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Cultivating seaweed at home: benefits and limitations

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Preface

The end of an era. After months of struggling, searching, and persevering, I am proud to present you my master's thesis as part of the Environmental Sciences master's program. What a journey it has been. A journey in which I immersed myself (literally and figuratively) in the cold seawater, met passionate people, and had the most enlightening conversations. All with the aim of better understanding the wonderful world of seaweed.

If you know me even a little, you know how thoroughly and passionately I have researched this topic for the last few months, but it should be said, this topic wouldn't even have been a topic without my wonderful promotor Dr. Hanne Lamberts-Van Assche and co-promotor Dr. Rosaly Severijns. Your guidance, open mind, and enthusiasm have made this thesis what it is. I am immensely grateful for that. A big thank you also to Ecosphere for the materials, Ghent University for the seaweed, Ilvo for the information, Wijnpers Leuven for your enthusiasm to learn how to grow seaweed, Sara Olyslaegers for adopting my beloved seaweed and Wildwier for guiding me through some seaweed species.

To my dear friends, parents, brother, family and partner Klaas, where do I even begin? Your support has helped me every step of the way. You were always there to encourage me, steer me in the right direction, and even taste seaweed with me (delicious, right?!). Thanks for going along with my crazy ideas. It's a huge cliché, but I could never have been able to do this without you, so a big thank you! Let's just hope that, after writing a dissertation for three years running, this is the last one (for the time being).

Enjoy reading and let me take you on a journey into the wonderful world of growing seaweed at home!



Summary

The food industry puts a high pressure on nature and its resources. Especially meat's pressure cannot be ignored. Plant-based alternative protein sources are needed to decrease this pressure. Seaweed could be one of these alternatives as it offers a good protein source as well as other benefits. However, the large-scale cultivation of both marine as land-based seaweed has their own limitations. Marine cultivation is easily affected by environmental circumstances and large-scale land-based cultivation requires a high energy demand. Home cultivated seaweed could offer a solution as it is not as much affected by environmental circumstances and it requires less energy by adapting the setup to only the absolute necessity. This thesis focusses on the opportunities, limitations and feasibility of cultivating seaweed at home by investigating the economics, environmental impact, and social requirements. Answers are formed by gaining information from literature review, interviews and a case study, supported by a list of indicators to assure a sustainable approach. It can be concluded that technically cultivating seaweed is feasible, but limitations are still present. Contamination is one of the main limitations of cultivating seaweed at home, resulting in food safety concerns. Depending on the used material for setup, the costs and reduced yield could also form a barrier. The choice of a suitable seaweed species and adapted environmental conditions turn out to play an important role. Cultivation mainly offers some opportunities regarding education and awareness and can be seen as a hobby.

Key words

- Seaweed
- *Palmaria palmata*
- Protein
- Home-cultivation
- Land-based
- Protein-shift
- Sustainability

Samenvatting

De voedingsindustrie legt een grote druk op de natuur en haar hulpbronnen. Vooral de druk die de vleesproductie uitoefent, kan niet worden genegeerd. Er is behoefte aan plantaardige alternatieve eiwitbronnen om deze druk te verminderen. Zeewier zou een van deze alternatieven kunnen zijn, aangezien het een goede eiwitbron vormt en bovendien andere voordelen biedt. De grootschalige teelt van zowel marien als op het land gekweekt zeewier kent echter haar eigen beperkingen. De mariene teelt is gevoelig voor omgevingsfactoren en grootschalige teelt op het land vereist een hoog energieverbruik. Thuis gekweekt zeewier zou een oplossing kunnen bieden, omdat het minder gevoelig is voor omgevingsfactoren en minder energie vereist door de opstelling aan te passen aan wat strikt noodzakelijk is. Dit proefschrift richt zich op de kansen, beperkingen en haalbaarheid van het thuis kweken van zeewier door de economische aspecten, de milieu-impact en de maatschappelijke vereisten te onderzoeken. Antwoorden worden gevormd door informatie te verzamelen uit literatuuronderzoek, interviews en een casestudy, ondersteund door een lijst met indicatoren om een duurzame aanpak te waarborgen. Geconcludeerd kan worden dat het technisch haalbaar is om zeewier te kweken, maar dat er nog steeds beperkingen zijn. Verontreiniging is een van de belangrijkste beperkingen van het kweken van zeewier thuis, wat resulteert in bezorgdheden omtrent voedselveiligheid. Afhankelijk van het gebruikte materiaal kunnen ook de kosten en verminderde opbrengst een barrière vormen. Het blijkt vooral belangrijk om de zeewiersoort zorgvuldig te kiezen en omgevingsomstandigheden aan te passen. Kweek heeft vooral mogelijkheden voor educatie en bewust zijn en kan gezien worden als hobby.

Kernwoorden

- Zeewier
- *Palmaria palmata*
- Proteïne
- Thuis-kweek
- Op land
- Proteïne-shift
- Duurzaamheid

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1. Introduction

There are currently more than eight billion people living on Earth and the population is predicted to reach 9.8 billion by 2050 (A Fricke et al., 2024). As the world's population grows, so does the demand for food. In particular Europe's high living standard drives demand for more and higher-quality food. Yet, we only have one planet and its resources are limited. These resources are under particular pressure from the food system (Springmann et al., 2018). This increases the need for innovative and sustainable ways of providing food (Relaes, 2022).

Proteins are a crucial nutrient in our daily diet and are therefore central to this challenge (Relaes, 2022). Proteins are important for repairing tissues, building muscles, hormonal regulation, enzyme production and growth. Proteins consist of amino acid chains, of which the human body requires twenty different types. Eleven of these amino acids are produced by our body, but nine, the so called "*essential amino acids*" need to be obtained from our food. Protein is found, for example, in meat, fish and eggs, but also in some vegetables and in nuts. Unlike animal products, plant-based products often do not contain all the essential amino acids needed for the human body (Cleveland Clinic, 2021; DAVID GRIGG, 1995; Popieul, 2014).

Current protein consumption in Western countries consists mainly of animal protein (Relaes, 2022). The ratio of animal to plant-based protein consumption is 60/40 (Departement Landbouw en Visserij, 2021). This meat consumption has a significant environmental impact and causes high greenhouse gas (GHG) emissions (DAVID GRIGG, 1995; Relaes, 2022). Meat can cause 6.2 Gt CO₂-eq emissions globally, which is approximately 12% of all anthropogenic emissions (Food and Agriculture Organization of the United Nations, 2023). In particular beef, has a large carbon footprint, ranging from 13.9 to 25.1 kg CO₂-eq. per kg of meat (Klenert et al., 2023). Animal products in general have a larger carbon footprint compared to plant-based protein sources as they generate the majority of the greenhouse gas emissions related to food. Per kilogram of protein, they also require more land and water and result in higher greenhouse gas emissions (Departement Omgeving, n.d.; Springmann et al., 2018).

Plant-based proteins such as soy offer an alternative, but their import and cultivation still have a significant impact on the environment (Relaes, 2022). Research from Lucić et al. (2025) shows that the average total emissions for 1 kg of soy are equivalent to 1.27 kg CO₂-eq, which is much lower than the value for meat. Soy cultivation, however, is a major cause of deforestation and habitat loss, particularly in South America. Reports show that soy remains one of the key factors contributing to the conversion of forests and ecosystems, particularly due to its high demand and use in animal feed (Fehlenberg et al., 2017; Lucić et al., 2025). This illustrates the pressure that protein consumption places on the planet. In addition to the pressure that food places on the planet, food production is also under pressure from climate change. It is increasingly being challenged by shortage of available agricultural land, extreme weather conditions and soil degradation (A Fricke et al., 2024).

In order to cope with these pressures, attention is increasingly turning to the oceans. Macroalgae (seaweed) are organisms from a lower trophic level and require only a minimal amount of fresh water and few additional nutrients. Activities that rely on these organisms have attracted increasing attention worldwide over the past decade (A Fricke et al., 2024). Their interesting composition and protein content reinforces the interest (Fleurence et al., 2018).

