Albatern and AquaBioTech
Aquaculture & Wave Energy Combination

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1.1 Introduction

1.1.1 Combination type

**Combines:** Offshore FinFish Culture and Wave Energy Generation

**Space share type:** Multi-use of Space

1.1.2 Company description

The **AquaBioTech Group** is an international aquaculture consulting and technology supply company strategically located in the center of the Mediterranean on the island of Malta, operating globally with clients and projects in over fifty-five countries.

**Albatern’s WaveNET** is a radical new wave energy device that captures energy from ocean waves and converts it into sustainable low-carbon electricity, providing improvements in operational efficiency at lower cost.

These two companies have come together to form a Special Purpose Vehicle (SPV) to provide a one-stop-shop for wave energy enabled aquaculture solutions utilising the synergies in sea-space equipment usage to provide electricity for energy intensive aquaculture installations, facilitating amongst others the movement of commercial cage farming further offshore. Utilising the combination, fish can be produced with a vastly reduced environmental impact by utilising the renewable electricity provided by the WaveNet devices to service specifically the energy requirements of the farming operations. The SPV’s target market focuses on both existing and new cage farming operations, however it is envisaged that the WaveNet will also be utilised extensively to provide power (and potentially potable water) to shore based marine aquaculture facilities in areas where wave energy is suitably abundant and supply of grid-based electricity is expensive or unavailable.
The targeted market stretches across the globe with the SPV initially focussing on the Mediterranean and broader European sea basins where suitable protected cage farming space is almost fully utilised and now requires the movement offshore to facilitate increases in production capacity essential to service the ever growing market for fish products.

AquaBioTech Group have identified the SubflexTM submersible cages as well suited to the offshore application in the Mediterranean due to their use of a single mooring point supporting a series of linked cages, resulting in minimised space use and environmental impact, as well as the ability to be submerged below the destructive energy zone of the waves during a storm.

1.1.3 Combination project description

1.1.3.1 Current status

The current status of the technology combination is considered to be at TRL 7, based on the proven ability of the cage farming technology and the level of testing of the wave energy devices in conjunction with cage farming operators, including world leading Salmon Farmers Marine Harvest, at pre-pilot scale. The first trials have taken place in Scotland (Isle of Muck) where the available wave environment is more abundant and energetic. As such the technology is yet to be verified in the less energetic Mediterranean where performance predictions will initially be based on available wave energy data as opposed to in-situ testing. Much work has also been carried out in the development of the supporting “hybrid” storage system that will convert and store the wave energy in the offshore application and provide the necessary power on demand.

1.1.3.2 Strategic Roadmap to commercialisation

The commercial development plan for the technology has three key stages, the first of which is already under way. This first stage is considered a pathfinder project involving a new Marine Harvest cage installation in Scotland with a WaveNet grid positioned slightly away from the cages but in a protected environment. The aim of this installation is to prove the functionality of the system and give a level of confidence that the WaveNet is a secure system and there is minimal risk to the cages, as well as to identify any unforeseen problems that need to be resolved. This pathfinder is not located in the Mediterranean so will not give a complete reflection of the offshore installations to be developed in the Mediterranean. As such it is the SPV’s intention to install initially a pilot combination of one full Subflex cage system able to produce 1,000 tons of fish and serviced by a WaveNet system and associated Hybrid plant housed in the farm service vessel. Once proven to be successful this will be followed by an expansion to a full commercial scale of 6,000 tons serviced by a much larger WaveNet grid and associated Hybrid plant service vessel, which will then be the commercial demonstrator utilised for the approach to the market.

Map images
Figure 3: Planned and existing aquaculture zones of Malta where Area 1 is the possible site for the coastal nursery cages, the off the coast site of the transfer cages can be planned in the Area 8, the offshore cages are planned in the area F designated as a future aquaculture zone.\(^1\)

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1.2 Technical Brief with Planned Phases of Development

1.2.1 Albatern WaveNet Energy Collection

“WaveNET is an offshore array-based wave energy converter that uses the motion of waves to generate electricity. The floating structure of WaveNET is flexible in all directions, and capable of capturing power from the waves regardless of wave direction and array orientation. WaveNET arrays are formed by interconnecting the unique SQUID generating units. The first development scale of WaveNET is Series-6, designed to operate in a minimum water depth of 20m and to generate electricity in waves with heights ranging from 0.3m to 6m.” (Source - http://albatern.co.uk/wavenet/wavenet/)

Figure 2: Deployed WaveNet Arrays

“WaveNET’s strongest features come from being designed and engineered from the start to function as an array of linked units. The most significant benefits of this array-based approach come from improvements in power yield and potentially dramatic reductions in project costs.”

Figure 3: Concept Drawing of WaveNet Array Configuration for Different Conditions

Key Benefits of WaveNET Arrays:
❖ Modular and scalable
❖ WaveNET arrays are configurable to match site conditions and project power requirements.
❖ By increasing the length of the array WaveNET can capture more power from longer waves, increasing the width allows WaveNET to capture more energy from lower density sites.
❖ High efficiency; WaveNET’s uniquely flexible design allows it to track the full orbital motion of the fluid particles in the ocean waves, as well as providing very efficient use of sea space and wave resource. As much as 300 MW per km² is possible for large arrays. This compares to 15-20 MW/ km² for other wave devices, with offshore wind typically in the range of 10 MW/km².
The space-frame type construction of the array allows these large amounts of sea area to be covered using comparatively small amounts of material, resulting in an exceptionally high power to weight ratio.

Interlinked WaveNET units react against the rest of the array to deliver dramatic non-linear yield improvements as array dimensions increase.

The SQUID generating units feature an innovative patented pumping module design, which avoids the use of mechanical end-stops. This is an extremely important feature for wave energy converters where storm conditions can create large waves with very high energy levels that can destroy normally robust systems.

Added to this, WaveNET’s low profile in the water, flexible structure and a mooring system featuring multiple points of connection allows large waves to pass over and submerge some or the entire array, minimising any potential damage.

WaveNET arrays appear from the surface as a series of isolated buoys, similar to those of mussel farms, reducing visual impact and potential conflict with other sea users.

Using small repeated units to build large arrays helps to reduce the capital and operational costs of wave energy.

Each SQUID generating unit uses a number of shared standard components which, as production volumes increase, should lead to dramatic savings in per unit costs. Some of these savings are already being seen from the first run of Series-6 units.

**Figure 4:** WaveNet Array 3D Concept Drawing

**Figure 5:** Image of the WaveNet Systems Adjacent Marine Harvest Cages Showing the Low Visual Impact

Small unit size helps minimise the costs of deploying and maintaining WaveNET arrays

Series-6 SQUID units are road transportable on standard articulated trailers and can be easily deployed and maintained using cranes and vessels already operating in an area.

**Figure 6:** Image of the WaveNet Systems Transported by a Standard Length Heavy Goods Vehicle
A further operational cost benefit comes from WaveNET’s submerged profile. Arrays can be navigated with small vessels, making access to individual devices for maintenance and inspection tasks easy.

