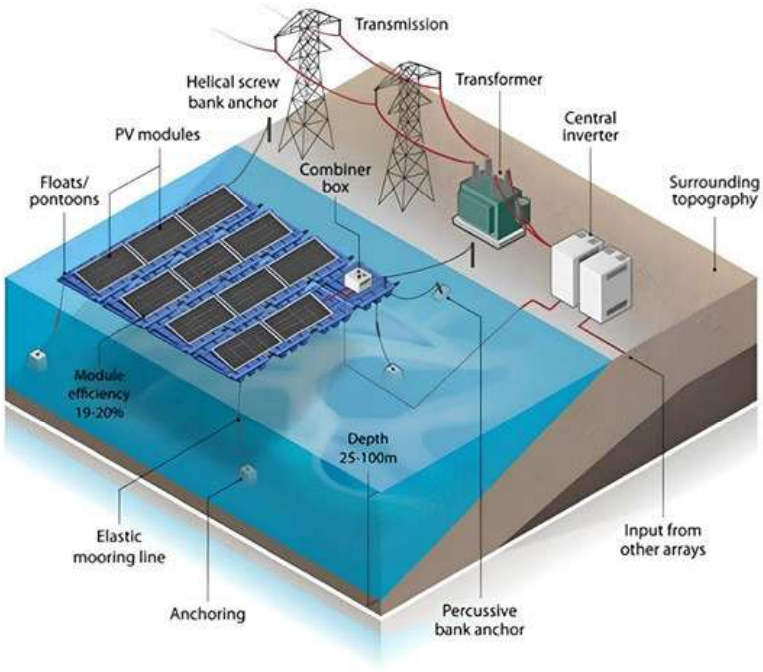
The REFOS platform also referred to as the *Renewable Energy Multi-Purpose Floating Offshore System,* is a European Union (EU) funded research project, which was developed through the collaboration of a vast majority of universities, research centers and industry partners, such as the National Technical University of Athens (NTUA), the Laboratory of Floating Structures and Mooring Systems (LFSMS), the Foundation Engineering Laboratory (FEL), the EUROPIPE group based in Germany, and many others. The leading goal of this project was to create an autonomous energy-generating tool that would combine wind and wave generation systems on a single floating offshore platform. This tool was designed as a steel tension-leg platform for offshore locations and was thoroughly tested through real-life simulations and scaled-model experiments.

Unlike fixed platforms that dive directly into the seabed, floating platforms, such as REFOS, are merely anchored or tethered through modern advancements (cabling systems, anchor systems) but still provide adequate stability. Floating platforms can operate at depths of hundreds of meters, making them ideal for offshore wind turbines, wave-energy converters, solar array fields, aquaculture fields, tourist facilities, logistics applications, and oceanographic research facilities. Thus, floating platforms function at the crossroads of marine engineering, renewable energy application, and sustainable development of offshore coastal environments.

REFOS represents a next-generation EU project concept that will develop an advanced floating platform design, which combines modular flexibility, environmental sustainability, and multi-sector functionality. The philosophy of REFOS is based on the premise that the use of marine space should be much more efficient through clustering complementary activities on shared infrastructure rather than separate zones and facilities for each activity.

The idea behind the project thus considers a floating base structure hosting a series of modules: renewable energy, offshore wind, wave, and solar; aquaculture cages; hubs for service and maintenance, which are crucial in offshore operations; and leisure or research facilities. This platform aims to be self-sustaining, scalable, and economically viable by means of hydrodynamic stability and new mooring systems together with smart energy management. It embodies the EU's ambition to move towards low-carbon, multi-purpose maritime systems with a view to enhanced environmental protection while boosting economic competitiveness.