In other disciplines, seaweed also gained interest. From a health perspective, researchers have examined seaweed for its therapeutic effects, anti-aging potential and its minerals and vitamins content (Popieul, 2014). The presence of diverse bioactive compounds has shown benefits for metabolic disorders including obesity, cardiovascular disease, hyperglycemia and insulin resistance (Jang et al., 2024). From a cosmetics perspective, seaweed provides polysaccharides that have been widely studied and integrated into skincare and cosmetic products (Shafie et al., 2022). Ecologists and marine biologists highlight seaweed's role in biodiversity, ecosystem functioning and carbon sequestration (A Fricke et al., 2024; Umanzor et al., 2019). Economists, in turn, consider seaweed as a driver of new value chains that support regional development and the bio-economy (Rath et al., 2025). Seaweed's amino acid profile resembles that of animal proteins and can contain all essential amino acids, making it especially interesting as human protein source (Departement Landbouw en Visserij, 2021; Popieul, 2014).

In Belgium, the use of seaweed for human consumption is being encouraged, as seaweed could play an important role in the Flemish Protein Strategy. This strategy aims to achieve a 40/60 ratio between the consumption of animal and plant-based proteins by 2030, with the dual objective of making current practices more sustainable and diversifying the protein supply. Cultivating seaweed is one of the potential pathways to diversify our protein intake to support a sustainable and healthy food system (Departement Landbouw en Visserij, 2021; Popieul, 2014). As mentioned earlier, plant-based proteins help to reduce greenhouse gas emissions and lower land and water consumption (Departement Omgeving, n.d.). In addition to the environmental benefits, the proposed protein shift also offers several economic opportunities, partly because of the growing demand for locally grown products. There are various opportunities in this area for Flemish businesses, as the characteristics of Flanders may offer potential for seaweed cultivation, both at sea and on land. In addition to their economic potential, these developments and the cultivation of seaweed also offer health benefits thanks to their beneficial composition (Departement Landbouw en Visserij, 2021).

To support and investigate this transition, a great deal of scientific interdisciplinary research is already being conducted on seaweed cultivation, both inside and outside of Belgium. This research focuses on both sea and land-based production systems and are usually applied on a large industrial scale, focused on biomass production (Tullberg et al., 2022).

Although seaweed brings major benefits as an alternative protein source, research also highlights several concerns associated with cultivating seaweed at a large scale. At sea, the increasing number of diseases and pests affecting aquaculture production is a global issue. This phenomenon is being intensified by the reduction in genetic diversity. When pests and diseases occur, seaweed cultivation might act as a reservoir for diseases and might impact natural populations (Campbell & Macleod, 2019). Cultivating seaweed at sea is also vulnerable to some environmental pollutants like arsenic, cadmium, iodine and pathogens such as *Salmonella* (Banach et al., 2020). Seaweed cultivated at sea can also be affected by environmental threats, such as flooding, storms or other natural disasters (Dinesh Kumar et al., 2023).

An alternative to overcome these issues is land-based seaweed cultivation, where seaweed is cultivated in tanks or ponds (Titlyanov & Titlyanova, 2010). Land-based cultivation of seaweed can provide high-quality biomass and addresses some of the challenges marine cultivation suffers from, but this method is not without problems itself. Cultivating seaweed on land is for example costly due

to the use of expensive materials and equipment and requires a great deal of energy for the continuous airflow and cooling (Dinesh Kumar et al., 2023; Hafting & Critchley, 2012).

Given the existing limitations in both sea and land-based cultivation, additional research and other approaches are required to supplement current practices. Although large industrial systems remain the primary focus of current research, small-scale and household-based seaweed cultivation has received minimal academic attention. Nevertheless, home cultivation can offer a unique opportunity: it could enable people to become more self-sufficient in protein, reduce their environmental impact by switching protein sources and contribute to a more varied diet. It could offer solutions to the existing difficulties related to large-scale cultivation at sea and on land. Given the shortcomings of existing production systems and the absence of research on domestic cultivation, exploring the potential of home-grown seaweed as an alternative protein source is both relevant and timely. Therefore, this work explores the benefits and limitations of cultivating seaweed at home.

2. Problem statement

Food systems and especially meat production put a lot of pressure on the available resources and our planet. Therefore, alternative protein sources become increasingly important (Springmann et al., 2018). Despite extensive research on both sea and land-based seaweed cultivation, previous studies offer little to no insight into small-scale home-based seaweed cultivation and are mostly focused on industrial scale. This leaves a significant knowledge gap regarding small-scale, home-based seaweed cultivation. Nonetheless, several organizations such as *seaweednetwork.id* (Seaweednetwork), *the better India* (Preethi, 2025), *hunker* (Gibbs, 2011), *seaweeding.com* (Volkova, n.d.), *Boothbay Sea and Science center* (Boothbay Sea and Science Center, n.d.) and individuals have begun experimenting with how seaweed can be grown in a domestic setting and have shared practical guidelines. To date, this knowledge has not been translated into a scientific framework.

To explore the possibilities of home-based seaweed cultivation as a potential alternative or complementary approach to the challenges of ongoing practices, this thesis dives deeper into cultivating seaweed at home. This thesis is a first step towards systematically evaluating the potential of domestic seaweed cultivation and examines **the opportunities and barriers of growing seaweed at home**. more specifically, the following topics are also being examined:

- **What are the economics of cultivating seaweed at home?**
- **How feasible is the cultivation of seaweed at home, in terms of growing conditions and material use?**
- **What are the social requirements and impacts of cultivating seaweed at home?**
- **What are the environmental impacts of the cultivation of seaweed at home?**
- **How do the opportunities and barriers of home cultivation compare to those of industrial cultivation?**

To answer these research questions, three research methods were used. These included a literature review, a custom-designed case study and interviews with practitioners. Each of these three methods were used separately to seek answers to the research questions.

The case-study is based on a literature background that highlights the latest developments in industrial-scale seaweed cultivation. The literature background also offered additional support for the interviews.

Specific attention is given to identifying the main advantages, limitations, and critical factors that influence the feasibility of domestic cultivation. This is achieved by adopting an interdisciplinary approach for each method to evaluate the sustainability of domestic cultivation, from a social, economic and environmental dimension.

This thesis is written as part of the *SUPROSEA* project (= Sustainable Proteins from Seaweed), a collaborative project between Ghent University, the Flemish Research Institute for Agriculture, Fisheries and Food, the University of Antwerp and Bio Base Europe Pilot Plant. The project aims to investigate the environmental sustainability and profitability of seaweed cultivation, with a focus on proteins, and is part of the Flemish protein shift (Bio Base Europe Pilot Plant, n.d.).

3. Literature background

This section provides a general background about seaweed, seaweed cultivation techniques, *Palmaria palmata* and seaweed on your plate. It provides the information needed to understand the thesis and lays the groundwork for the case study.

3.1 Seaweed

Seaweeds are also referred to as macroalgae and live in salt water. They have a multicellular structure, whereas many algae are unicellular. They have a very simple body structure called a thallus and do not possess true stems, roots, or leaves. Seaweed is a type of spore-bearing plant but does not produce flowers. Like land plants, seaweed contains chlorophyll, which may be masked by other pigments. Chlorophyll ensures that seaweed can do photosynthesis. Seaweed also consists of water, protein, polysaccharides, minerals, vitamins and lipids (Popieul, 2014). This composition has recently sparked interest in seaweed as a source of macronutrients, micronutrients and bioactive compounds, as edible seaweed has the potential to serve as a rich and sustainable source of these nutrients for the human diet (Cherry et al., 2019).

Just like land plants, seaweeds have their own specific habitats. Some species live deeper in the sea, whilst others grow on rocks near the coast. Slow or fast-flowing water and river estuaries can also support a rich diversity of species, but the greatest diversity of species is found in intertidal zones. Seaweed can be found in all kinds of regions: tropical and subtropical areas, temperate areas and subarctic, and arctic areas. In warm areas, small, oily algae are particularly common as they are better able to protect themselves against extreme heat. In cold areas, long (up to 10 metres) and lush seaweed is found (Popieul, 2014).

