

### Study Context-Hypothetical installation of SA into Hornsea Wind Farm

The United Kingdom (UK) does not possess Seaweed Aquaculture (SA) inside Wind Farms. A hypothetical scenario has been provided to illustrate features of SA based in a Wind Farm of the UK. The purpose of the hypothetical scenario is used to justify and establish a context for performing the qualitative integrative assessment- defining social and ecological variables and system boundaries (Hodgson *et al.*, 2019). The hypothetical scenario was produced using a background review and consultation with offshore SA stakeholders. Participants are asked to visualise the establishment and expansion of SA inside of Hornsea Projects 1 and 2 Wind Farms. The total size of the Seaweed farm has an upper boundary placed at 869.19 km<sup>2</sup> and cannot exceed this zone (Figure 1).

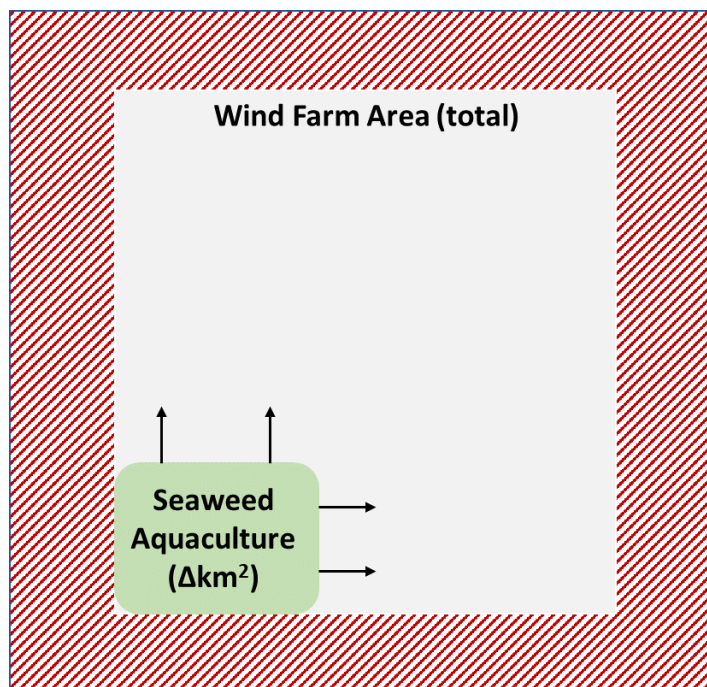


Figure 1- Schematic of hypothetical scenario illustrating SA expansion with upper boundaries (red zone).

The upper boundary is equal to the total area of Hornsea projects 1 and 2 (Ørsted, 2020). Participants need to visualise the farm occupying 1% of the total available area in 2021 and increasing in size over the next 10 years to reach the upper boundary. Biomass density of the farm has been excluded due to data and resource limitations. Figure 2 defines the components that will form the basis of the qualitative integrative assessment and modelling (IAM).