WaveNET arrays are fully redundant systems and have a number of unique features to maintain high availability regardless of individual component or device failures. Each unit makes three connections to the mooring grid and can be isolated from the rest of the array for maintenance or in the event of failure. Multiple power-take-off (PTO) modules within the array act in parallel – if one fails the others will automatically maintain production. The array’s hydraulic network has automatic cut-off valves to protect against local failures. Any failed region is automatically isolated allowing continued operation.

In December 2013 the first three WaveNET Series-6 SQUID units were transported from Albatern’s Edinburgh base for testing at Kishorn in Wester Ross, before being deployed in conjunction with Marine Harvest (Scotland) on their new salmon farm site off the Isle of Muck on the west coast of Scotland. Further work has since been done by way of a feasibility study as well as in a further pilot scale installation utilising a hybrid power management system to provide at the facility with necessary power for operations. Following commissioning of this system in a sheltered site, it is now being deployed next to an operating salmon farm site near Ardnamurchan on Scotland’s west coast. This
work should now be taken to the next step of doing similar investigation for a specific Mediterranean
opportunity that potentially can be commercialised

1.2.2 TRL7 Pilot

<table>
<thead>
<tr>
<th>TRL 7 Pilot Malta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim:</strong> Prove Feasibility of Offshore Combination in the Mediterranean wave climate</td>
</tr>
<tr>
<td><strong>Comprises of:</strong></td>
</tr>
<tr>
<td>➢ Albatern: 16 x Series 6 (7.5kW) plus Hybrid Plant (120kW rated capacity)</td>
</tr>
<tr>
<td>➢ Aquaculture: Target Output of 1150MT Per Annum, 8 Cages of 7,240m$^3$ each</td>
</tr>
<tr>
<td><strong>Footprint:</strong> Cages 5,760m$^2$, Max Total 45,000m$^2$, WaveNet 4,000 m$^2$</td>
</tr>
<tr>
<td><strong>Located:</strong> 5km to 8km South-East of Malta Mainland</td>
</tr>
<tr>
<td><strong>Water depth:</strong> 50m to 70m</td>
</tr>
<tr>
<td><strong>Fabricated at:</strong></td>
</tr>
<tr>
<td>➢ WaveNet &amp; Hybrid Plant: Albatern - Scotland</td>
</tr>
<tr>
<td>➢ Aquaculture cages: Subflex - Gili Ocean Technology Ltd.</td>
</tr>
<tr>
<td><strong>Brought to location by:</strong></td>
</tr>
<tr>
<td>➢ WaveNet &amp; Hybrid Plant: Albatern &amp; Shipping Agent</td>
</tr>
<tr>
<td>➢ Aquaculture cages: Aquabiotech &amp; Shipping Agent</td>
</tr>
<tr>
<td><strong>Installed using:</strong></td>
</tr>
<tr>
<td>➢ Albatern: Aquabt/Albatern/Marine Contractor</td>
</tr>
<tr>
<td>➢ Cages: Aquabt/Gili Ocean Technology Ltd./Marine Contractor</td>
</tr>
<tr>
<td><strong>Cable to Service Vessel:</strong> 120kW</td>
</tr>
<tr>
<td><strong>Array/Hybrid Plant Connection &amp; Diesel Back-up:</strong> 120kW</td>
</tr>
<tr>
<td><strong>Moorings:</strong></td>
</tr>
<tr>
<td>➢ WaveNet: Albatern/Marine Contractor</td>
</tr>
<tr>
<td>➢ Cages: Aquabt/Gili Ocean Technology Ltd./Marine Contractor</td>
</tr>
<tr>
<td><strong>O/M and Access:</strong></td>
</tr>
<tr>
<td>➢ WaveNet &amp; Hybrid Plant: Albatern/Aquabiotech</td>
</tr>
<tr>
<td>➢ Cages: Aquabiotech</td>
</tr>
<tr>
<td><strong>Target deployment in:</strong></td>
</tr>
<tr>
<td>➢ Albatern: 2017</td>
</tr>
<tr>
<td>➢ Cages: 2017</td>
</tr>
</tbody>
</table>

The minimum scale to render the Pilot Farm viable is expected to be 1,000 metric tonnes per annum, largely relating to the need of scale to bring down the capital cost per cubic meter of production volume, and to increase the proportion of operating costs taken up by feed to closer to 50%. For ease
of aquaculture production planning, the initial forecasted production target will therefore be to harvest 1000 metric tonnes of fish per annum.

Fish will be stocked into the offshore cages at a minimum individual weight of 25g to 30g, necessitating 2 main production units; a coastal nursery cage production area (or a land-based nursery facility), as well as the main offshore production site utilising submersible cages for production of fish to market size.

Depending on the distance of the chosen main site from the land base it may be more efficient to have a transfer cage system and site closer to the packing facility, to periodically move bulk numbers of fully grown stock to within easy reach so they can be landed for processing timeously and on demand.

Energy needs of the farm operation and potentially for the land based processing and logistics can be supported by wave energy generation by WaveNET arrays.

1.2.2.1 Logistic Centre and Fish Processing Unit

Should the fish farm not be able to deliver fish into a central processing and distribution hub, the logistics centre will need to incorporate this extension to the standard packing facilities required. As such the logistics centre needs to be fairly large so as to facilitate the storage of fish feed, expected to peak in the region of 250 Metric tonnes to ensure that there is at least six (6) weeks supply retained in stores when cages are fully stocked. The fish feed will then be transferred offshore to the service vessel able to hold 65 metric tonnes at peak loading, thus reducing the logistics of feed movements and facilitating a more effective automated feeding strategy that will make use of current sensors and underwater cameras.

The grading and packing facility required will also be housed on the logistics site, comprising the physical receiving, harvest, grading and packing facility, as well as having the facilities for the production of roughly 150 metric tonnes of different types of ice every month. With an anticipated four to six shipments per week leaving the facility during normal and peak seasonal demands, the facility will require a large contingent of full-time and part-time staff.