Most of the cultivated seaweed is produced in Asia, with China as the main producer of biomass (62%). Each year, over 35 MT of seaweed is produced globally (Werner, 2011). Western countries barely harvest seaweed compared to Asian countries. This is mostly due to the difference in traditional food use. Besides China, also Indonesia, the Philippines and the Republic of Korea produce large amounts of seaweed (van den Burg et al., 2021; Werner, 2011). The seaweed sector is growing in size and value every year. Seaweed cultivation in Europe takes place in niche businesses with specific applications, rather than in large-scale mass-production facilities. Europe is a relatively minor player in the seaweed market, but interest is growing. European seaweed production accounts for 0.8% of global production. Within Europe, France is the largest producer (Khan et al., 2024; van den Burg et al., 2021).

3.1.1 Types of seaweed

There are over 2500 different types of seaweed and algae that have been documented over the years (Popieul, 2014). Worldwide, only 17 genera are used for industrial cultivation, which represent 221 seaweed species (Titlyanov & Titlyanova, 2010; van den Burg et al., 2021). The most common classification is based on pigmentation and has three broad groups: red, green and brown seaweed. Botanists refer to these as *Rhodophyceae*, *Chlorophyceae* and *Phaeophyceae*. Red seaweeds can be purple or even brownish-red as well as red. Red seaweed is usually smaller compared to brown seaweed, ranging from a few centimetres to a metre in length, and can be found in cold, temperate and tropical waters. Green seaweed is also small and have a similar size to red seaweed. They contain a lot of chlorophylls and there is a wide variety of species. Brown seaweed is generally larger and can

grow up to 20 m in length and is mostly found in estuaries and cold waters with temperatures up to 20 °C (Popieul, 2014; S. K. Laha, 2022). Figure 1 shows some examples of different types of seaweed.



Figure 1: Examples of different types of seaweed

The difference between red, brown and green seaweed is not only a matter of pigments, also the protein content is different. Red seaweeds have the highest protein content (19.1–28.2 g/100 g dry weight) and highest average ratio of essential amino acids to total amino acids. Some green seaweeds also have a high protein content (20.5–23.3 g/100 g dry weight) but brown seaweeds generally have the lowest protein content (6.90–19.5 g/100 g dry weight) and essential amino acid ratio (Arakaki et al., 2023; Vieira et al., 2018). Growth rate might also differ between groups and within groups, as this is species- and circumstance-specific. Among the many seaweed species cultured in tanks, the *Palmaria mollis*, a red seaweed, was found to generally have the highest growth rate (414 g WWT/m²/day) (WWT= Wet Weight Tonnes) under the right conditions (Dinesh Kumar et al., 2023).

The choice of seaweed for cultivation depends on which species can easily be sourced and on the intended end product obtained from the cultivated biomass (Dinesh Kumar et al., 2023). The choice may also be influenced by the location of the farm and the available cultivation facilities. The productivity and adaptability of a species also play an important role in the decision-making process. Finally, the dimensional characteristics of an aquatic ecosystem (size and depth) may influence the decision, as may factors such as light intensity, temperature conditions, nutrient enrichment, pollution, water movement and the degree of wave action (Titlyanov & Titlyanova, 2010). Currently, *Eucheuma* spp. and *Kappaphycus alvarezii* are the most commonly cultivated seaweeds. These species are used for the gelling agent carrageenan. For food purposes, *Saccharina* spp. (kelp), *Undaria pinnatifida* (Wakame), *Pyropia* spp. (Nori) and *Sargassum fusiforme* (Hiziki) are the most farmed species (ASC, n.d.).

3.2 Current cultivation techniques

All types of seaweed can be cultivated using different techniques. All cultivation methods can be divided into two main types: extensive (using natural environment and resources) and intensive cultivation (using artificial conditions). The actual methods of seaweed cultivation vary greatly and can be categorized into three main methods: wild harvesting, land-based farming (tanks/ponds), and

marine farming (offshore/nearshore) (Titlyanov & Titlyanova, 2010). The different methods are shown in figure 2.

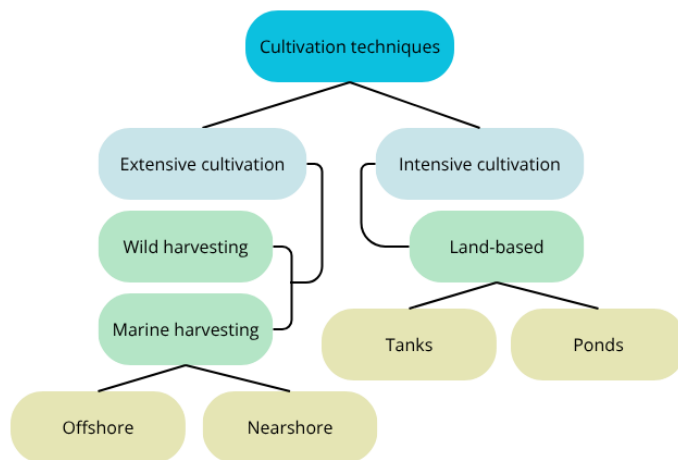


Figure 2: Cultivation techniques (source: author's contribution)

Which cultivation method is used depends on the cost effectiveness and the targeted end product (food, cosmetics, ...) (Titlyanov & Titlyanova, 2010). The mentioned cultivation techniques are almost all carried out for commercial or research purposes, not taking into account small-scale home cultivation.

3.2.1 Extensive cultivation

Extensive cultivation methods are used in natural water areas and only use available light, heat, water motion, energy, and nutrients. Both wild harvesting and marine farming are considered to be extensive methods (Titlyanov & Titlyanova, 2010). A lot of seaweed can be found naturally in the sea. Countries such as Scotland, Ireland, France, Norway and Canada use and harvest seaweed using extensive methods. This is an example of wild harvesting techniques. To harvest in the wild, different techniques can be used. It can be harvested by hand, but in some countries, they invented a specific mechanical harvesting technique to harvest wild seaweed (Werner, 2011). In addition to harvesting in the wild, large scale commercial seaweed cultivation can also be practised, using both native and introduced seaweed species. These can be grown on various types of natural and artificial substrates, distributed across the water to make the best use of natural resources. Growers can utilise the seabed, lines and ropes at the water's surface or a few metres below the surface. Seaweed farms can be located in the open sea, but also in enclosed bays, lagoons, and estuaries (Titlyanov & Titlyanova, 2010).

3.2.2 Intensive cultivation

Intensive cultivation uses artificial conditions. Land-based cultivation falls within the category of intensive cultivation. Two main methods are used here: cultivation in tanks and cultivation in small natural water bodies (ponds). Compared to other cultivation techniques, cultivation in tanks yields the highest returns but this technique is also associated with high electricity consumption. When cultivating seaweed in a pond, the seaweed is attached to the bottom or to ropes and nets. Ponds use seawater or a mixture of seawater and river water (Titlyanov & Titlyanova, 2010).

3.3 *Palmaria palmata*

This research is part of the project *SUPROSEA*, which focuses on the cultivation of *Palmaria palmata* and *Ulva*. For the case study *Palmaria palmata* was used. For this reason, this species will be described in more detail.

Within the *Palmaria* family, *Palmaria palmata* (*P. palmata*) (see Figure 3) is commonly referred to as *Dulse*. The name *Palmaria palmata* reflects the typical shape consisting of flattened oblong lobes expanding from the middle of the frond as the shape of a hand or a palm but the morphology can be very different, depending on the environmental conditions (Stévant et al., 2023; Werner, 2011). *P. palmata* is grouped under the genus *Rhodymenia* and can grow up to 50 cm but is usually between 10 and 20 cm. When the plant is old, the texture is leathery and the colour is reddish-brown dark. New parts on the other hand, have a fresh red colour. When exposed to higher temperatures and increased sunlight, the colour might become greenish or even bleach (Stévant et al., 2023).

