Transforming UK offshore marine algae biomass production
Phase 1 Report - February 2022

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1. Executive summary

Seaweed is among the fastest growing sources of biomass on Earth. Farmed offshore, seaweed needs no power, fresh water, fertiliser, pesticides or land to grow on, eliminating reliance on valuable resources that are required for terrestrial food crops. It benefits the marine environment by supplying a variety of ecosystem services - oxygenating seawater, removing excess nutrients and providing a habitat for marine life. Seaweed stores 2-3 times more carbon from the atmosphere than woodland, constituting a powerful tool towards the UK's net zero targets. However, the current state of the art in seaweed farming is a longline based method. This approach limits biomass production because it is expensive, time consuming, labour-intensive and failure-prone, especially in offshore waters.

Scarborough-based SeaGrown operates the UK's first offshore seaweed farm in the North Sea off the Yorkshire Coast. During Phase 1 SeaGrown designed an innovative, automated end-to-end seaweed farming system known as the Fully Automated, Transportable, Holistic Offshore Macroalgae System (FATHOMS). FATHOMS addresses the problems arising during longline seaweed farming, increasing the efficiency of seeding, line deployment and harvesting using custom-designed deck machinery tailored to handle an innovative growing rig in the water. This innovation will open up the seaweed industry to year-round production, open-water sites and greater assurance of optimal biomass yields. Phase 1 results projected that FATHOMS has the potential to achieve > 45% saving in capital costs and >60% saving in running costs over the longline method for operation of a 40,000m offshore seaweed farm.

This transformational change from cottage industry to a major source of sustainable bulk biomass from the ocean will position the UK to lead the way in European seaweed farming and to develop a nationwide Blue Carbon capability. The team is ideally placed to deliver this project. SeaGrown works successfully in the offshore environment, operates its own seaweed farming vessels with experienced crew, seaweed hatchery and licensed offshore area. The team also includes experts in hydraulic engineering, marine offshore engineering, marine seaweed hatcheries, management of complex marine projects and commercialisation

2. Proposed innovation

BACKGROUND:

Aquaculture is identified in UK Blue Growth policies as a strategic sector and priority industry requiring rapid innovation and disruptive advancement. Despite this, the wider industry remains nascent. Through this project SeaGrown aims to disruptively innovate seaweed aquaculture, leading to a step change in UK output.

In the UK, scientific and small-scale seaweed farming has been trialled in calm sheltered waters such as sea lochs. This inshore cultivation draws on the approach used in mussel farming infrastructure - growing seaweed on parallel longlines. There are two main barriers to scaling up the biomass that can be grown on longlines in inshore areas (a) nutrient limitation and thermal stress limits the seaweed growing season (b) spatial competition for aquaculture developments in sheltered bays, lochs and estuaries has now reached saturation, limiting expansion. These restrictions drive the need for offshore expansion, however longline aquaculture is not viable at offshore sites. First, longline infrastructure does not cope well with strong current and wave conditions in offshore settings. Second, the current longline cultivation approach is not deemed financially viable at scale - it is capital intensive, requires extended hatchery incubation times, and is inefficient to deploy and recover. Furthermore, the footprint required for seaweed longlines makes them difficult to co-locate with other marine activity.

With innovation, offshore cultivation can circumvent many of these problems and dramatically upscale biomass production because seaweed thrives in high-energy open water environments, where strong currents and mixing replenish nutrients, maintaining cooler temperatures, and huge areas are available for cultivation. With this clear justification for moving towards offshore sites the challenge is creating infrastructure that can withstand the harsh environmental conditions at an economic level. Overcoming these barriers could unlock huge swathes of the UK EEZ, potentially also previously inaccessible areas such as offshore windfarms. This step change will transform the UK’s capability to produce marine biomass at volume to support industrial challenges including sustainable food and decarbonisation without the need to use any land.

SeaGrown is currently the only UK company engaged in offshore (as opposed to sheltered water) seaweed farming, holding the lease of a 25-hectare offshore cultivation site in the North Sea. Seagrown has already developed a pilot-scale seaweed farm, delivering the first offshore cultivated seaweed in Summer 2021. Simultaneously, SeaGrown has built an operational seaweed hatchery, which has capacity to produce substantial volumes of seed.