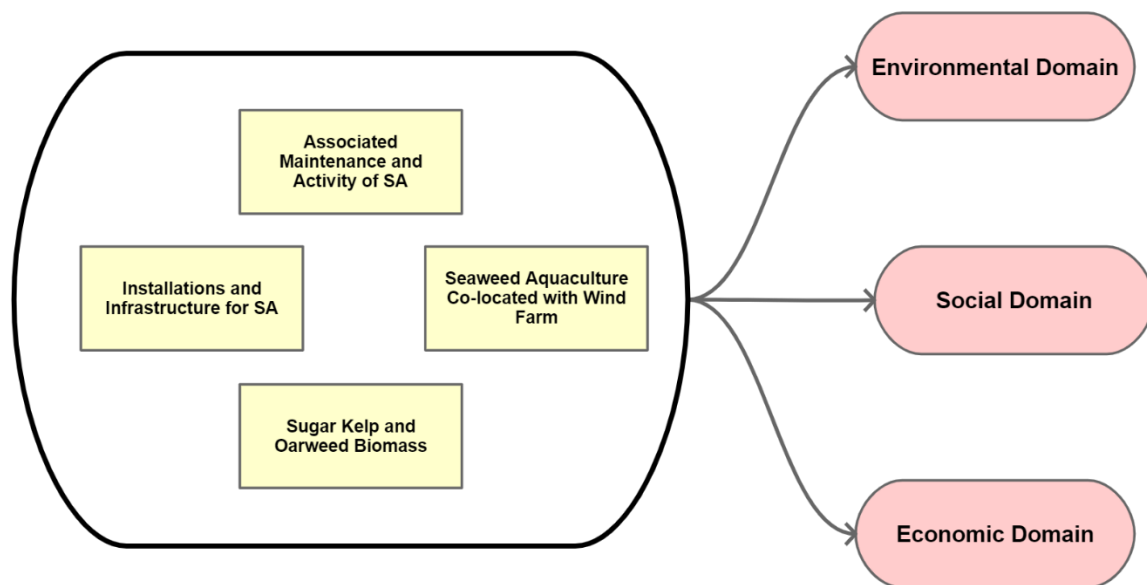


Figure 2- Schematic outlining the system components for the qualitative IAM.

The proceeding sections justify and illustrate the elements of the hypothetical scenario.

### Location

The North Sea territory will form the basis of the study area. Hornsea Projects 1 and 2 are the zones allocated for the Seaweed Farms to be installed. This is based on the suitability of cultivating laminarian species in this region (Marine Management Organisation, 2019), successful pilot tests of installations in neighbouring regions to the UK (Buck *et al.*, 2017) and has one of the largest commissioned wind farms sited in this area; namely, Hornsea Project One (Ørsted, 2020). The Hornsea Project one is the first stage of four total developments that are being constructed and was commissioned for operation in 2020 (Ørsted, 2020). The site location is approximately 65km off the coast of the Yorkshire county and consists of 174 fixed turbines that are dispersed across a total area of 407.30 km<sup>2</sup> (Ørsted, 2020). Table 1 summarises the Hornsea Wind Farm development stages including dates the projects are operational, total number of turbines per project, the size of project zones and the total area the HWF is planned to cover.

Table 1- Hornsea Wind Farm development broken down into respective stages of the project (1-4) with date of operation, individual project sizes and total area (Ørsted, 2020).

Hornsea Project stage	Operation date	Total No. of Turbines	Size (km <sup>2</sup> )	Total Area (1-4) (km <sup>2</sup> )
1	2020	174	407.30	2412.98
2	2022	165	461.89	
3	N/A	up to 231	695.83	
4	N/A	up to 180	847.96	

### Seaweed Aquaculture Installation

Infrastructure designs are a key area of research to promote the feasibility of offshore production. Germany has been performing offshore seaweed aquaculture trials as early as the 1990s (Buck *et al.*, 2017). Based on experimental studies of three aquaculture designs, a 5-metre diameter ring shaped rig device, comprising of an anchor point, metallic components, 80-100 metres of rope culture line and a central buoy- was the most successful at operating offshore in the German North Sea zone. Illustrations and images of the rig design used in the study can be seen in figure 3 of Buck and Buchholz (2004).

The report by Buck *et al* (2017) also discusses successful offshore cultivation of seaweed in Norway, using a device known as the “Seaweed Carrier” and is identified as one of the first contemporary installations in Norway capable of seaweed production on an “industrial scale”, however, the report does not fully disclose the materials used in this installation and patent links appeared broken. Nonetheless, the Seaweed Carrier device is briefly explained in Grandorf Bak *et al* (2020) as a “sheet-like structure with free moving cables and single mooring” with “flexible hybrid long-line 6.5 metres long and 5 metres deep”- See Figure 2.7 of Buck *et al* (2017), and Figure 2 of Grandorf Bak *et al* (2020), for referenced imagery.

The installations provided are illustrations of potential structures participants can use to assist with visualising and investigating the hypothetical scenario.

## Species

A report by the Marine Management Organisation (MMO) (2019) evaluated the potential sites for aquaculture around the UK, including, cultivation of seaweed. The report identified that two main species; namely, Sugar Kelp (*Saccharina latissima*) and Oarweed (*Laminaria digitata*), are suitable for farming in above 50% of the UK's Shoreline (Marine Management Organisation, 2019), especially, extending along and off the east coast of England and Scotland (Figure 3).