P. palmata is a well-known cold temperate red seaweed species and can be found in the first 10 m below the surface or, when offshore, up to 20 m when the water is exceptionally clear. The species has been important for commercial purposes for centuries and is mostly harvested by hand-picking. Because of increasing demand and the fact that future sustainable commercial development cannot solely rely on wild-harvesting, research and industrial actors have been trying to cultivate this species with other industrial methods such as land-based cultivation. The cultivation of *P. palmata* mainly experiences some difficulties concerning spore release and germination, high mortality and epibiont contamination (Stévant et al., 2023).

The seaweed is found along the coasts of the North Atlantic Ocean between latitudes 40° (Portugal and New Jersey) and 80° north (Spitsbergen and Greenland) (see Figure 4), but the future range of *P. palmata* is likely to be affected by climate change, which is leading to rising sea temperatures. Thereby, the species may face local extinctions in areas near its thermal tolerance limit (Stévant et al., 2023; Werner, 2011).

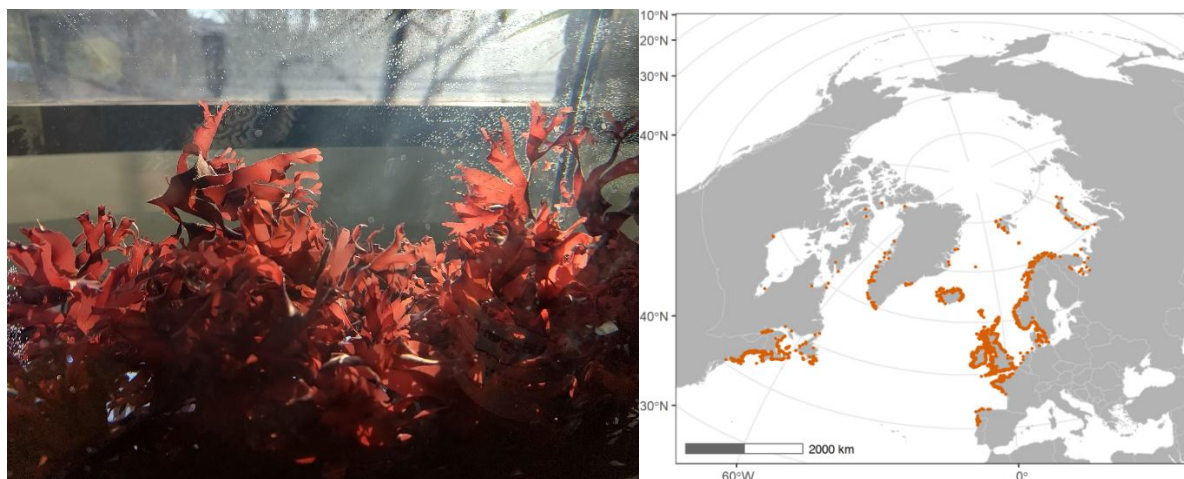


Figure 3: *Palmaria palmata* (source: author's contribution); Figure 4: Distribution of *Palmaria palmata* (Stévant et al., 2023)

3.3.1 Composition

Palmaria palmata (dulse) has a high protein content, which is the main reason for commercial interest in this species (Cherry et al., 2019; Stévant et al., 2023). It can have a protein content up to 35% DW (dry weight). Especially in tank cultivation on land, a high-level of proteins can be achieved (Stévant et al., 2023). A healthy person needs about 50–75 grams protein per day (WHO, 2026). This results in a required intake up to 262g seaweed per day, not taken into account the digestibility.

P. palmata has a low total lipid content, but it is proportionally rich in mono- and polyunsaturated fatty acids. It contains high amounts of the omega-3 fatty acid EPA, making *P. palmata* a good source for high-purity EPA. The lipid profile varies with location, plant age, storage conditions and season (Stévant et al., 2023).

The species also is a rich source of minerals and vitamins. It contains macro elements such as Na, K, Ca and Mg as well as micro elements such as Fe, I and Mn. The vitamin C content of *P. palmata* is rather low compared to other plants and can therefore not significantly contribute to the recommended intake. Vitamin B on the other hand seems to be sufficiently present. The daily consumption of 1 g dried seaweed will cover 10% of the recommended nutrient intake of B₁₂. It also contains fat-soluble vitamins and is especially rich in β -carotene and vitamin K (Stévant et al., 2023).

3.3.2 Life cycle

Palmaria palmata has a life cycle consisting of two stages: a phase in which the seaweed has a half set of genetic material, and a phase with a full set of genetic material (Stévant et al., 2023). After about a year of growth, mature plants develop dark red patches on their blades. Once released, the spores grow into either microscopic female gametophytes, or male gametophytes. The female gametophyte produces eggs and are designed to capture the sperm released from a mature male gametophyte that is at least one year old. Because spermatia cannot swim, successful fertilization depends on water movement to reach the female plant and get caught by the female gametophytes. Once a spermatium fertilizes the female gamete, the resulting zygote grows directly on the female plant and grows into a young plant that overgrows the female gametophyte early on, eventually forming its own small attachment point. From this attachment point, a new blade develops and grows into a mature plant. *Palmaria palmata* is considered pseudo-perennial: the holdfast survives for multiple years, while the blades grow, reproduce, and senesce annually (Stévant et al., 2023; Werner, 2011). The whole life cycle is shown in Figure 5.

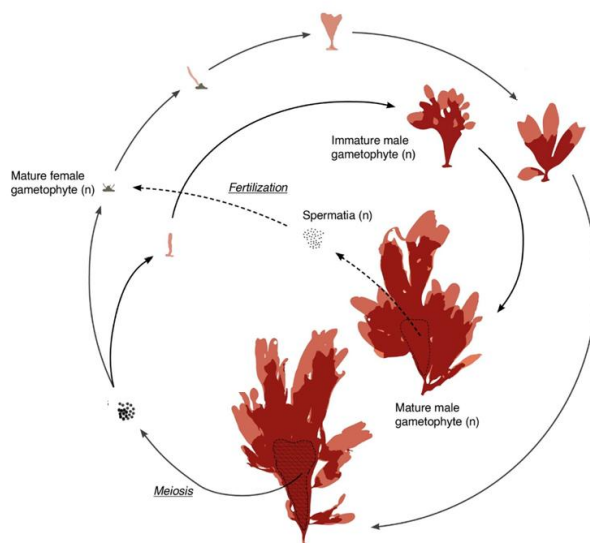


Figure 5: Life cycle of *Palmaria palmata* (adapted from Stévant et al., 2023)

In wild populations, *Palmaria palmata* experiences its strongest growth between May and July, after which growth slows and even becomes negative during the summer due to the breakdown of the fronds. This is caused by a combination of factors such as high solar radiation, high temperatures, a lack of nutrients, grazing by invertebrates and the presence of epibionts on the surface of the fronds. The maximum growth rate recorded varies between 0.9 and 1.5% per day in Northern Ireland and Northern Spain respectively. In the Bay of Fundy (Canada), the growth rate is estimated at over 4% per day due to ideal circumstances (Stévant et al., 2023).

3.3.3 Environmental requirements for *Palmaria Palmata*

To assure growth, *Palmaria palmata* requires specific environmental circumstances. One of the most critical abiotic factors is temperature. This affects photosynthesis, growth and reproduction directly. The sea water temperatures vary from 0 to 20°C but the ideal growth temperature for *P. palmata* ranges between 6 and 12°C, as it is a cold temperate red seaweed. Above 14°C, a reduction in productivity is reported. Above 21°C, mortality may occur. The ideal salinity level for *P. palmata* is around 30–40 PSU (Practical Salinity Units) or must remain stable. However, the species also occurs in intertidal zones where it may be exposed to fluctuations in salinity caused by rainfall, or in zones subject to seasonal fluctuations, for example due to meltwater (Stévant et al., 2023). Seaweed also needs nutrients. It absorbs nutrients from the environment via the entire surface of its thallus. It can absorb ammonium (NH_4^+) and nitrate (NO_3^-), both of which serve as nitrogen sources for the growth of the macroalgae. *P. palmata* has a greater affinity for NH_4^+ . PO_4^{3-} and carbon is also absorbed and can be stored to support growth in situations where there is a shortage of nutrients (Stévant et al., 2023).