1.2.2.2 Coastal Nursery Cages (Potentially an Onshore Facility)

The 2g fish fry will be raised up to between 30g and 60g in size before being transferred to the offshore cages allowing for vaccination procedures prior to stocking. If not land based the production site should have a high level of protection in a bay, ideally at a distance of 500 m from the Logistic centre and fish processing unit. The maximum biomass of the cages should be kept below 14 kg/m$^3$. Indications for cage selection as follows:

<table>
<thead>
<tr>
<th>Cage dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cage depth</td>
<td>8 m</td>
</tr>
<tr>
<td>Cage diameter</td>
<td>10 m</td>
</tr>
<tr>
<td>Cage volume</td>
<td>628 m$^3$</td>
</tr>
<tr>
<td>Max Stocking Density</td>
<td>14 kg/m$^3$</td>
</tr>
</tbody>
</table>
Max Cage biomass 8,792 kg

Number of cages 4 cages in a 2x2 cage module

1.2.2.3 Off the coast transfer cages

The main function of this unit to store the fish harvested from the offshore cages to ensure a continuous and balanced supply of the fish processing and packaging. The fish at the 350-400 g size will be harvested and transferred to these cages where a minimal feed rate will be applied. These cages should ideally be within 2km. Indications for cage selection as follows:

<table>
<thead>
<tr>
<th>Cage depth</th>
<th>15 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cage diameter</td>
<td>20 m</td>
</tr>
<tr>
<td>Cage volume</td>
<td>4,710 m³</td>
</tr>
<tr>
<td>Maximum Stocking Density</td>
<td>20 Kg/m³</td>
</tr>
<tr>
<td>Max Cage biomass</td>
<td>95,000 kg</td>
</tr>
<tr>
<td>Number of cages</td>
<td>2</td>
</tr>
</tbody>
</table>

1.2.2.4 Offshore Production Site Requirements

The offshore production should ideally be feasible at one production site that has the capability to produce a minimum of 1,000 MT per year, and with expansion potential to full commercialisation, preventing the requirement for additional permitting, logistics etc. The chosen site must have enough water depth and water exchange so as to disperse the level of nutrients coming from the cage farming operation, and which will have the added benefit of being out of sight from the mainland.

Due to the high establishment and service costs of an offshore cage farm, as well as the relatively low value of Sea bream and Sea bass on the European markets that now treat it as a commodity, offsetting this increase in production costs must come from a high-level production volume and a super-efficient production platform. As such it may be necessary to extrapolate the targeted production to a level closer to 5,000 metric tonnes to create an investment with sufficient economies of scale to render attractive enough returns for investment to justify the risks involved. Shifting certain costs like that of providing power onto the balance sheet is one way of achieving this.

The choice of cages and supportive technology used is largely related to the level of protection of the location, and hence intensity of the wind, wave, tidal and current based forces expected to impact the proposed production site. As such, of the numerous new technologies for offshore fish farming available it can only be decided which technology will be used once a specific site/case study for the project is carried out, which requires wave size and intensity modelling for cage selection and
insurance. Fortunately, a recent study by Drago, A. et al (2013) has provided much of the detail required.

The Subflex Submersible Cages (from GILI Ocean Technology Ltd) are considered as well suited to the less energetic positions presented in the Figure 1 Map above. These systems have all undergone significant testing and are currently in use in commercialised operations. Ironically it may be necessary to identify more energetic locations that have a better annual balance between wave energy and protection to ensure viability of the wave energy component.

<table>
<thead>
<tr>
<th>Planned maximum fish stocking density</th>
<th>30</th>
<th>kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of the cages</td>
<td>7,240</td>
<td>m³</td>
</tr>
<tr>
<td>Maximum cage biomass at harvest</td>
<td>217,000</td>
<td>kg</td>
</tr>
<tr>
<td>Number of submersible cages</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Water depth</td>
<td>50-70</td>
<td>m</td>
</tr>
<tr>
<td>Distance from the coast</td>
<td>5-8</td>
<td>Km</td>
</tr>
</tbody>
</table>
### TRL 9 Commercial Malta

- **Aim:** Commercialisation
- **Comprises of:**
  - Albatern: 2 x (96) x Series 6 (7.5kW) plus Hybrid Plant (720kW rated capacity)
  - Aquaculture: Target Output 6,000MT per annum – 500MT/Mnth, 48 Cages of 7,240m³ each
- **Footprint:** Cages 34,560m², TL- 270,000m², WaveNet 48,000m²
- **Located:** 5km to 8km South-East of Malta Mainland
- **Water depth:** 50m to 70m
- **Fabricated at:**
  - WaveNet & Hybrid Plant: Albatern and ex Scotland
  - Aquaculture cages: Subflex - Gili Ocean Technology Ltd.
- **Brought to location by:**
  - WaveNet & Hybrid Plant: Albatern & Shipping Agent
  - Aquaculture cages: Aquabiotech & Shipping Agent
- **Installed using:**
  - Albatern: Aquabt/Albatern/Marine Contractor
  - Cages: Aquabt/Cage Manufacturer/Marine Contractor
- **Cable to Service Vessel:** 720kW
- **Array/Hybrid & Diesel Back-Up & Grid-Tied:** 720kW & 720kW
- **Moorings:**
  - WaveNet: Albatern/Marine Contractor
  - Cages: Aquabt/Gili Ocean Tech. Ltd./Marine Contractor
- **O/M and Access:**
  - WaveNet & Hybrid Plant: Albatern/Aquabiotech
  - Cages: Aquabiotech
- **Target deployment in:**
  - Albatern: 2019
  - Cages: 2019

AquaBioTech is interacting with a commercial partner/client who wishes to establish their own fish production to ensure the continuous supply of fresh fish to the international retail and wholesale chains owned by the client. The primary interest is to establish a full cycle production fish farm in Malta by using the latest technologies to ensure the sustainability of all elements of the production process. The planned production goal at the start of the project is around 6000 tonnes of Sea bass (Dicentrarchus labrax), Sea bream (Sparus aurata) and Meagre (Argyrosomus regius). The proposed investment includes a land based hatchery, fish processing facility and storage site, a nearshore
nursery and harvest transfer site, and an offshore on-growing production site. To ensure the energy supply of the production sites and the land based operations, the application of an Albatern Ltd. wave energy generation network is being investigated.

With the exception of the hatchery site and higher level of processing that are largely sensible due to the large initial scale, much of the characteristics of this operation will be identical to that of the Maribe Concept Farm.

1.2.3.1 Facts and Figures at a Glance

The production plan at the beginning is to harvest 100 tons of fish weekly.

❖ Logistical and supply support as well as primary processing (gutting and packaging for transport on ice) will be carried out in the land based unit.
❖ Land based hatchery and nursery to provide fry and vaccinated fingerlings to the sea-based operations.
❖ Establishment of three main marine cage units; coastal nursery cages (20g to 60g), off the coast transfer cages to store the harvested fish, and submersible offshore cages for production of market sized fish.
❖ Energy needs of the farm operation (roughly 720kW peak load) and for the land based processing and logistics (roughly 720kW continuous load) will be supported by wave energy generation by WaveNET arrays, ideally grid linked with two-way metering.
❖ Energy needs for offshore operations to be provided by a “hybrid” power plant utilising wave energy generation as a power source, as well as storage and backup diesel power generation as required and mirroring current backup arrangements.

