Version June 2020

Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS – FOR PUBLICATION

Project Title	Offshore Aquaculture Renewable Power Solutions (OARPS) 19/RDD/540
Lead Grantee (Organisation)	Impact9 Energy and Marine Limited
Lead Grantee (Name)	John Fitzgerald
Final Report Prepared By	John Fitzgerald
Report Submission Date	12

	Name	**Organisation**
Project Partner(s)	Michael O'Shea, Jimmy Murphy	University College Cork
Collaborators		

Project Summary (max 500 words)
This project directly addresses power consumption in aquaculture, in particular relating to fin-fish aquaculture in exposed offshore locations. There is a trend that new aquaculture operations are located at increasingly exposed locations due to licence conditions and environmental sensitivities in more sheltered bays. This unique emerging application for offshore renewable energy requires power that is available and reliable at offshore locations and in particular is abundant during times of storms (restricting intervention by supply vessels for fuel replenishment). This makes the application uniquely suited to wave energy and offshore wind power, while solar cells and energy storage solutions can also help to greatly reduce the diesel consumption. Impact9 is developing a novel fish pen architecture called "Net9", which addresses the survivability challenges of moving such operations to exposed offshore Atlantic locations, including the need for autonomous operations and embedded power solutions. Net9 was at an early stage of development (TRL2/3) but is now approaching TRL4/5 under ongoing work including that funded under this project. Under this project, Impact9 is working with UCC to research power solution options, including Wind, Wave and/or Solar power options as well as

research energy storage options that reduce the need for backup fuel consumption to acceptable levels and eliminate the risk of total power loss during weather-restricted periods.

Crucial to assessing the above is a fundamental understanding of the interplay between the level of power demand for aquaculture operations, when critical power is needed and the scale of structures onto which solutions must be integrated. The form of power demand is also important. Air blowers are used extensively for feed supply in aquaculture while alternative water-borne feeders offer routes to reduce power consumption. Cranes and other temporary operations incur power demand spikes for critical operations. Net9's solution includes specific ballasting and pumping operations for which the power demand must be understood. Developing an understanding of this and determining solution options is a key objective of the research.

This project includes tank testing, numerical modelling and concept design work to refine the Net9 technology solution & TRL4 validation to address renewable power solutions. Significant public dissemination on the general opportunity is also undertaken.

Keywords (min 3 and max 10)	Offshore aquaculture renewable power marine salmon farming

NB – Both Section 1 and Section 2 of this Final Report will be made publicly available in a Final Technical Report uploaded online to the National Energy Research Database.

In the following Section, please provide a clear overview of your project, including details of the key findings, outcomes and recommendations. The section headings below are provided as a guide, please update or add to these as best suits your project.

By submitting this project report to SEAI, you confirm you are happy for Section 1 and Section 2 of this report to be made publicly available. If you wish to request edits to this section in advance of publication, please contact SEAI at EnergyResearch@seai.ie.

SECTION 2: FINAL TECHNICAL REPORT – FOR PUBLICATION (max 10 pages)

2.1 Executive Summary

This project directly addresses power consumption in aquaculture, in particular relating to fin-fish aquaculture in exposed offshore locations. There is a trend that new aquaculture operations are located at increasingly exposed locations due to licence conditions and environmental sensitivities in more sheltered bays. This unique emerging application for offshore renewable energy requires power that is available and reliable at offshore locations and in particular is abundant during times of storms (restricting intervention by supply vessels for fuel replenishment). This makes the application uniquely suited to wave energy and offshore wind power, while solar cells and energy storage solutions can also help to greatly reduce the diesel consumption.

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2.2 Introduction to Project

Impact-9’s Net9 product is an offshore containment architecture for marine fin fish production. One challenge for the concept technology is how to meet energy demands to sustain the offshore operations, independently of grid power. This project was conceived to understand the renewable power solution options available to meet this need.

It is split into 4 Work Packages as follows:
WP1 End User Engagement & Research Dissemination
WP2 Renewable Power Solution Research & Recommendations

WP3 Numerical Modelling & Net9 Concept Integration
WP4 Experimental Performance Test

The work was completed from July 2020 to July 2021, culminating in a series of experimental tests and follow-up engineering analysis, as shown in the following figures.