To do photosynthesis, also sunlight or UV radiation is needed. *P. palmata* can temporarily lower its photosynthetic activity when the light is too intense to avoid stress. Especially UV-B light is harmful for the growth and photosynthesis of *P. palmata*. When the stress lasts too long, damage may occur. When Nitrogen is low and the light too strong, bleaching can occur. How well *P. palmata* handles light stress

depends on where it grows. Plants from areas with more light show better protection mechanisms than those from deeper water. Light tolerance is also influenced by other factors such as changes in salinity and temperature (Stévant et al., 2023).

3.3.4 Cultivation of *Palmaria palmata*

As mentioned before, *P. palmata* can be found in nature in cold temperate conditions. Here, extensive wild harvesting can take place. Wild harvesting is not the only possibility, also marine cultivation at sea can take place, for this purpose, seeded substrates on ropes or nets are placed in open waters. *P. Palmata* can also be cultivated in tanks, ensuring controlled conditions (Stévant et al., 2023).

3.4 Seaweed on your plate

Eating seaweed is often associated with Asian cuisine. Seaweed is frequently regarded as healthy, but not as tasty (Popieul, 2014). Research shows that willingness to eat seaweed depends on the population group and region. People not willing to add seaweed to their diet have a variety of different reasons. This indicates the need to provide effective information on seaweed's nutritional benefits (Tenorio-Rodríguez et al., 2025; Zheng et al., 2024). However, various chefs have already demonstrated that seaweed can also be very tasty. It can be used in all sorts of dishes, such as crisps, soup or on mashed potatoes. It can also be incorporated into desserts, such as cheesecake (Popieul, 2014).

The pictures below show some possibilities to eat seaweed, tested by myself.



Figure 6: Seaweed crisps



Figure 7: Seaweed with zucchini and goat's cheese



Figure 8: Dried seaweed

4. Methodology

In order to examine the answer to the research questions as thoroughly as possible and from different perspectives, the research uses a mixed-methods approach. It integrates insights from academic **literature**, **interviews** and a **case study**. This combination of sources offers theoretical as well as practical insight. This chapter explains how the answers to the research questions were collected and compiled using the three research methods. It describes the framework and methods used to achieve the result.

4.1 Framework and indicator selection

The main purpose of this thesis is to examine the limitations and possibilities of cultivating seaweed at home. To investigate this, a set of indicators was selected and analysed. These indicators serve as a structured framework that allows the research questions to be addressed in a focused way and ensures that the analysis covers the main themes of the thesis.

To select the appropriate indicators, this thesis is built on the three dimensions of sustainability (reference). Cultivating seaweed is a future oriented topic that is currently receiving increased attention in scientific research. Given the role this practice plays in the protein shift and its increasing market, its sustainability is of great importance. Sustainability is often defined as *“meeting the needs of the present without compromising the ability of future generations to meet their own needs.”* (Development, 1987). The triple bottom line (TBL) concept of sustainability was used as the foundation for selecting the indicators. TBL highlights the balance between people, planet and profit, thereby integrating social, environmental and economic dimensions of sustainability and offers a useful framework to reflect upon today’s and tomorrow’s seaweed cultivation (Knight, 2023).



Figure 9: TBL: the three dimensions of sustainability (Dębicka et al., 2018)

The used indicators are based on a list provided by Tan et al. (2015), implement the TBL and were supplemented with indicators that are based on the available literature relevant to the research questions. They form a framework to identify the main barriers and opportunities of cultivating seaweed at home. Within the environmental dimension, there is a focus on resource use. Within the

social dimension, there is a focus on the time investment and the potential challenges and lastly within the profit dimension, there is a focus on the costs. Together, these indicators enable a structured evaluation of the perception of the opportunities and barriers of home seaweed cultivation. The list of indicators can be found below.

Table 1: List of indicators

INDICATORS			
Dimension	Pillar	Indicator	Source
Environmental	Emissions and pollution	Greenhouse gas emissions	(Tan et al., 2015)
		Waste water production	(Tan et al., 2015)
		Solid waste generation	(Tan et al., 2015)
		Chemical use (nutrients)	(Dinesh Kumar et al., 2023)
	Resources	Use and reuse of resources (water, nutrients, ...)	(Tan et al., 2015)
		Availability of resources	(Dinesh Kumar et al., 2023)
		Energy consumption	(Tan et al., 2015)
		Water consumption	(Tan et al., 2015)
Economic	Financial	Costs saved	(Tan et al., 2015)
		Materials costs	(Tan et al., 2015)
	Manufacturing	Energy costs	(Tan et al., 2015)
		Water costs	(Tan et al., 2015)
		Yield (kg)	(Dinesh Kumar et al., 2023)
		Essential material	(Dinesh Kumar et al., 2023)
Social	Skills	Difficulty level	(Stévant et al., 2023) (van den Burg et al., 2021)
		Hours of work	(Tan et al., 2015)
		Space required	(Tan et al., 2015)
		Required knowledge	(Tan et al., 2015)
	Safety	Personal protective and safety equipment	(Tan et al., 2015)
		Food safety and health	(Cherry et al., 2019)

4.2 Methods

The indicators, and consequently the research questions, are examined using the three methods employed in this paper: literature review, case study, and interviews.

4.2.1 Literature review

The first method to approach the research questions and indicators is the literature review. A wide range of scientific sources were consulted for the literature review. These articles were mainly consulted via the university's available databases, with an emphasis on Web of Science, ensuring high quality articles.

Although the literature review is not systematic due to time and resource constraints, some examples of key words and search strings are 'seaweed' or 'macroalgae' and specifying terms such as 'benefits', 'environmental impact', 'protein' or 'economic aspects'. Especially papers on 'tank cultivation', 'on

land' or 'on shore' were selected. The aim was to use mainly recent articles (after 2015). Both general information and a broad knowledge base were gathered, along with more detailed information. The articles used were selected based on relevance, year of publication or research perspective, and were chosen after reading the title and abstract.

Not all the information concerning the indicators could be obtained from scientific sources. Government sources and research institutions also provided useful information on the current situation, practices and the measures relating to proteins and seaweed. Mostly searches on 'protein shift' and 'seaweed' provided information for this thesis.

Finally, other, non-governmental websites were also consulted to obtain more information about how to grow seaweed at home. These were often of Indian origin and provided step-by-step guidance on how to grow seaweed at home.

These articles and websites provided information on the topics listed in the indicators. Different sources were used for each dimension (environment, society, economy), and some sources could be used for more than one category.

4.2.2 Interviews

Although little research has yet been conducted into growing seaweed at home, some people have already attempted to grow seaweed themselves. Various channels such as Google were used to recruit participants, including online platforms such as Facebook, Reddit and Instagram. Contact was also made with individuals recommended by project connections. Potential participants were approached, contacted and invited for an interview via these channels or by email.

The interviews took place individually and online due to the diversity of the participants and the diversity of the topic. The participants provided information from different points of view. Four interviews took place in total. First, an interview was conducted with a person who grew seaweed at home as part of an art project. This was followed by an interview with someone who worked for *Hortimare*, a large-scale company that supplies knowledge and seaweed to other businesses, develops technologies and describes itself as one of the few companies worldwide specialising in the cultivation and propagation of seaweed (Hortimare, n.d.). The third interview was with the company *Rijtak* that specialises in growing vegetables but has also been focusing on microalgae since 2021 and has been in the early stages of seaweed cultivation for a few months (Rijtak, n.d.). The Last interview took place with a PhD student from University of Antwerp, specialized in the microbiome of red seaweed, with main focus on *Palmaria palmata*, of which small amounts are grown by the student.