1.2.3.2 Proposed Sites Selected

The basis of the client’s interest in developing a site in Malta is that there is an offshore site available that can be quickly developed at a size that creates economies-of-scale that make the operation viable. That said, the offshore site is unproven for the farming of seabream and seabass and lessons learnt from the tuna penning industry suggest that there may be a number of technical and operational challenges ahead. Assuming that these are overcome the requirements for a near-shore facility and a suitable land base cannot be underestimated.

a. Logistic centre and fish processing unit

Finding the right land-base is an important exercise as this can have a direct and significant impact on the capital and operational cost of the entire operation. The onshore facility will be the main base of operations for all of the staff, as well as the logistics hub for the entire operation. Its proximity to the sea is critically important, and the facility also needs to be close to main roads and infrastructure so as to facilitate transportation in and out, as well as the movement of personnel. Size is largely dependent on the targeted final production and level of vertical integration (in-house hatchery, consumable storage and fish processing).
In this case the land base needs to be quite large so as to facilitate the storage of six weeks supply of feed, which at an FCR of 1.2:1 and production target of 6,000 metric tonnes is expected to breach 800 metric tonnes. The harvest and processing facility will also be housed on the same site and will require the physical harvest receiving facility as well as production capacity for ice of roughly double that of the weight of fish to be harvested; initially 900 to 1,000 metric tonnes of different types of ice per month in this case. This temperature controlled facility will sort, automatically grade and pack the fish into boxes for export. With an anticipated ten shipments per week leaving the facility during peak seasonal demands and four (4) shipments as the norm, the facility will require a large number of full-time and part-time staff.

It is envisaged that the construction of a larger and slightly longer jetty will be required as part of the operational platform, however, given the existing structure, an extension is not considered as anything significant in terms of facility change of use or localised impacts.

b. Hatchery Facilities

As the heart of the fish farming operation, the requirement for a localised hatchery is logistically essential as well as making business sense for several reasons, including but not limited to:

❖ The viability of importing over twenty million 2g fry per year is logistically problematic and very costly, resulting in a positive cost benefit scenario for having a localised hatchery.
❖ The localised hatchery would have the potential to supply the existing local production of the selected species and would therefore be a strategic development move for the developing business as well as the Sector and Government.
❖ Locally producing twenty to twenty-five million fry per year with brood-stock that will be developed over a six-year period of time will ensure that the project is as vertically integrated as possible whilst also ensuring a product with the highest possible localised production and efficiency.
❖ Fry supply is a major risk to the production business and hence, success of the business relies on the ability to ensure a secure supply of the stock fish.
❖ It is also the intention of the project developers to seek collaboration with the Government so as to work on various aquaculture, aquatic environmental and oceanographic related research to continually develop the industry and improve efficiency wherever possible.
❖ Diversification of the species produced is one key area the client is interested in and the hatchery facility would have a new species development area to provide for this. New species tend to fetch higher local prices due to the supply deficit and hence, can be seen as a combined strategy to mitigate price risk of existing commercialised species as well as for maximisation of profits from existing infrastructures. For these reasons it is likely local Government would also be supportive in following this development agenda.

Due to the high level of biosecurity and sensitivity of the hatchery it is generally good practise to keep this area of the business isolated from harvest fish operations. For the hatchery we envisage that this facility will cover some 10,000 – 12,000m², as well as an additional 2,000m² for storage, workshops and administration.
c. Nursery Facilities

The design, construction and start-up of the hatchery facilities will take several years of development until fully operational and stable. As such the nursery facility is where the process will start and should become the development priority for reasons including but not limited to:

❖ This is where we need to ensure that we make the greatest economic saving, whilst also ensuring the highest possible quality fish from the outset.
❖ Being able to import small fry from various European hatcheries and on-grow them at a land-based facility will ensure that there is a high degree of biosecurity in the process, as well as allow for the physical adaptation to local conditions.
❖ Most importantly, is to ensure that all of the fish are vaccinated before being placed at sea, thus maximising the fish's ability to withstand natural disease challenges and further reduce the potential requirement for treatment of fish at sea.

At this time, we envisage the nursery to require an area of around 20,000 – 22,000m² so as to be able to provide all of the fish required to stock the cages at a size where they have all been vaccinated before being released into the sea. Current indications suggest the most successful vaccination procedures for the selected species taking place at between 20g and 30g individual weight.

Finding a suitable site location has been a challenge as the hatchery and nursery require a large area that needs to be out of the way. The site has to be out of the way of the general public and all of the required developments will be concealed from public view, as well as protecting the site from the elements. Being close to the sea is a huge advantage and having been excavated down to sea-level may facilitate the successful drilling of marine boreholes known to be the choice water source for a hatchery due to biosecurity and water quality benefits. The proximity of the site to the sea also allows for ease of outflow water discharge post wastewater processing.

The hatchery and nursery facilities will be power intensive and hence, require a significant electrical network. Given the presence of the Reverse Osmosis plant nearby, which also requires a lot of electricity, it is likely that a distribution network of sufficient capacity already exists. The road infrastructure is already in place and adequate, and the hatchery will not significantly increase the traffic loading. The close proximity of the site to the sea will also facilitate deployment of the WaveNet generators within a feasible distance to provide for some or all of the power, and which could be linked to the national grid with the proposed dual direction metering.

d. Nearshore Nursery & Transfer Cage Sites

The requirement for a nearshore site is considered of utmost importance to the project and without it we would consider the offshore operations to be far less un-viable. The key reasons for this can be summarised as follows:

❖ The exposed nature of the offshore site poses certain technical challenges that can in part be overcome with the very latest cage farming technology for larger fish. Despite this the operational and commercial requirements for small fingerlings remains a challenge and will required the higher level of stability and control of the inshore site.
❖ The need to be able to transfer fish to and from offshore cages, which can only be done when conditions are good requires a large amount of fish to be moved at once. This is not feasible without the transfer cages and protected site.

❖ Harvesting of market ready fish multiple times per week throughout the year so as the ensure continuity in supply for the supermarket chains is paramount. Doing this at a high frequency from an unprotected site is not feasible. A nearshore site enables harvest size fish to be brought closer to shore in a less exposed area that would then enable the fish to be harvested as required.

❖ The placement of small fish in the water from a hatchery/nursery is a process that requires close management of the sensitive fish to minimise risks and losses.

❖ The placement of small fish directly into an offshore cage operation is not deemed to be viable for various reasons, including feed fed to the smaller fish is relatively small compared to the grow-out site and requires more stable conditions and closer management to ensure efficient uptake, and there will be the requirement to vaccinate fish.

❖ The creation of a nearshore site that will effectively act as an acclimation and transition site will mitigate these management risks.