Notwithstanding this progress, SeaGrown has identified four fundamental bottlenecks to increasing biomass production to commercial scale: (a) streamlined and consistent production of seaweed seeds (b) capital costs for in-water rigging (c) efficient seeding and deployment of growing lines (d) efficient harvesting of cultivated seaweed. This project will remove these barriers, creating an integrated, mechanised system for rapid, consistent cultivation of bulk marine biomass.

Prior to Phase 1, SeaGrown adopted the longline method of seaweed farming. In this method, a strong backline rope is suspended horizontally at the required depth using a series of surface buoys with counterbalance weights and anchors at each end to hold the line in position. During deployment a thin, pre-seeded string is wound around a strong backline. This process is labour-intensive, from seeded string production in a hatchery through to deployment at sea and capital costs are also high. Additionally, since seeding in this manner requires extensive manual handling under load it can only be carried out in calm seas, restricting available sea-days and driving up costs and labour requirements.

In order to achieve industrial scale production and economic viability, seaweed farming must be mechanised, increasing speed, expanding the weather operating window, removing seasonality and allowing year-round operation.

DESCRIPTION OF THE INNOVATION:

During Phase 1 SeaGrown conducted extensive at-sea trialling of longline deployment and recovery, assessing the closest line spacing and examining efficiencies throughout the process. SeaGrown established that it was not feasible to work multiple, closely-spaced longlines in an offshore setting without adjacent lines interfering with their neighbours or affecting the safe operation of the workboat.

During Phase 1 SeaGrown designed an innovative new operating method which avoided the problems encountered with the highly restrictive longline method, allowing large amounts of seaweed line to be deployed quickly and safely. This new method showed great promise and will be developed further in Phase 2. We will also build and trial a prototype, fully mechanised seeding, harvesting and handling machine (FATHOMS) which was designed during Phase 1.

FATHOMS development will build on Phase 1 knowledge to commercialise offshore seaweed farming, offering improved capital costs, growing line density, labour costs and consistency.

QUANTIFIABLE METRICS OF THE INNOVATION:

Since 2018 SeaGrown have been developing and trialling innovative farming methods and systems tailored to the challenges of the North Sea’s offshore environment, securing and holding the UK’s only dedicated offshore seaweed farm licence at 25 hectares. Trials during Phase 1 (P1) using longline systems (the current industry standard in small-scale sheltered seaweed operations) have demonstrated that system to be inoperable in an offshore context.

In contrast, the FATHOMS prototype developed in P1 indicated a 46% capital saving and 62% running cost efficiencies in comparison to longlines. Economic modelling of the running costs forecast a break-even point on capital investment after one year.

Our Phase 2 (P2) proposal and requirement of scale, is to quantify and verify that these efficiencies are scalable and perform as expected at full farm scale and full two year harvesting cycle. As a prototype product we need to demonstrate predicted production and yield, and there are currently unknown influences on seaweed biomass which need to be tested in the field.

P1 allowed development and trialling of cost and labour efficiencies over 5 core operational areas of offshore seaweed farming. Scaling these efficiencies to project this impact over a full commercial-scale operation we estimate potential capital savings of 46% and running cost efficiencies of 62%. Operating at a reduced pilot scale our P1 assessment demonstrated efficiencies in each of the five core areas under assessment which we intend to use as quantified metrics of performance for P2:

i. At sea components

ii. Rigging

iii. Hatchery

iv. Offshore Deployment

v. Harvesting

SIGNIFICANCE OF INNOVATION:

The current UK seaweed market is addressing a supply need for artisan food products and simple cosmetics with minimal processing, with insufficient current production volumes to meet demand from industrial sectors such as pharmaceuticals and animal feeds, who instead rely on international imports or alternative source materials. The UKs current seaweed production is sourced predominantly from hand-harvested wild stock with very limited expansion potential, and increasing pressure for long-term phasing out.

Offshore seaweed aquaculture is an emergent industry with no dedicated operators within Europe and only a handful of single site demonstrators globally due to the significant challenges of operating in these extreme environments.

Van den Burg et al (2016) undertook a review of potential seaweed production and economics in the North Sea based on co-location potential with windfarms The study modelled an offshore scenario for a large 4,000 hectare farm. The authors concluded the model was not financially viable and would make an annual loss, proposing a need to produce 63T per hectare, or 252,000T p.a. at a price of $1747 per tonne to breakeven. Similarly, a multi-partner trial in Ireland assessed commercial scale propagation of seaweed in a hatchery followed by grow-out at a part-sheltered nearshore area. Based on their study results 4 economic case studies were modelled concluding a need for a yield price of £1.82 to £0.95 per kg to break even.