Semi-structured interviews were conducted with a prepared interview guide (see Appendix 10.1). The questions from the questionnaire are not presented in a particular order and depend on the answers given by the interviewees. The interview was based on the structure and steps provided by Adeoye-Olatunde and Olenik (2021). Based on their step-by-step plan, the suitability of the research was assessed, participants were selected and recruited, the data collection was designed, the interviews were conducted, the analysis was carried out and, finally, conclusions were drawn. During the first phase, a specific investigation was carried out to determine whether a semi-structured interview was the most suitable instrument for this study. It was concluded that semi-structured interviews leave room for the participants to share their own story, while also answering the specific questions, which is why it is fitting for this thesis.

The semi-structured questionnaire was drawn up based on indicators and structured according to the principles of the triple bottom line. The indicators were translated into questions with the aim of obtaining more information about each dimension of the indicator list. The questionnaire also included a few more general questions, so that respondents had the opportunity to provide additional information on the reason of interest in cultivation. At the end, respondents were asked if they had any more information they would like to add, so they could provide additional information if wanted.

The interviews were conducted online and subsequently transcribed, anonymised and securely stored. The data collected was then analysed by categorising the responses, based on the indicators, partly manually and partly using online available tools. Some responses could be classified into more than one category. An attempt was made to draw a general conclusion for each category based on the various interviews.

4.2.3 Case study

In addition to the knowledge gained from the interviews and the literature review, a practical case study was conducted. This case study provided a third method for gathering information on the listed indicators. It offers the opportunity to experience seaweed cultivation at first hand and provides unique insight into the cultivation of seaweed and the use of domestic kitchen and gardening tools.

Due to the focus of the *SUPROSEA* project, and availability, *Palmaria palmata* was used for the case study. *P. palmata* also offers an interesting composition for the human diet. Simultaneously, a school independently conducted their own case study. Over the course of a few months, they have been growing *Ulva* and keeping track of the yield and their experiences. While not described in detail, their results are reported as additional information to answer the research questions.

To gather information on how this case study should be designed and carried out, the findings of the literature background on cultivation seaweed on land in tanks were used. Especially information on *P. palmata* was consulted. As mentioned earlier, this literature focused primarily on controlled large-scale cultivation, with an emphasis on biomass. When growing seaweed at home, these controlled conditions present a challenge. For this reason, and because this study is investigating the potential of home cultivation as an alternative to the difficulties associated with industrial-scale production, the design described in the literature is not fully replicated. However, the literature was used to determine what the ideal conditions for *P. palmata* are.

As part of determining the barriers and opportunities, a logbook was kept. In this logbook, the days on which a handling was required and the time spent on this handling were recorded. On these days, also the temperature and salinity were monitored. Additionally, the spend costs were listed and supplemented with online available information (for example electricity cost). In this logbook, also the used calculations, for example for the yield of salt needed, were kept. Lastly, this logbook provides an overview of the amount of seaweed in grams.

If growing seaweed at home is to be accessible to everyone, it is important that the barriers to entry are kept as low as possible. To ensure this, people must be able to use inexpensive, readily available materials. The principles and structure of the case study are explained in the following section.

4.2.3.1 Set-up and considerations

Cultivating seaweed industrially on land under totally controlled circumstances causes a high energy demand due to the usage of different equipment such as lightning, aeration, cooling and filtering (Dinesh Kumar et al., 2023). To address this difficulty, the setup for this case study only uses the most basic necessary equipment. This way it can be tested whether seaweed can be cultivated even without laboratory conditions and equipment but with domestic and easily available material instead. For this case study, an aquarium of 100 l was set up at home. This aquarium was used because of availability and the transparency on all sides, making it easier for light to reach the seaweed. To receive light for photosynthesis, the aquarium was placed next to a window, and no additional light source was added.



Figure 10: Tank setup

To create a marine water environment, tap water and sea salt were used without any filtration or sterilization. For sea salt, an easy to mix salt mixture called 'Instant Ocean' was used to imitate seawater.

To minimise the risk of biological contamination, hands were washed before being placed in the aquarium and plastic sheeting was placed over the tank to prevent airborne contamination.

Literature research suggests that the ideal temperature to optimize growth of *P. palmata* is between 6 and 12°C (Rolin et al., 2014; Stévant et al., 2023). For this case study however, no heater nor cooler was used. This way, the water temperature was influenced by the room temperature and incoming sunlight.

Literature states that a continuous air supply is required. This way, the seaweed cultures are mixed and oxygenated (Rolin et al., 2014). Because of the importance of air circulation, a basic air pump was used in the case study. This pump was split into two tubes so aeration could take place on two sides and more circulation was provided. It was put at the bottom of the aquarium to encourage water circulation.

Seaweed also needs sufficient nutrients to grow. In research, often a preparation called F/2 mixture is used containing all the essential macro- and micronutrients and a blend of trace metals and vitamins, all needed for healthy macroalgae growth (Algae research and supply, n.d.). For the general public, this might be more difficult to obtain and more expensive, so an alternative commercial nutrient source, 'Easy-life GreenScape', containing nitrate, phosphate, potassium, iron, manganese, magnesium and spore elements was used instead (Easy-life, n.d.). The nutrients were added twice a week to reduce the possibility of contamination. Additionally, half of the recommended amount of nutrients was added each time, to reduce the possibility of contamination.

Besides the absolute necessities discussed above, also some additional material was used to monitor the cultivation. First, a thermometer was installed so temperature could be monitored. Besides a thermometer, also a refractometer and weight scale were used for measurements. Other basic equipment included bowls, a spatula to stir, paper towels and a sponge to clean. The used materials are shown in Figure 11.