The 20g to 30g fish fry from the land based nursery will be stocked in cylindrical HDPE cages and raised up to 50g to 60g size at the near-shore site before being acclimated during transfer to the offshore cages. The targeted production site will be in a bay, in a distance of 500 m from the Logistic centre and fish processing unit. The maximum biomass of the cages should be kept below 14 kg/m³ for the juveniles and below 20kg/m³ for the market ready stock. Selection criteria for the cages as follows:

<table>
<thead>
<tr>
<th>Cage depth</th>
<th>8 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cage diameter</td>
<td>10 m</td>
</tr>
<tr>
<td>Cage volume</td>
<td>628 m³</td>
</tr>
<tr>
<td>Cage biomass</td>
<td>8,792 kg</td>
</tr>
<tr>
<td>Number of cages</td>
<td>20 cages in two 2x5 cages modules</td>
</tr>
<tr>
<td>Distance between cages in a module</td>
<td>2m</td>
</tr>
<tr>
<td>Surface area of the nursery cages</td>
<td>1,508 m² for each module (2 modules)</td>
</tr>
<tr>
<td>Water depth</td>
<td>15 m</td>
</tr>
<tr>
<td>Mooring distance of the module</td>
<td>60 m</td>
</tr>
<tr>
<td>Surface footprint with mooring</td>
<td>10,148 m² for each module (2 modules)</td>
</tr>
</tbody>
</table>

An assessment of the requirements of a nearshore site have been more complex as we are very much aware that this will be one of the most critical stages in the production cycle, and has some of the largest hurdles to overcome in terms of bringing this entire project to fruition. In seeking ways to develop the project quickly, yet within the established planning and development requirements of Malta, one must think out-of-the-box to develop a creative development plan that will satisfy all parties concerned. In consultation with Tristan Camilleri, Director of Aquaculture, Department of
Fisheries and Aquaculture, we believe that the project can start by utilising two (2) existing sites that are already licenced fish farming areas. The first is the area inside the Qajjenza Bay where there are already a number of cages using the government owned licence. This site can be useful in the first year, potentially two (2) years of the project until the nursery project is established, thus enabling larger fish to be placed into larger cages at the near-shore transition site.

Figure 11: Proposed Site in Qajjenza Bay

The second site is the fish farming site formerly utilised by Fish and Fish Limited in Xrobb l-Għagin, limits of Marsaxlokk. It is our understanding that this site was a well-functioning cage fish farm site but the farm was required to move offshore as the carrying capacity of the site was exceeded by the type of operation that was being performed. The utilisation of the site by our client does not, in our opinion, conflict with this previous action as we can prove that the way that we will utilise the site will ensure that the biomass maintained on the site is significantly lower than before and that the feeding levels and corresponding nutrient discharges would also be significantly lower.

e. Off the Coast Transfer Cages

The main function of this unit to store the fish harvested from the offshore cages to ensure a continuous and balanced supply of the fish processing and packaging. The fish at the 350-400 g size will be harvested and transferred to these cages where only minimal feeding rate will be applied. The distance of the planned site from the coast is 1 km while from the planned processing and logistic facility is around 4 km in a straight line. The maximum fish density should ideally be kept below 20 kg/m³. This may be exceeded for the first day or two since fish will immediately be harvested, reducing the density.

<table>
<thead>
<tr>
<th>Cage depth</th>
<th>15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cage diameter</td>
<td>20m</td>
</tr>
<tr>
<td>Cage volume</td>
<td>4,710m³</td>
</tr>
<tr>
<td>Cage biomass</td>
<td>100,000kg</td>
</tr>
<tr>
<td>Number of cages</td>
<td>6 cages in a 2x3 module</td>
</tr>
<tr>
<td>Distance between cages in a group</td>
<td>5m</td>
</tr>
<tr>
<td>Surface area of the transfer cages with safety area</td>
<td>4,400m²</td>
</tr>
</tbody>
</table>
The offshore farm will require one or two production sites that collectively have the capability to produce a starting production of 6,000 MT, and able to accommodate increases in output to between 9,000 MT and 12,000 MT per year, developed over five years. At this stage of the project planning and after an in depth investigation into the offshore cage technology available it is believed that the Subflex cages will be best suited due to their proven suitability to Mediterranean conditions, single point mooring system supporting several cages and ease/efficiency of operation management. Due to the lack of sufficient environmental data from the proposed final production area, the cage technology is not yet fixed, however indications as to the cage requirements are as follows:

- **Planned maximum fish stocking density**: 30kg/m$^3$
- **Maximum cage biomass at harvest**: 217,000kg
- **Volume of the Cages**: >7,240m$^3$
- **Number of submersible cages**: 48
- **Water depth**: 50-70m
- **Distance from the coast**: 5-8km
- **Footprint of Cage Pod**: 270,000m$^2$
- **Footprint of WEC**: 48,000m$^2$
- **Total surface area occupied by the farm**: 318,000m$^2$

The offshore site that has been indicated through documents provided by MIMCOL is, in principle, acceptable, but the absence of certain environmental data is concerning. Knowledge of the water currents and other environmental data in the area is limited and we would require such information so that suitable technology can be sourced for the site, as well as enabling us to accurately model the impact of the oceanographic conditions.
Table 1. Roadmap to commercialisation.

<table>
<thead>
<tr>
<th>Level</th>
<th>Year of Implementation</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL6</td>
<td>Mingary Bay, Scotland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRL7</td>
<td>Malta TRL7 Pilot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRL9</td>
<td>Malta Commercial Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRL10</td>
<td>Ready for Market</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.2.3.4 Other technical project details

In the commercialisation phase of the project we aim to install 2 full grids of 96 x Series 6 Energy Grids (Wavenet Squid units). One grid to provide power for the Offshore Cage Installations. This Grid will be linked to the specially designed and constructed feed barge housing the hybrid system’s (batteries as ballast). We aim to have Several WaveNet units altered for potable drinking water production (still under development) for the operational staff on site.

The second grid will be positioned on the more energetic side of the Island and will provide grid linked power for the land-based facilities. Should the second grid-linked system show success, it is anticipated there will be significant funding in place from both commercial partners and the local power (and Water) authorities to install much larger arrays (up to 30 times bigger) to assist Malta to reach their 2020 Renewable Energy ratio target of 10%, and to improve the water limitations for the Island.
We foresee various aspects of this project requiring specific development of various componentry which we hope to be part of the following research calls. We believe it is possible to combine the Sea Space use with three end products – Fish, Potable Water and Renewable Electricity.

1.2.4 Advantage of combination

1 General for both sectors

❖ Cost savings on Delivery, Storage, Installation and Commissioning, O/M due to shared vessels,
❖ Cost savings on Technical Support Team and Overhead: (Skippers, engineers, workshop, maintenance, Support/Operational base facilities, Moorings, Key Executives (CEO, MD admin staff)

2 Aquaculture

❖ Cost savings on energy due to energy supplied by sustainable power from on site wave resource.
❖ Increases sustainability of operations and reduces additional logistics costs and challenges of transporting and handling diesel fuel in rougher waters offshore.,
❖ Wave farm to provide protection from rough seas - calmer waters for aquaculture farm,
❖ Enables aquaculture farm to be further offshore where clean nutrient rich water exists, higher stocking densities due to the depth and limited environmental impact.
❖ Vastly increases aquaculture production capacity and wider species farmed in Mediterranean,
❖ Farm serviced by wave-energy has marketing edge of renewably powered farm produce with sustainable margin at least in the medium term.

