COMPLETED PROJECT CASE STUDY

ZOEX: CONVERTING WAVES INTO ENERGY FOR FISH FARMING

PARTNERS

ZOEX Ltd, Sealand Projects, Scottish Sea Farms, Umbra Group SpA, AKVA Group, University of Strathclyde

PROJECT LEADS

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SUPPORTED BY

Scottish Enterprise SMART:SCOTLAND, Sustainable Aquaculture Innovation Centre (SAIC)

BACKGROUND

Aquaculture, like many other sectors, increasingly seeks to decarbonise and demonstrate strong environmental principles as countries, including Scotland, adopt net zero policies. Due to the nature of aquaculture operations, this impacts energy-related measures in particular.

Growth in this sector is constrained by geographic factors, such as the lack of availability of sheltered, inshore sites. This, alongside other factors, has encouraged many fish farms to move to locations further offshore. These need higher amounts of diesel to meet electrical power requirements, as they are off-grid. Fish farmers aim to reduce the need for diesel generators in order to increase sustainable practices and reduce both cost and emissions.

For these reasons, there is a clear interest in renewable energy solutions within the industry. However, any renewable solution must ensure reliable power to protect fish health, offer energy storage options, and be a competitive alternative to diesel.

This research project brought together government bodies, industry leaders, academic institutions, and potential customers. The main funding body of the project was Scottish Enterprise. Project partners include Scottish Sea Farms, a fish farm and potential customer; SAIC, to support with expertise, advice and dissemination; Umbra Group SpA, which provided Power Take Off system details; AKVA Group, which undertook the feed-barge drawing; and finally, ZOEX Ltd, the creator and provider of the ZOEX WEC IP and collateral. Testing of the model took place within the tank test facility at the University of Strathclyde's Kelvin Hydrodynamics Laboratory.

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AIMS

This project primarily aimed to confirm whether mounting the ZOEX Wave Energy Converter (WEC) to a suitable feed barge could provide sufficient clean electrical power to meet the needs of a typical fish farm in Scotland.

To achieve its primary objective, the study also sought to benchmark the market drivers and confirm whether energy derived from the ZOEX WEC would be competitive against diesel.

These objectives were evaluated by:

- developing numeric models;
- analysing met-ocean data from farm sites to identify which sites would be most suitable for the technology;
- designing and constructing a 1:10 scale 3D-printed model of the ZOEX WEC and testing this model at the Kelvin Hydrodynamic Laboratory's tank test facility.

WAVE ENERGY AS A RESOURCE

The reliability of power is of the utmost importance to fish farms. Loss of power for even one day can present problems such as disruption to feeding routines or loss of signals from sensors. Current options for energy include subsea cables providing mains power, solar panels, small wind turbines, hydrogen fuel cells, and ammonia fuel cells.

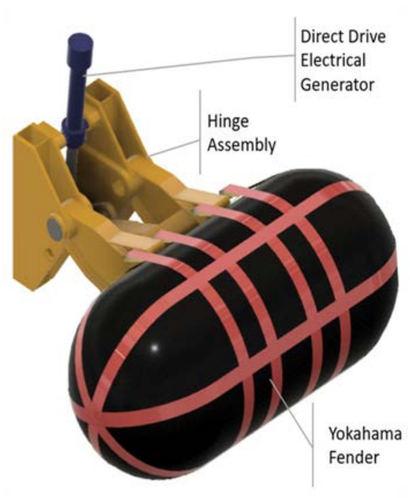
Each of these faces unique challenges that can make their adoption in coastal Scottish waters difficult and expensive. For example, while mains power supplied by a subsea cable is more reliable and for nearshore farms, it is not an option for remote sites off the coast of Scotland, where there is not sufficient grid infrastructure. And while solar panels offer an affordable price, they do not produce enough power during winter months in the northern latitudes preferred by salmon.

Emerging wave and tidal technologies offer potential, although currently, they are comparatively expensive. Most wave energy technology requires two-metre waves in height; a demanding requirement for traditional farms in sheltered areas and calmer swell. However, as farms increasingly move to more exposed, high-energy locations, wave resource levels should meet this requirement.

The ZOEX WEC is a modular wave energy converter that can be attached to marine structures to provide cost-effective, reliable, and clean power to help reach sustainability goals. The device is a simple hinge plus float, designed to be attached to the platform of a marine structure.