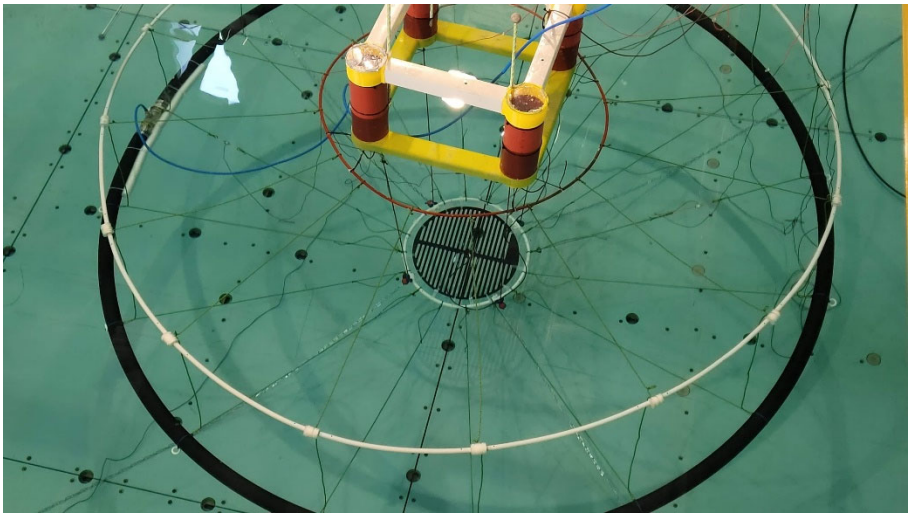

Fig 2.1 Net9 Model, Full Assembly installed without net features

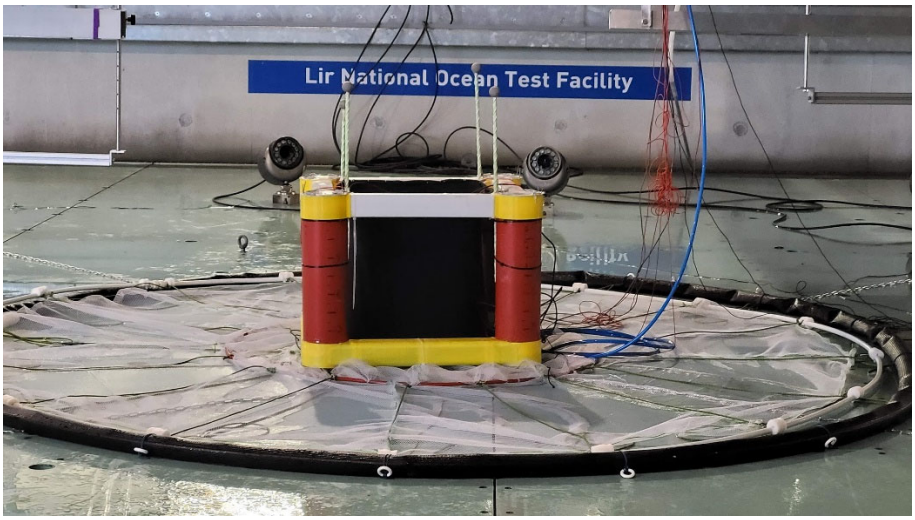

Fig 2.2 Net9 Model, Full Assembly with tank floor raised – fitted with net features. The central model platform with calibrated weights with inflatable variable ballast beam and associated control hardware are provided by Impact-9.

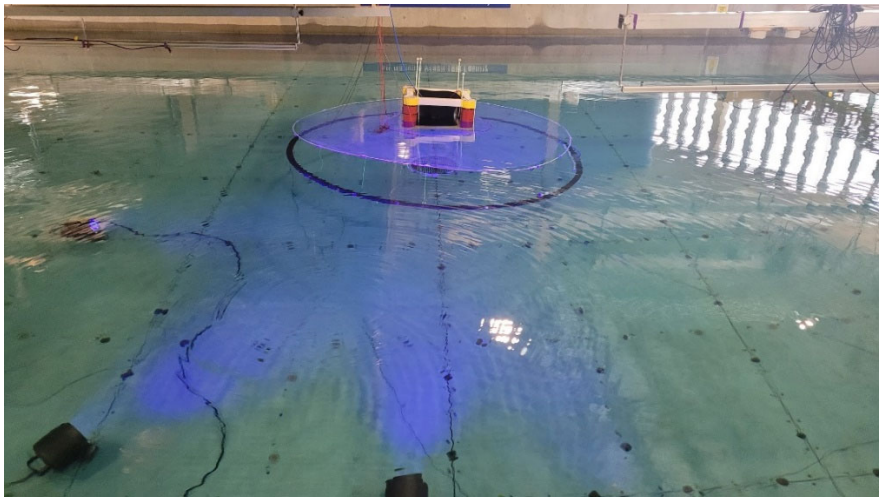

Fig 2.3 Experimental set-up with underwater motion tracking, provided by UCC as well as integrated load cells and above water qualysis connected to UCC data acquisition systems.