3 Wave

❖ Guaranteed sale of electricity to aquaculture customer.
❖ Low electrical losses and cabling costs due to proximity of customer.

Electricity provision for onshore enterprises and national grids in constrained grid environment with high power costs enabling earlier parity achievement
### 1.3 Business section

#### 1.3.1 Competition

Table 2. Key Competitors.

<table>
<thead>
<tr>
<th>Competitor</th>
<th>Key Differentiators</th>
<th>Competitive Threat Rating (1-5)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resen Wave</td>
<td>Resen Wave is developing a range of units at sizes from 0.3kW to 5kW designed to provide power from waves for offshore applications. Units can be deployed in a modular way. Power outputs generally lower than required in aquaculture sites.</td>
<td>4</td>
</tr>
<tr>
<td>Polygen</td>
<td>Resen Wave is developing a range of units at sizes from 0.3kW to 5kW designed to provide power from waves for offshore applications. Units can be deployed in a modular way. Power outputs generally lower than required in aquaculture sites.</td>
<td>3</td>
</tr>
<tr>
<td>AWS Ocean Energy</td>
<td>AWS have tested a half scale AWS-3 wave power generator with the intention of developing it for various applications, including offshore fish farms. Testing has taken place at Lyness in Orkney. The AWS-3 device uses a diaphragm to capture wave power which turns it into pressurised air that turbines can use to turn into electricity.</td>
<td>2</td>
</tr>
<tr>
<td>Resolute Marine</td>
<td>Resolute Marine Energy are attempting to build smaller-scale WEC's (1-50kW) and using them in commercial applications including aquaculture. Prototype testing was undertaken combining the AirWEC device with the Aquapod aquaculture system. Resolute's flap device requires a shallow water location rendering it unsuitable for offshore use and less applicable to Malta's deep water shore in target locations</td>
<td>2</td>
</tr>
<tr>
<td>InnovaSea (formerly Oceanspar and Ocean Farm Technologies) (USA)</td>
<td>Submersible cages and designed for offshore. Leaders in offshore cages culture in the Americas. Also working on a total offshore package. ABTG in comms with them and can use their systems instead of Subflex</td>
<td>4</td>
</tr>
</tbody>
</table>
1.3.2 Business Model

Albatern and ABT will create a Special Purpose Vehicle (SPV). This SPV will be tasked with supplying wave energy enabled fish farms to potential customers such as aquaculture operators. The SPV will sell wave energy arrays as part of overall offshore, nearshore and onshore site solutions to aquaculture operators. This business model would see the wave energy array forming part of the overall package for an offshore site along with cages, nets, moorings, feed barge, comms equipment, workboats etc. Along with sales, the SPV will offer customers operation and maintenance services as part of the overall package. The following business model canvas is based on this:

Table 3: Business Model Canvas Building Blocks

<table>
<thead>
<tr>
<th>1. Customer Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Marine Harvest are a PPA customer; Pisciculture Marine de Malte (P2M), Scottish Salmon Company, Scottish Sea Farms, Cooke Aquaculture, New Zealand salmon farmers, Chilean salmon farmers, and Canadian salmon farmers are also potential customers.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Value Proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>● The combination of both sectors will result in a one stop shop for wave energy enabled farms.</td>
</tr>
<tr>
<td>● The combination of activities could potentially be more beneficial in terms of licensing, with 1 application rather than 2.</td>
</tr>
<tr>
<td>● The SPV will provide full installation services and activity.</td>
</tr>
<tr>
<td>● Electricity generated by the wave energy devices will initially supplement and then replace the electricity requirements of the fish farm operation and reduce OPEX for aquaculture operators.</td>
</tr>
</tbody>
</table>

| 3. Channels |
| 4. Customer Relationships |
|● Maintaining long-term customer relationships will be important for growth |
- Sales of the combined fish farm and wave energy device will be directly to the end buyer.
  - The combination offering will be marketed at trade shows, industry events, conferences, etc.
  - The combination device can be transported to the final location using already established transports methods, road, rail, ship.

- Opportunity to build on Albatern and ABT already established customer relationships
  - Customer Relationships will be highly personal (first name basis) as a high value product being offered in a niche market.

### 5. Revenue Streams
- The main revenue stream is from the sale of wave energy enabled fish farms to potential customers.
- A smaller revenue stream will come from the provision of operation & maintenance activities.

### 6. Key Resources
- Knowledge and expertise
- Manufacture and assembly location
- Operation & maintenance resources such as vessels, equipment and personal
- Already established relationship with customers

### 7. Key Activities
- Research support and product Development
- Manufacturing and assembling wave energy enabled fish farms
- Installation of wave energy enabled fish farms
- Provide Operation and Maintenance Services

### 8. Key Partners
- Marine Harvest, Pisciculture Marine (Customers)
- Subflex and InnovaSea (Fish Cage Supplier)
- ABT Environmental (Environmental)
- Scottish Enterprise (Investment)
- Dept. Energy & Climate (Governmental)
- Hvalpsund (Support Vessels)

### 9. Cost Structure
- Research and Development (Minimal)
- Provision of device manufacture and assembly
- Running of Operation and Maintenance Services provided to customers
1.4  Management Section

1.4.1  Management team and company organisational structure

The SPV will be formalised once there is tangible evidence that the concept is viable. This is considered to be on installation of the Malta Pilot Facility. At this point in time the key individuals involved will become directors of the SPV and a dedicated Operations Manager/Director appointed to manage the newly created vehicle. Key directors will therefore likely be Mr Shane Hunter (ABTG) and Mr David Campbell (Albatern) with one other key officer from each company elected to fulfil the Chief Financial Officer and Technical Director Roles foreseen as a requirement to ensure effective management of the SPV.

The main operational responsibility will be held by the Operations Director whose core role will be to coordinate the supply of technologies from each of the existing companies to ensure effective delivery of a combined package.

Figure 13: Management structure
1.5 Market Section: Market Share from 2020 until 2040

1.5.1 Market Analysis

In Europe there is a limitation on the amount of available coastal and off coastal sites available for aquaculture activities. Farmers are also seeing better fish growth in more active wave sites. This is encouraging the industry to move offshore and it is expected that the majority of new sites will be offshore. One of the natural progressions of such a move is to explore the use of wave energy within the offshore region to power aquaculture activities. The main market will be Mediterranean finfish aquaculture where the move of aquaculture offshore is expected. The main product of this sector is sea bass with largest producers Greece, Turkey, Spain and Italy. Of the expected growth in aquaculture production over the coming years, it is assumed that there will be a 10% increase in the number of companies resulting in 79 new production licences. These new producers require the latest technology and represent a potential market, especially in regions of Italy where production is expected to increase by 150%. Using the conservative calculation that only 20% of the recent aquaculture producers will establish at least 1 new site, this gives 158 potential new marine cage fish production sites until 2040. There is also evidence of similar rates of growth in Scotland, New Zealand, Pacific Canada and potentially Ireland.