2.1 What are the capabilities of REFOS

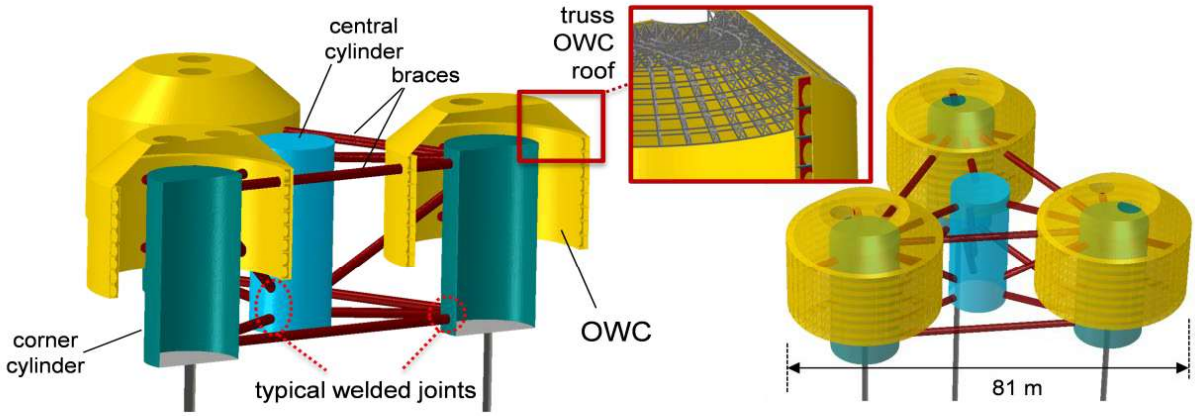


REFOS focuses on developing a groundbreaking floating platform capable of harnessing both wind and wave energy, in order to respond to growing demand for cost-efficient renewable energy solutions. This dual-purpose energy system represents a major technological advancement with the capacity to significantly enhance the competitiveness of engineering firms in Europe, especially those within the steel sector. Through an integrated life-cycle approach, REFOS aims to make wind and wave energy exploitation more efficient, systematic, and reliable, which will contribute directly to the EU's sustainability goals and the broader transition globally toward low-carbon energy systems.

The main and most important capabilities of this platform are the following: Firstly, its ability to house two power generation systems, through its wind turbine and wave energy system, allows it to be one of the most efficient in its range, generating approximately 132,000 kWh per day in ideal conditions. Secondly, its efficient optimization of space, consisting of one small and agile structure, replacing two separate installations, revolutionizes the renewable energy generating market. Finally, the most important feature that this engineering masterpiece manages to offer is its excellent environmental impact. Specifically, it has been designed with a life cycle assessment which optimizes its lifetime, and alongside this, its incredible ability to generate large amounts of electricity together showcases its success.

3. Technical Features

Focusing on the technical components of the platform, it has two ways of generating energy, one is through the use of a triangular base consisting of three cylindrical floaters on each corner, which oscillate along with the movements of waves, and the second is a central deck supporting an offshore Turbine of approximately 10 megawatts (MW). In more detail, the platform manages to generate electricity through its single offshore turbine, which has been strategically placed in a central position to maximize stability, designed to operate in deep water where fixed mounts and foundations are not found. Furthermore, the Oscillating Water Columns (OWC) capture the energy of ocean waves by letting water into a chamber, which builds pressure on the gas above the water. The gas over water is ventilated with air, which in turn powers the air turbines upward and downward to generate electricity. Two technologies---wind and wave---are utilized by the REFOS design to harvest complementary energy resources within the same marine area. The technological combination provides improved reliability of energy and maximizes the use of offshore space. In essence, this platform is appropriately equipped in such a way that simultaneous harvesting of wind and wave power is feasible, making it a very efficient piece of technology.



4. Research Until Now

While hybrid platforms like REFOS include promises, they still present a number of engineering challenges to be addressed. Superimposition of wave and wind loads creates new dynamic loads that cannot be managed without sophisticated modeling and testing. For this purpose, there have been experiments conducted that investigate the fatigue that the welded joints and stiffeners experience during their lifespan. Under 4-point bending, T-joint specimens made of mild (S355) and high-strength steel (S700) showed the differences between these two different categories of industrial steel under high-cycle loads, simulating the conditions that the welded stiffeners experience.