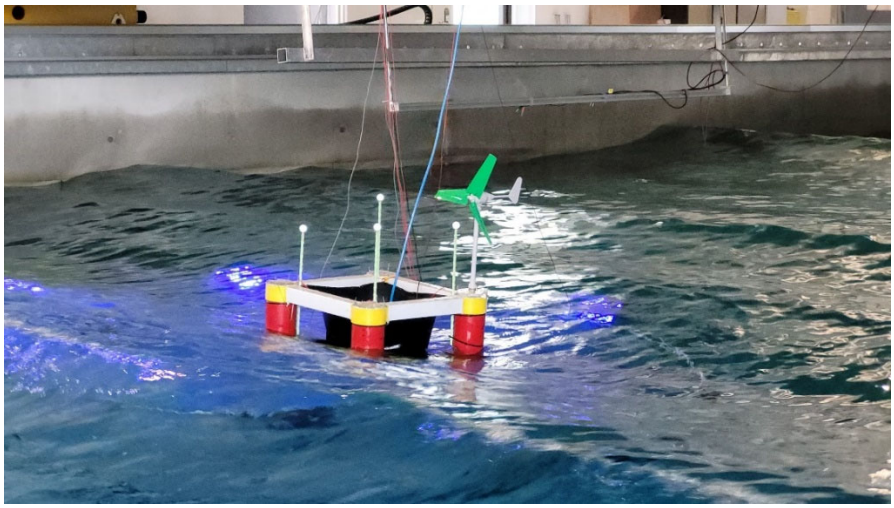

Fig 2.4 OARPS Experimental modification: wind turbine stability and dynamic tests.

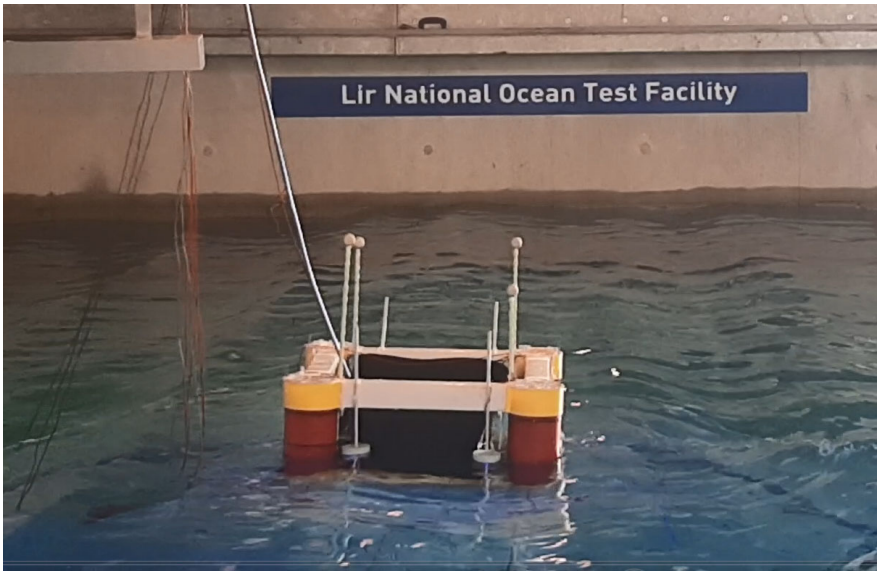

*Fig **Error! No text of specified style in document.**.5 OARPS Experimental modification: wave energy converter absorbers stability and dynamic tests.*

2.3 Project Objectives

The Project Objectives were as follows:

- Identify power demand attributes and operational constraints for offshore aquaculture, including for Net9 solution.
- WP2-O2: Determine energy storage / back-up fuel storage required to guarantee continuity of essential power.
- Compare renewable power solution options and recommend optimal solutions for the general application.
- Assess one or two solution options in more detail, considering integration with the Net9 concept architecture.
- Undertale numerical and physical testing of the system to understand loads and motions in the ocean environment.
- Update Net9 Concept Design including structures and subsystems design selection to integrate preferred renewable power solution.