![Market Share from 2020 until 2040](image)

Figure 14: Market Analysis: Devices

1.5.2 List of investors and sources of funding

1.5.2.1 Investors and funding to date

❖ Albatern received approx. £1.7m of private investment with £400k so far of public matched equity
❖ Scottish R&D grants of £800k

1.5.2.2 Grants funds required and potential sources
❖ Wave Energy projects in general:
➢ European Regional Development Fund (ERDF) can provide grants for renewable energy investment funding in the Priority Axis 4: Shifting towards a low-carbon economy (Total Budget in Malta: €57 million)
➢ Horizon 2020 Blue Growth programme
❖ Aquaculture projects in general:
➢ EMFF aquaculture investment grants in the Mediterranean including Malta, where the total (EU+National) funding for the whole period is €3,306,822 which can provide maximum 50% of the CAPEX.
❖ Pilot:
➢ Funding will be needed equivalent to the CAPEX of the wave device of €1.3 million.
➢ The project’s aquaculture component is of a scale that is economically feasible stand alone, and there are still some questions regarding to the WEC that can only be answered through a Pilot to finalise the performance, readiness and risk profile. As such it is unlikely that a private or institutional funder would approve the financing of the WEC aspect as a direct capex ownership purchase.
➢ To mitigate this it will require funding the WECs externally to bridge this development gap.
1.6 Risk section
1.7.1 Commercial Risk Analysis
1.7.1.1 Hazards description


❖ Hazards were colour coded (risk matrix 1-25) depending on risk magnitude revealing

➢ 21 High (red),
➢ 33 Medium (orange) and
➢ 32 Low (green).

❖ Issues and causes described for each hazard, including the effect (+/-) of multiple industry and technology co-location.

❖ A ranking (1-5) used to quantify Consequence and Likelihood with resultant risk magnitude for each hazard.

❖ Risk response strategy proposed and residual risk magnitude quantified for each hazard.

![Risk Before Mitigation](image)

**Figure 9: Hazards before mitigation**

1.7.1.2 High risk (red) hazards identified pre/post mitigation

**Table 11: Identified Hazards**
<table>
<thead>
<tr>
<th>Hazard Category</th>
<th>Issue</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Operation</td>
<td>Pre-construction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site Problems and Licensing</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Insurance</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Operational</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Component/system failure less product output</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Component/system accidental damage</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pollution</td>
<td>2</td>
</tr>
<tr>
<td>2. Economic and Political</td>
<td>Public sector support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grants and subsidies</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Applied price forecast</td>
<td>1</td>
</tr>
<tr>
<td>3. Financial</td>
<td>Financial support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of investment</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Low yield</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Energy related annual yield issues</td>
<td></td>
</tr>
<tr>
<td>4. Environment</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>5. Socio-economics</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>6. Health and Safety</td>
<td>Personal Injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ergonomics</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Fire</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Personal Injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ports and Mobilisation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subsea Operations</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Working at Height</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>21</td>
</tr>
</tbody>
</table>

1.7.1.3 Commercial High Risk Response

**Operation (all stages)**

**Description:** The Operational risks account for approximately 38% of all red-category risks identified. “Site problems and licensing” issues relate to site compliance from environmental perspective, and granting of licence process as regulation and legislation may prove more complex than expected coupled to a prolonged process. Currently intensive aquaculture for finfish has a long licensing process (circa 6 months) with numerous environmental and biological studies needed to validate the site suitability. Adding to this the relatively unknown wave energy technology is likely to prolong the process and add further investigation requirements prior to approval being granted. In addition
granted license duration may be too short to guarantee safe return on investment and discourage investors. These risks can result in higher costs and delays.

Insurance issues may be encountered due to the perceived increased complexity and unproven nature of technology combination resulting in over-cautious approach which could severely limit the scale of the aquaculture deployment. In addition, over-cautiousness on the potential impact from each industry to the other may result in prohibitively high insurance quotation. These risks can result in higher costs, delays and even project failure since investors will not wish to trigger the development without sufficient insurance in place or if the costs are prohibitive.

Risk response: Risk avoidance strategy will include identification of other site options, promotion of results from the current pathfinder project underway supporting increases in confidence levels of insurers as well as deploying aquaculture first with wave energy generation to be added later in the development once the facility is seen as secure.

WEC licensing may require having adaptive management procedures in place to avoid conflict with the aquaculture site (Installing WECs a distance away from the cages). Additional specialist wave energy studies and forecasts for the chosen environmental will be undertaken to ensure suitability and feasibility of the devices prior to triggering the addition of the renewable energy generators to the overall capex list, validating the technology. There is vast support from the Maltese authorities for WECs as a potential energy supplier to the island as well as for the offshore aquaculture industry as GDP and employment contributor to the Island’s economy, giving the development a priority status to mitigate against delays associated with a prolonged licensing process which would otherwise likely fall within a normal lengthy statutory timeframe.

Working closely with licensing authorities and investment community will help overcome the risk of limited license duration for aquaculture activities as in order to meet requirements for investment and ensure a healthy return aquaculture operations need to be able to run beyond a 15-year period.

Existing experience on insurance may cover the combination purely resulting from the already employed pilot tests carried out and from the pathfinder now underway. Despite this it is new and unique and as such insurance risk status will be very high. This can only be tackled by liaising closely with the insurance industry from the early planning stages of the commercial deployment and positive results from the pathfinder strengthening the case for the combination. This will ensure that both sectors’ requirements are fully understood and appropriately addressed.

Description: At operational stage the biggest risks are associated with equipment or system failure, accidental damage and pollution, the latter of which could be devastating to the projects and business as a whole. Equipment and system failure would be largely related to damage resulting from lack of sufficient engineering to be able to cope with the environment.

Component failures are likely to present themselves during extreme weather conditions (e.g. mooring failure). This could be a significant risk to the nearby aquaculture farm components with wave farm structures colliding with and damaging cages for example, releasing valuable stock.

Bad weather may also increase downtime and shorten maintenance time windows. The consequence of the above risks is losses and/or less revenue generated, redesign efforts, higher costs and project
failure if not addressed appropriately or so significant in so as to render the project uninsurable or bankrupt.

**Risk response:** Extensive testing will be undertaken at component and system level considering presence of aquaculture type activities and possible adverse effects (e.g. accelerated corrosion), determining safe distance between the two operations. Knowledge and experience from the pilots and pathfinder projects. Installing the WECs a distance away from the cages and using proven cage technologies that can be submersed in extreme conditions.

Moorings extensive testing and fail-safe solutions by the aquaculture and wave farm will reduce the risks associated with this particular issue which could pose a collision.

Mitigation against environment broad pollution is difficult but the use of submersible cages could allow sufficient time for surface based pollutants to blow over or be swept away with currents. Insurance against this event would prevent the business collapse.