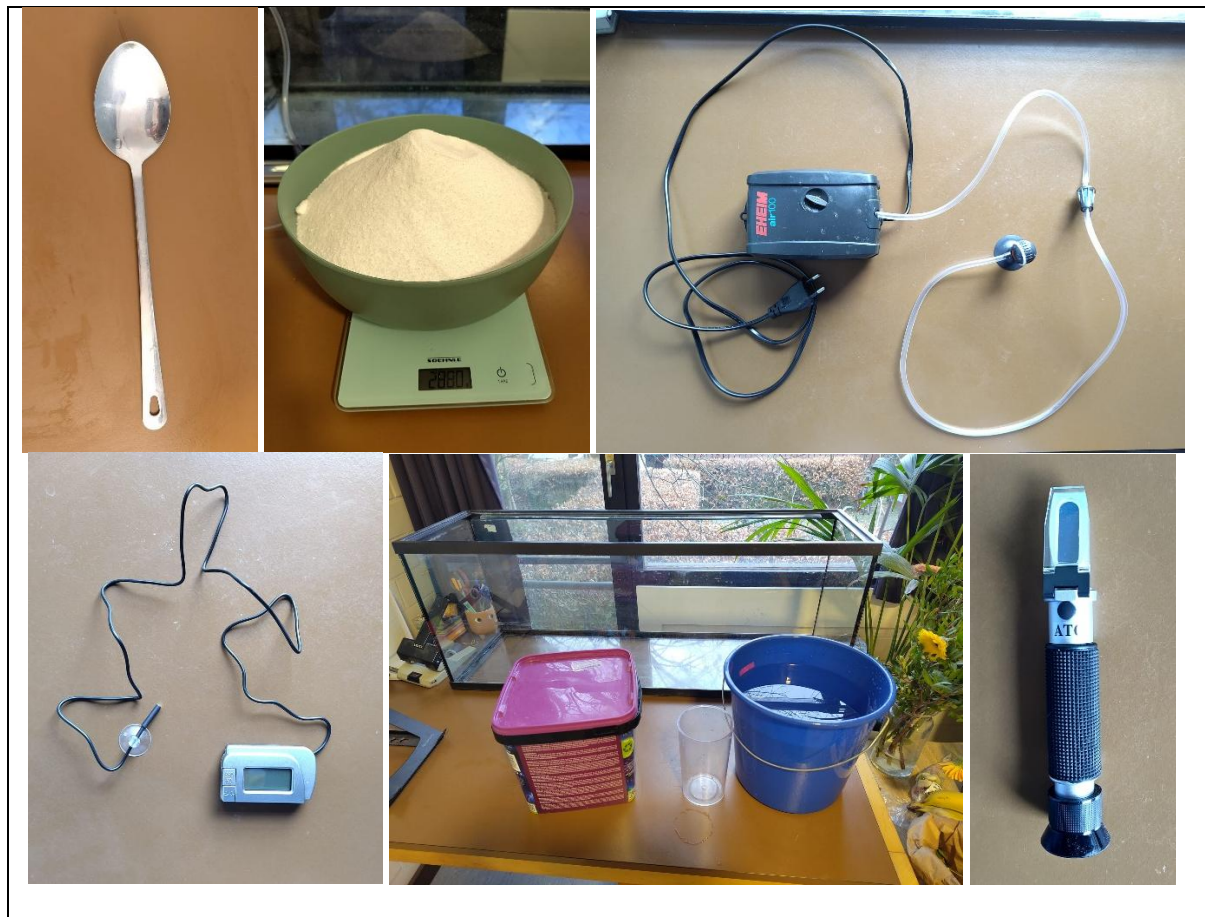


Figure 11: Materials used for setup

4.2.3.2 *Ulva*

For the *Ulva* cultivated at the mentioned school, a simple setup was used consisting of a bucket filled with distilled water. Sea salt was added to create a marine environment. An F/2 mixture was used as a nutrient source and to ensure sufficient oxygen and circulation, a small air pump with an air stone was placed in the bucket. No heating or cooling was used. The used setup can be seen in Figure 12.



Figure 12: *Ulva* setup

5. Results

This section provides an overview of the different method's perspectives on the research questions by using the indicators as a framework to structure the information. First the information gained from the literature review will be discussed, followed by the interviews and case study. Lastly, a cross-method result section is added, comparing the results from the separate methods.

5.1 Literature review

The literature review focuses mainly on the literature available of controlled land-based tank cultivation because this technique most resembles home cultivation. Controlled seaweed biomass cultivation includes both land-based commercial cultivation and land-based research-focused cultivation aimed at supporting industrialisation and maximising biomass yield.

5.1.1 Environmental dimension

This section provides information on resources, emissions and pollution and the related indicators, based on the literature.

5.1.1.1 Resources (use and reuse of resources, energy consumption, availability of resources, water consumption)

When cultivating seaweed in tanks under controlled conditions, a lot of parameters play an important role in assuring the ideal seaweed living conditions. In contrast to the before-mentioned extensive cultivation techniques, where conditions can barely be controlled, the parameters of intensive cultivation techniques can easily be monitored and adjusted when needed (Titlyanov & Titlyanova, 2010). Especially the water quality is important during seaweed cultivation. The pH, salinity, temperature, nitrate and phosphate content, microbial load and solar irradiation should be monitored closely to assure ideal circumstances (Dinesh Kumar et al., 2023; Titlyanov & Titlyanova, 2010).

The seawater itself needs to have a high salinity, clarity and cleanliness. On industrial scale, seawater is often filtered to 1 μ and sterilised by UV light (Titlyanov & Titlyanova, 2010). It is important that the tank has an ideal salt concentration of around 29-35 parts per thousand (ppt) (Vlaanderen Huisdierinfo, n.d.). This corresponds to 29 to 35 g of salt per litre of water. Besides the water, the material used for the tank needs to be sterilised as well (Rolin et al., 2014). There is, to the best of my knowledge, no information on the exact amount of water needed to cultivate land-based seaweed but it can be assumed it depends on tank size.

A temperature-controlled room is preferred and must be adjusted for the specific type of seaweed and monitored closely. Another important aspect is the continuous supply of air to oxygenate the seaweed. A pump is the simplest way to assure a constant flow of air (Rolin et al., 2014). The depth of the tank and the density of the seaweed are also important factors that must be controlled (Titlyanov & Titlyanova, 2010).

A proper illumination is required for growth of the seaweeds. For land-based settings, this can be easily accomplished by installing a lamp (Rolin et al., 2014). To develop the proper amount of irradiation, the light intensity and light quality should be carefully regulated. This can be accomplished by using light filters, screens, and additional lamps (Titlyanov & Titlyanova, 2010).

Lastly, nutrients should be perfectly balanced. In ideal settings, F/2 mixture is used. F/2 is a mixture including all essential macro- and micronutrients and a blend of trace metals and vitamins. 1.5 ml per litre of mixture should be added to provide nutrients and vitamins to the seaweed (Algae research and supply, n.d.; Rolin et al., 2014).

When not under ideal circumstances such as too strong light or too little nitrogen, bleaching of the seaweed can take place (Stévant et al., 2023).

The cultivation of seaweed on-land offers opportunities to change low-value residual streams to high-value. Research stated that sewage sludge potato industry sludge could be used as nutrient source to cultivate seaweed (Spaans et al., 2025). Cultivating seaweed on land also offers opportunities for integrated farming with animals such as fish and shellfish. However, the co-cultivation of different types of seaweed can lead to problems (Dinesh Kumar et al., 2023).

Per kg of dry weight harvested seaweed, about 188.5 MJ of fossil fuels as energy source is needed (Nilsson & Martin, 2022). This could be reduced by using renewable energy sources.

5.1.1.2 Emissions and pollution (greenhouse gas emissions, chemical use, wastewater production, solid waste generation)

When seaweed is cultivated at sea, it can play a significant role in climate change mitigation, as it can absorb large amounts of CO₂ (Directorate-General for Maritime Affairs and Fisheries, 2025). Especially fast-growing seaweeds have the opportunity to extract substantial amounts of CO₂ out of the atmosphere (Woods hole oceanographic institution, n.d.). Seaweed can also remove nutrients from the water, limiting eutrophication (van den Burg et al., 2021). When cultivating seaweed at home, these benefits might differ.

Research shows that about 9.2 kg of CO₂-equivalent is emitted per kg of dry weight harvested seaweed (Nilsson & Martin, 2022). Yearly, about 37.8 million tonnes of seaweed is being produced. This results in huge amounts of CO₂ being emitted (FAO, 2025).

The environmental impact of seaweed processing can be reduced in various ways. When the entire mass of the seaweed is processed into products, waste is prevented and consequently, so is the environmental impact. By using energy and chemicals only when this increases the product's value, no unnecessary resources are consumed. Where waste is generated during seaweed cultivation, it can be fermented to produce biogas. When seaweed needs to be transported, it is beneficial to reduce the water content in the seaweed prior to transport, or transport can be eliminated by processing the seaweed at the harvest site. All these measures reduce the environmental impact of seaweed cultivation (van den Burg et al., 2021).

For on-land tank cultivation, mostly the electricity used for pumping can cause an environmental impact (van den Burg et al., 2021). To tackle the high environmental impact, related to the energy demand, alternative energy sources such as wind, solar and other renewable energy could be used (Dinesh Kumar et al., 2023). It is expected that both the energy and the chemicals required for processing will decrease as the process is scaled up. Both factors can lead to the depletion of fossil fuels and climate change (van den Burg et al., 2021).

To the best of my knowledge, no information could be found on the amount of wastewater generated.

5.1.2 Economic dimension

This section provides an overview on the manufacturing and financial aspects of cultivating seaweed and describes the related indicators.

5.1.2.1 *Manufacturing (energy costs, water costs, yield, essential material)*

When looking at the necessary setup, a tank is a first essential requirement and can be categorised according to size and material. It is particularly important that the tank is able to provide filtered aeration, adequate light and nutrient circulation and is easy to clean. Various tank designs are available, such as round tanks, tanks with D-shaped ends or raceway tanks, each of which has its own advantages. An article from Dinesh Kumar et al. (2023), recommends a fiberglass reinforced tank for both indoor and outdoor systems with a size of 100l to 5000l. Piping systems are also required, such as PVC pipes, aeration tubes, control valves, agitators, aeration motors, water suction pumps and cooling units. The aeration and climate control systems are important for healthy seaweed and an UV and sand filter are required for the water supply. These are used to prevent contamination and epiphytes. A reliable power supply is also important to prevent temporary power cuts (Dinesh Kumar et al., 2023). To check the salt concentration, you can use a refractometer (Vlaanderen Huisdierinfo, n.d.).