A rubber fender moves up and down as a wave-actuated body. An electro-mechanical generator captures the fender's movements. The design incorporates a mechanism to enhance power production in small waves while mitigating end-stop problems in large waves, making it suitable for low and high sea states. This research project is part of the feasibility testing of the ZOEX WEC prototype.

Figure 3-1 WEC General Arrangement



WEC DEVELOPMENT

The project included four initial work packages: project management, hydrodynamic analysis, structural analysis, and electrical analysis. These steps paved the way for testing the 1:10 WEC model in a tank at the University of Strathclyde.

First, the project management team undertook a site selection process, which looked at sites near the west and north coasts of Scotland. The team selected the following sites for site screening: Oban, Isle of Mull, the northwest mainland at Loch Nevis, the north mainland, Orkney Islands, and Shetland Islands.

The second work package focused on the numerical investigation of the conceptual hydrodynamic performance of the ZOEX WEC. This work package investigated how the arm length of the converter affects the energy output, as well as the development of an advanced computer model, which allowed simulations to evaluate the energy output at different sea states.

Analysis from the model simulation resulted in valuable guidance for optimising the design of the WEC, possibly leading to an even more efficient converter. Specifically, this analysis found that the converter could be effective in applications even at smaller sea states (wave height less than 0.55m), in applications such as fish farming, unlike many other wave technologies that require heights of two metres to be effective.

The third work package focused on the installation method, and also assessed the feasibility of integrating the ZOEX WEC onto a typical feed barge. This work included studying the typical feed barge interface and developing an installation method by which the ZOEX WEC could attach to it safely.

Work performed during this work package concluded that installation of the ZOEX WEC onto a typical feed barge is mechanically feasible. An installation methodology was developed, including a quick-hitch concept for ease of installation. A tapered hook would guide, locate and restrain the ZOEX base into position, where it would be secured by pins. This nature of this work package was to prove the concept; a physical attachment of the WEC onto a feed barge did not take place.

Electrical analysis was performed as part of the fourth work package, evaluating a suitable electrical system architecture for the converter after installation. This phase concluded that electrical integration is technically feasible. A levelised cost of energy (LCOE) analysis estimated the energy would cost in the range of £223-600 per megawatt hour, although this will differ from site to site. This estimate accounts for capital expenditures such as equipment and project development, as well as operating expenditures such as maintenance, insurance, and other annual charges.

Finally, a 1:10 scale model of ZOEX was created and tested in the 3D compact wave tank at the University of Strathclyde's Kelvin Hydrodynamics Laboratory. This step sought to test the proof of concept, prove that the double link arm has 180 degrees of freedom of movement, and measure the power output against the numeric model results.

Testing within the tank demonstrated that the device can rotate up to 180 degrees. The team was also able to identify how to enhance or reduce the power output using the air holes within the device.

IMPACT

This study achieved its objectives and illustrated that the ZOEX Wave Energy Converter (WEC) is a good value proposition to customers, costing less than or equal to diesel alternatives. Further, the WEC produced zero harmful emissions to the atmosphere. Therefore, the study has concluded that the ZOEX WEC is a promising net-zero solution that is technically feasible and commercially attractive to the aquaculture industry.

In the short term, the device encounters higher costs. However, the WEC results in lower long-term expenditure, as waves are a free energy source and the generator requires minimum maintenance. Additionally, initial costs can be reduced even further with multiple government grants and programmes available to assist with implementing renewable energy solutions.

Electrical integration of the ZOEX WEC with the Umbra 100kW EMG Power Take Off is advantageous to operators, as electricity generated can be used instantly or stored in a battery for later use. ZOEX can be regarded as a trickle charger of battery systems, topping up and always keeping the batteries full, reducing a fish farm's dependence on diesel while reducing costs and carbon emissions.

The feasibility study also usefully highlighted certain limitations and considerations, e.g. the need for any retro-fit of the WEC to an existing structure (such as a feed barge) not to compromise the structural integrity of the vessel; and that any retrofitting exercise would need to consider the space required for batteries/power storage.

The proof of concept experiment within the tank confirmed the effectiveness of the converter design. The authors of this study recommend that advanced simulation methods, such as Computational Fluid Dynamics (CFD), and testing with a larger-scale model should be undertaken in the future for more accurate predictions. Plans and funds are currently in place to build and test a full-scale prototype.

FURTHER DEVELOPMENTS

Following this feasibility study, a full R&D project has been funded by the Seafood Innovation Fund (SIF) and supported by SAIC. At the time of writing, the full-scale ZOEX WEC has been manufactured and is installed at Aberdeen Harbour South for testing, and a successful launch event has taken place.