**Economic and Political**

**Description:** Increased delays in the approval process for required grants and subsidies for the rollout of the project may result in loss of investor confidence and removal of supportive funding.

**Risk response:** The need for renewable energy sector growth will negate the risk of removal or phase-out of subsidies.

If WaveNet experiences problems in funding this will not prevent the aquaculture component from going ahead. Alternative power sources can if necessary be deployed (diesel generator, solar PV, floating wind etc.)

**Description:** Potential issues identified under “public sector support” and “competition” subcategories. Grants and subsidies issues could arise from change in policy direction and appetite for renewables, conditions of Feed-in-Tarif eligibility criteria (inc. value and period) could affect the financial projections for the wave farm. The financial modelling results could also be affected from other factors including sensitivity analysis, exposure to market risk, long-term price forecast and divergence in the expectations for power prices. For aquaculture, variations in consumer preferences, potential major disease outbreak, improvement of capture fisheries productivity and effect of climate change could affect product demand and pricing. This could result in less revenue generated affecting rates of return on capital investment.

Other factors in relation to issues around market entry or space utilisation due to intense competition including against established sectors such as shipping and fisheries vs offshore aquaculture and wave energy installations. The above risks could ultimately result in higher costs and/or lower revenue generated.

**Risk response:** Accepting the above risks will include careful monitoring for possible escalations. The current trend dictates that the renewable energy sectors (including ocean energy) need to grow if national governments are to meet obligations around emissions (mitigate climate change), security of energy supply and energy cost reduction, as well as renewable energy target commitments. Therefore,
it is expected that the need for growth will negate the risk of removal or phase-out of subsidies. The Paris Climate Agreement has targets to combat climate change by carbon reduction which can only be met by reducing fossil fuels and increasing renewables.

The aquaculture sector including offshore aquaculture is expected to grow significantly in order to meet the global demand for protein source to satisfy fast growing global population. It is projected that by 2030 aquaculture will overtake fisheries and cover over 60% of global total fish demand as projected by FAO.

Financial

Description: “Financial support” related potential issues were identified as very acute risk to the business with all 5 direct risks being seen as high and fundamentally of major consequence and resulting in failure of the business to begin or continue due to lack of (or removal of) investment which could be triggered due to a number of possible causes:

- many wait-and-see investors who do not invest due to risk of losing development costs and due to little benchmark data
- Lack of experience with or knowledge of may discourage key investors
- finance instruments related problems
- poor lending appetite from banks due to low economic climate
- lender fail to comply with financial legislation/regulation (Basel III, Solvency II)

Risk response: In the absence of benchmark data, clearly demonstrable results from studies undertaken during pre-commercial TRL stages validated during early pilots and commercial deployments. Flexibility to form Special Purpose Vehicle with partner/investor organisations will reduce financial risk exposure.

Results from “Pathfinder” projects and well recognised partners like Marine Harvest will be key in mitigating these risks. Market/PR efforts targeted at key public and private investor forums will also have a positive impact.

HEALTH & SAFETY

Description: Red risk identified under several subcategories which could lead to personal injury including:

- Ergonomics (difficult to construct design; moving around system: slips, trips and falls; restricted movement: lack of space to access components; lifting: hoisting parts and tools into position)
- Fire Risk (fume inhalation, indirect injury during escape or direct acute burn injuries from on-board fires relating mainly to the presence of fuels on board the service vessels)
- Ports and Mobilisation (vessel movements: collision; port operations: material handling, refuelling, waste disposal; unsuitable facilities: quayside loading limits)
- Subsea Operations (entrapment, falling objects, decompression sickness, use of tools underwater)
- Working at Height (falls, dropped objects)

Risk response:
● Ergonomics
  ○ Rigorous safety plan for fabrication and construction which must be adhered to including preliminary safety plan including risk analysis from all designers.
  ○ Fully resourced, site specific construction safety plan including programme for the works
    ○ Independent onsite safety team with marine safety experience
    ○ Regular independent equipment inspections
● Fire
  ○ Properly positioned and serviced fire-extinguishers with heat sensors
  ○ Rigorous fire safety plan
  ○ Regular preventative maintenance plan
● Ports and Mobilisation
  ○ Port traffic management plan enforced by harbour master.
  ○ Adequate site safety plan
  ○ In-port medical facility including medical helicopter for emergency evacuation
  ○ Warning notices re loading limits clearly visible and communicated
● Subsea Operations
  ○ Minor requirement for divers to be met using fully certified, reputable dive company with accident free track record are used.
    ○ Ensure this company produces and complies with high level safety plan for the work being undertaken
    ○ Ensure access to emergency services and decompression chambers etc.
● Working at Height
  ○ All work to take account of the principles of prevention in relation to working at height. Risks to be taken account of and mitigated against in safety plan for the project.
    ○ All workers to undergo certified working at height training.
    ○ Safety cages to be installed around all ladders
    ○ Fall arrest systems (harness etc.) to be employed in all risk areas.

1.7.2 Pilot Risk Analysis
1.7.2.1 Pilot High Risk Response
As with the commercial scale case study, in the pilot stages key high risk areas are predominantly taken up largely by the operational and financial aspects of the project with the escalation of risks in areas of performance and durability (system breakdown) that one would anticipate to be more likely at this stage of the development. All of these significant and potentially devastating risks for the project can be mitigated by increased efforts in the preparation for the different stages of the project to ensure a higher level of confidence that the risks are mitigated or the likelihood diminished to an acceptable level.

The Operational risks account for approximately 38% and financial 29% of all red-category risks identified effectively two thirds of all identified risks. “Site problems and licensing” issues relate to site compliance from environmental perspective, and granting of licence process as regulation and
legislation may prove more complex than expected coupled to a prolonged process. Adding to this the relatively unknown wave energy technology is likely to prolong the licensing process and add further investigation requirements prior to approval being granted. These risks can ultimately result in higher costs and delays.

Insurance issues may be encountered due to the perceived increased complexity and unproven nature of technology combination resulting in over-cautious approach which could severely limit the scale of the aquaculture deployment. In addition, over-cautiousness on the potential impact from each industry to the other may result in prohibitively high insurance quotation.

Component failures are likely to present themselves during extreme weather conditions (e.g. mooring failure). This could be a significant risk to the nearby aquaculture farm components with wave farm structures colliding with and damaging cages for example, releasing valuable stock. Bad weather may also increase downtime and shorten maintenance time windows. The consequence of the above risks is losses and/or less revenue generated, redesign efforts, higher costs and project failure if not addressed appropriately or so significant in so as to render the project uninsurable or bankrupt.

The risk avoidance strategy will therefore include identification of other site options, promotion of results from the current pathfinder project(s) increasing confidence levels, as well as installing WECs a distance away from the cages, and undergoing additional specialist wave energy studies and forecasts for the chosen environmental conditions.

Working closely with wave energy specialists, the licensing authorities and the investment community will help overcome many of these risks.