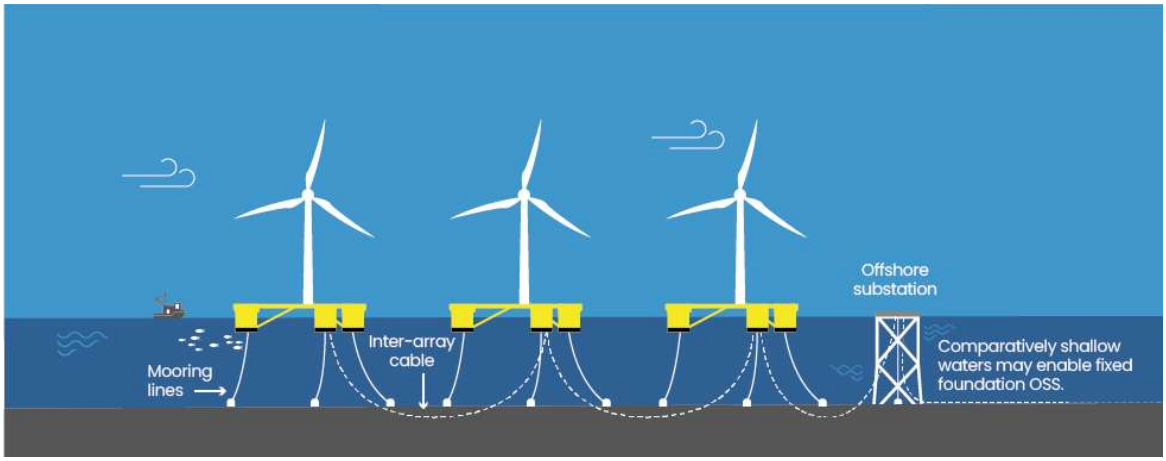
In addition, hybridization of energy systems also implies the existence of power management and control strategies. To ensure these safety guidelines, stability, and economic feasibility are ensured in REFOS, research teams involved in the REFOS project are performing sophisticated simulations, models, and prototypes.

5. Future Applications

The creation of floating multi-use platforms poses significant challenges from both the engineering and regulatory viewpoints. There are sophisticated design solutions to be considered in the process, including structural stability under extreme wave and wind conditions, long-term material durability such as corrosion, fatigue, and biofouling; efficient energy storage and transfer; and coexistence of diverse activities, including safe aquaculture near turbines. In addition, multi-use offshore installations lack unified legal frameworks, a fact that also entails governance challenges, especially in international waters.

On the other hand, opportunities abound. The rapid cost reduction of offshore wind technologies, growth in the European aquaculture market, and a number of advances in materials science and digital monitoring systems make floating platform projects

increasingly viable. In this respect, the REFOS platform is a timely effort to bring together technological, economic, and environmental factors into a coherent, scalable design.



6. Conclusion

To conclude, the REFOS platform is a landmark innovation in the future of offshore renewable energy. The integration of wind and wave technologies into a single floating platform demonstrates how engineering and innovation can enable sustainable energy production and maximize marine space utilization. With increasing energy demand across the globe and countries keen on outgrowing the fossil fuel age, hybrid platforms like REFOS could have a crucial part to play in leading the propagation of renewable capacity, lowering costs, and hastening the transition towards a clean and resilient energy infrastructure. The proposed floating solution will represent a significant advancement in renewable energy technology, enabling the cost-effective harnessing of both offshore wind and wave energy in Europe, opening up new market opportunities for both the steel and renewable energy sectors.

7. References

1. European Commission (2021). *The EU Blue Economy Report 2021*. Luxembourg: Publications Office of the European Union.

2. Horizon 2020 Programme (2014). *Horizon 2020 – The EU Framework Programme for Research and Innovation*. Brussels: European Commission.
3. Perez-Collazo, C., Greaves, D., & Iglesias, G. (2015). *A review of combined wave and offshore wind energy*. Renewable and Sustainable Energy Reviews, 42, pp.141–153.
4. Quevedo, E., Delory, E., Castro, A., Hernández, J., Llinás, O., & Adam, F. (2013). *Multi-use offshore platform configurations in the scope of the TROPOS project*. Proceedings of the 3rd International Conference on Ocean Energy (ICOE), Bilbao, Spain.
5. Rusu, E., & Onea, F. (2017). *Joint evaluation of wind and wave energy resources close to the Greek islands*. Renewable Energy, 102, pp.132–147.
6. Sánchez, A. S., Blanco, J. M., & Ramos, V. (2014). *New concept of marine floating platform for offshore wind turbines*. Journal of Renewable and Sustainable Energy, 6(4), 043109.
7. TROPOS Project Consortium (2015). *TROPOS – Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources: Final Report*. Grant Agreement No. 288192. European Union Seventh Framework Programme (FP7).
8. Vega, L. A. (2010). *Ocean thermal energy conversion*. Encyclopedia of Sustainability Science and Technology. New York: Springer.
9. WindEurope (2020). *Floating Offshore Wind – Vision Statement*. Brussels: WindEurope
10. **Billis, D.A.**, Mourlas, C.K. & Karamanos, S.A. (2024) '*Fatigue resistance of welded T-joint connections made of mild and high-strength steel for offshore applications.*' Dissertation/Thesis. [University of Thessaly/Department of Mechanical Engineering]