In our baseline assessment of seaweed farming economics and efficiency modelling, we have drawn similar conclusions to existing authors, including those above, that longline systems are not suitable for offshore applications, due to both the spatial footprint required, capital and running costs.

In contrast, given the combined capital and running savings demonstrated by the FATHOMS systems through evidenced performance in P1, we can demonstrate economic viability even whilst operating at conservative yield projections.

Given the multiple derivatives possible, achievable price points per harvest and by seaweed species vary significantly, with Capuzzo and Mckie (2016) producing informed estimates demonstrating a range from <£1/kg for fuels and animal feed, to >£2,000 for cosmeceuticals. The accessibility of these price points is dependent on species, seaweed quality, nutrient consistency and supply, which can all be more closely regulated and managed through aquaculture systems than wild harvests. Adam et al (2021) evidenced this further through a macroalgae bio-refining study, demonstrating a significant increase in labour costs with bio-fouled samples and lower key nutrient yields when seaweeds are harvested outside of peak condition.

Seaweed is well known to deliver a wide range of qualified environmental and societal benefits. One is the ability of seaweed to absorb huge amounts of carbon dioxide, absorbing over 70% of the world's carbon dioxide. Clearly this makes seaweed a potent but grossly underutilised method of sequestering carbon and seaweed farming at industrial scale could play a key part in achieving the Net Zero targets. Identified within a series of global blue carbon portfolios, seaweed has been recognised as an important new industry to contribute to Net Zero targets which has partially driven pump-prime investment strategies from a number of governments. In January 2022 the Chinese Ministry of Agriculture and Natural Resources supported the first authorised carbon credit trade for seaweed, trading 15,000T of credits for £1.33m. A number of countries, in particular across Asia, Europe and Australasia, are investigating carbon codes and quantification methods to allow the introduction of similar blue carbon credit schemes, paving the way for similar activity in the UK. A key study and comprehensive review of seaweed farming operations in a carbon context assessed and developed a series of key findings on seaweed potential in this market and concluded that expanding seaweed farming four-fold to cover 7.3 million km^2 would offset the entire global agricultural industry at present rates.

Overall, this innovation has the potential to put the UK at the forefront of the growing International Market for farmed seaweed, taking advantage of our huge Exclusive Economic Zone as well as exporting technology internationally.

INTEGRATION WITH SEPARATE INNOVATIONS:

In the context of the wider UK biomass supply chain and production, the positioning of FATHOMS and the seaweed market is huge in scope. The range of applications for seaweed is ever increasing - including cattle feed to reduce GHG emissions, biofuels, plastic alternatives and bio-complete agricultural fertilisers.

POSITIVE IMPACT ON UK BIOMASS FEEDSTOCKS:

The positive impact of commercialisation of FATHOMS on UK biomass production is significant. Projections show new production equivalent to a tripling of current UK seaweed wild-harvest production. Without use of restricted land space, and with no need for fertiliser or freshwater, FATHOMS represents an opportunity to catapult a versatile and previously untapped source of marine biomass to commercial viability. From this point it can be rolled out nationally and internationally to provide a wide range of societal, economic and environmental benefits and position the UK to lead the charge in the global seaweed farming revolution.

ENVIRONMENTAL BENEFITS:

Farmed offshore, seaweed needs no power, fresh water, fertiliser, pesticides or land to grow, eliminating reliance on resources essential for terrestrial food crops. It also benefits the marine environment by supplying a variety of ecosystem services - oxygenating seawater, removing excess nutrients and providing a habitat for marine life. The EU's Pegasus project concluded that large-scale macroalgae farming can reduce the effects of ocean acidification, as well as leading to notable increases in marine biodiversity in otherwise barren areas. Both of these factors would directly benefit the sustainability of the local fishing industry which is currently focussed on shellfish which are particularly susceptible to changing ocean acidity. With the potential for seaweed cultivation to be a part of the net zero solution given its rapid uptake of carbon, it is fully aligned with UN Sustainable Development Goals and supported by leading international conservation bodies such as the WWF.