2.4 Summary of Key Findings/Outcomes

- *Innovation 1: Power Demand Modelling Tools*

  One output of the project is an improved understanding of the power demand of new aquaculture production systems, especially in the offshore zone and tools to model that demand.

- *Innovation 2: Integration of Energy Storage and Battery Systems*

  The results of the research has identified the high instantaneous demand of aquaculture but also the more modest mean power demand requirements. The demand is not well suited to being met directly by diesel generators. The inclusion of batteries alone greatly improves the general efficiency of the drive train and the size requirements are suitable for hosting within the concept structures under consideration.

- *Innovation 3: Integration of Wind Energy Turbine*

  Together with the battery system the size of wind turbine required to meet a high proportion of on-board demand and to reduce diesel consumption to negligible levels has been identified. This power system design has been incorporated by Impact-9 for future development. While the size of turbine is modest it does have potential to interfere with aquaculture operations. (See Fig 2.4)

- *Innovation 4: Integration of Wave Energy Converters*

  The integration of wave energy converters with the platform was also assessed and shown that they would have less impact than wind on overall aquaculture operations. If made to work reliably they could be a good solution, especially at target sites where the wave resource is stronger. (see Figure 2.5)

2.5 Project Impact

Impact-9 stands for "Strength in Flexibility", having the world-leading understanding of how compliant marine structures should be designed for aquaculture, where contained biomass must live within and in sympathy with the ocean, including to move with the dynamic waves of an ocean environment. Just as battery cell technology underpins sustainable mobility, Impact-9 believes that flexible marine structures will underpin offshore food and biofuel production. Impact-9 understands how compliant structures shed loads in storms such that they need not be as large, expensive or resource intensive as conventional steel structures. Our vision is to be a trusted partner to deliver the novel structural

components and design validation services required to assure sustainable offshore aquaculture, as part of a rapidly expanding global offshore food production system.

The mission is to enable sustainable aquaculture & food systems at offshore locations, utilising offshore zones and resources that do not add to existing human demands for fresh water and energy. Impact-9 technology aims to enable high-quality seafood, more cost-effectively than for competing wild caught fisheries practices and in a manner that will have a minimal impact on wild stocks and biodiversity. Impact-9 promotes more sustainable use of ocean zones to benefit humanity, but only where human impacts are limited to well-managed zones that contribute to energy and food production in a way that restores and protects the broader ocean wilderness and its biodiversity.

A component of this mission is to ensure that power demand for offshore activities do not impact negatively. The results of this project will ensure that the renewable energy sources available at the target offshore locations will be used to meet the power consumption demands. Opportunities for broader co-location with renewable energy projects are also highlighted.

2.6 Recommendations

1. Emerging Offshore Aquaculture needs to be considered in the context of national marine spatial planning, particularly linked to Offshore Wind project consenting, to ensure that the available ocean zones are exploited efficiently with minimal impacts on marine ecology, biodiversity and existing marine users. Co-locatin of aquaculture within offshore wind arrays will more than double the economic return on the ocean space.
2. Incorporation of battery storage on offshore aquaculture systems has a significant efficiency improvement, even where only diesel-hybrid systems are used. Where renewable generators are connected, it is possible to meet nearly all power demand locally. It is recommended that this strategy is employed for offshore aquaculture design developments.
3. New marine finfish aquaculture presents an offshore power demand source that could provide an early adopter market for wave power technology. While end user engagemetns suggest that this market will be slow to emerge in Ireland, it is recommended that wave energy technology developers are made aware of the opportunity as it emerges and also that it should be differentiated from conventional aquaculture where the wave resource is typically too small.

2.7 Conclusions and Next Steps

The important conclusion of the project for the lead researcher was that a hybrid wind turbine, battery storage and smaller diesel generator system based on off-the-shelf technology can be integrated with their Net9 design to meet the power demand needs envisaged for their Offshore Aquaculture Operations.

The tools and capabilities developed for the project can have broader application to aquaculture power solutions and future research can focus on how diesel generation in the sector can be replaced. Battery Solutions present the most impactful upgrade and coupling to a renewable power solution will be highly dependent on site specific resource conditions, with wind power and solar PV being likely candidates at conventional aquaculture.

The Net9 offshore system definition has been taken forward for further development, including an integrated renewable power system base don a wind generator. Future research could look at wave energy alternatives that might be better adapted to the application where wave resources exist.