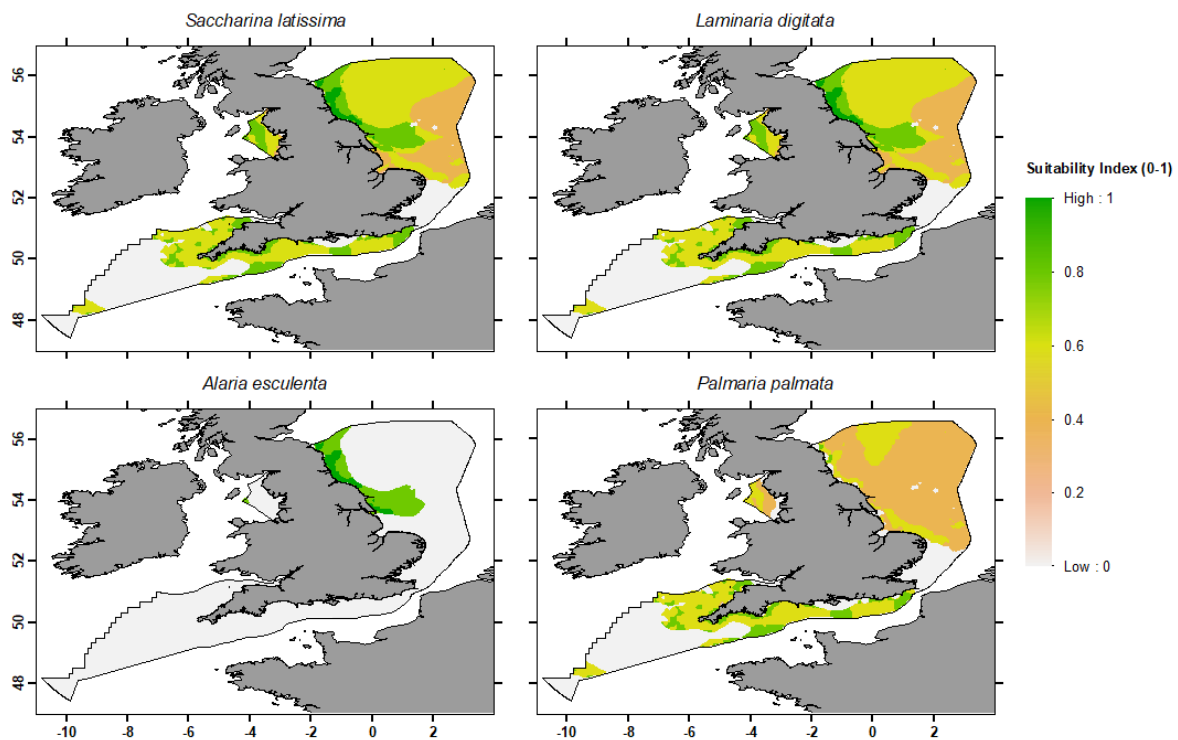


Figure 3- seaweed cultivation suitability maps extracted from MMO (2019)

Similarly, the report by Buck et al (2017) suggests seaweed species potentially best suited to offshore conditions in the European case studies generally derived from the *Laminarian* genus such as *Saccharina latissima* and *Laminaria digitata*, however, other species from different genus are also disclosed in the report but less often. The species cultivated during the hypothetical scenario are Sugar Kelp (*Saccharina latissima*) and Oarweed (*Laminaria digitata*).

## References

- Buck, B.H., Nevejan, N., Wille, M., Chambers, M.D., et al. (2017) Offshore and multi-use aquaculture with extractive species: Seaweeds and bivalves. In: *Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene*. [Online]. Springer International Publishing. pp. 23–69. Available from: doi:10.1007/978-3-319-51159-7\_2 [Accessed: 14 May 2021].
- Grandorf Bak, U., Gregersen, Ó. & Infante, J. (2020) Technical challenges for offshore cultivation of kelp species: lessons learned and future directions. *Botanica Marina*. [Online] 63 (4), 341-353-undefined. Available from: doi:10.1515/bot-2019-0005 [Accessed: 14 May 2021].
- Hodgson, E.E., Essington, T.E., Samhouri, J.F., Allison, E.H., et al. (2019) Integrated risk assessment for the blue economy. *Frontiers in Marine Science*. [Online] 6 (SEP), 609. Available from: doi:10.3389/fmars.2019.00609 [Accessed: 24 May 2021].
- Marine Management Organisation (2019) *Identification of areas of aquaculture potential in English waters (MMO 1184)*. [Online]. Available from: [www.nationalarchives.gov.uk/doc/open-government-](http://www.nationalarchives.gov.uk/doc/open-government-) [Accessed: 14 May 2021].
- Ørsted (2020) *Hornsea Project One- About the Project*. [Online]. 2020. Available from: <https://hornseaprojectone.co.uk/about-the-project#project-timeline-2020> [Accessed: 24 May 2021].