A high yield can be produced by cultivating land-based seaweed on an industrial scale compared to marine cultivation. Where cultivation at sea might be influenced by environmental factors (temperature, salinity, pH and nutrient level), this can easily be kept under control when cultivating on land. Although diseases and epiphytes might still occur, a correction and solution for these diseases is possible when cultivating on land. Land-based cultivation offers the opportunity to maintain ideal circumstances, improving the growth of seaweed in each stage. At sea, nitrate requirements vary depending on water depth and seasonal conditions. Proper optimization and control of nutrient levels are crucial in the cultivation of edible seaweeds to ensure the production of nutritionally valuable biomass. Such control is generally more feasible in land-based cultivation systems. Land based cultivation also offers the opportunity to provide new species of seaweed that are not available in sea throughout the year (Dinesh Kumar et al., 2023). Cultivating in tanks can also provide high value co-products. Some seaweed species have been used as fertilizer and soil improver for decades (van den Burg et al., 2021).

There is a lack of detail regarding land-based seaweed cultivation, specifically concerning the design of the cultivation tank, the seeding method, the harvesting method and the post-harvest process (Dinesh Kumar et al., 2023).

5.1.2.2 *Financial (costs saved, material costs)*

Looking at the economic side of cultivating seaweed, especially energy costs are high. Seaweed tank cultivation is often considered an unsuitable method for large-scale commercial production. This type of cultivation requires high energy consumption and the use of expensive materials and specialized equipment, causing operational costs to rise significantly. According to Titlyanov and Titlyanova (2010), this makes tank cultivation economically unattractive for large-scale seaweed production. Equipment such as air pumps must remain in continuous operation for weeks to months. Selecting a blower with the correct power is essential, yet this remains one of the most energy-intensive components of the system (Khan et al., 2024).

In addition, the set-up of a tank cultivation system requires a substantial initial investment. Infrastructure is needed for the construction of tanks, buildings, and shelters, as well as a reliable electricity supply and installations for water pump, aeration and circulation systems (Dinesh Kumar et al., 2023). Besides these fixed costs, labor-intensive maintenance tasks also result in additional expenses. For instance, regular weeding (= the physical removal of algae and epiphytes) significantly increases production costs (Stévant et al., 2023). The seaweed sector in Europe still has some challenges as production is expensive (Directorate-General for Maritime Affairs and Fisheries, 2025).

The set-up of the tank will be different than described for home cultivation, as less material is available. Some examples of cultivation on industrial scale or in a lab can be seen in figure 13.



Figure 13: Installation at Ilvo, UGent and University of Antwerp

The indicator *costs saved* is not applicable for this section.

5.1.3 Social dimension

This section will discuss the social dimension, including the needed skills and safety measures.

5.1.3.1 Skills (difficulty level, hours of work, space required, required knowledge)

From a social perspective, various themes can be investigated within the seaweed sector. In the European context of seaweed production and processing, for example, working conditions, employment for women or the deployment of Asian migrants with specific knowledge and experience in seaweed cultivation could be relevant points of attention (van den Burg et al., 2021).

Labor-related aspects also play an important role within the operational phase of seaweed cultivation. The maintenance of seaweed cultivation farms and daily activities, such as cleaning, water changes, transplanting, harvesting and post-processing, require continuous and careful execution. To ensure these processes run efficiently and at a professional level, the deployment of skilled to highly skilled workers is necessary. This underscores the importance of human expertise and professional knowledge for the successful functioning and scaling up of seaweed farms. However, there appears to be a shortage of skilled and semi-skilled workers. Skilled workers will expect higher wages, making it a challenge to keep skilled staff (Dinesh Kumar et al., 2023). On the number of hours needed and the required space is no data available. It is assumed this will depend on the size of the set-up.

5.1.3.2 Safety (personal protective and safety equipment, food safety and health)

Cultivating seaweed also has some difficulties. Literature states that when cultivating seaweed in a tank, it can mostly be affected by epiphytes and other cyanobacteria. Epiphytes are types of life forms such as bacteria, protozoa and invertebrates that can colonize seaweed by growing on the seaweed's surface. The removal of this parasitic disease is important due to the potential crop loss (Dinesh Kumar et al., 2023; Khan et al., 2024). *Palmaria palmata* specifically is often affected by epiphytes such as filamentous red such as *Acrochaetium secundatum* and brown algae such as *Ectocarpaceae*. These epiphytes are shown in Figure 14. Epiphytes are a problem due to their competition with the host plant for nutrients and light. Also epibiont colonization such as encrusting bryozoan or also called *Membranipora membranacea*, can result in mechanical stress and tissue damage to the host plant and may reduce the reproductive output (Stévant et al., 2023). The impact of the epiphytes and epibionts can efficiently be controlled when cultivating seaweed in a tank. By a continuous water exchange and through controlled environmental conditions, this impact can be reduced (Dinesh Kumar et al., 2023). Biological hazards represent a major risk to food safety, with *Salmonella* being considered one of the most significant hazards. Other microorganisms, including *Bacillus* species, Hepatitis E virus and Norovirus, generally pose a moderate to low risk. In addition, heavy metals are seen as one of the biggest concerns for food safety. Other potential contaminants, such as pesticide residues, dioxins, brominated flame retardants, polycyclic aromatic hydrocarbons, marine biotoxins, plastics and pharmaceutical residues are mainly associated with marine-cultivated seaweed and are therefore expected to present a lower risk in land-based cultivation (Banach et al., 2020).



Figure 14: *Acrochaetium secundatum*, (Guiry, 2004) *Ectocarpaceae* (Wikipedia, n.d.–a) *Membranipora membranacea* (Wikipedia, n.d.–b)

There is no data available on personal protective and safety equipment, to the best of my knowledge.

5.2 Interviews

Interviews were conducted with four participants. Interviewee 1 cultivated seaweed at home as part of an art project. Interviewee 2 is an ex-employee at *Hortimare*, a big seaweed company. Interviewee 3 is an employee at *Rijtak*, a company recently specializing in seaweed and interviewee 4 is a PhD student at *University of Antwerp*, specialized in red seaweed.

As interviewee 1 is the only person cultivating seaweed at home, it is interesting to note that this person achieved a DIY set-up where seaweed could survive and grow. This person only used easily available and second-hand materials. Besides the success, they also faced some challenges, mainly on food safety, space and energy use.

5.2.1 Environmental dimension

This section provides information on the resources, emissions and pollution based on the related indicators.

5.2.1.1 Resources (use and reuse of resources, energy consumption, availability of resources, water consumption)

As nutrients, interviewee 1 used their own kitchen compost where the other two used F/2 media. Interviewee 2 does not think it is possible to add nutrients based on kitchen waste or kitchen materials. To make the cultivation of seaweed circular, interviewee 2 and 3 suggested to use the seaweed waste as fertilizer or for salt recovery. However, the participants have not yet carried out these proposed actions themselves. Interviewee 3 also suggested to use the wastewater to irrigate tomato crops at the company he works for. Interviewee 4 however stated that if you cultivate seaweed for food purposes, you normally harvest all the seaweed, so no organic waste is generated.

All four interviewees found it most important to find good seaweed and to know the ideal environmental conditions for this seaweed. They all state that replicating the natural habitat and to know the water, nutrients and light supply are essential to succeed in cultivating seaweed. The interviewees more specifically believe you should treat it as a houseplant.

"I think that's the most important thing. You always have to water a houseplant and make sure it gets some sun. I imagine it's the same with seaweed."

"Dat is denk ik het voornaamste. Een thuisplantje moet ook altijd water geven, zien dat dat zon krijgt. Dat zal met zeewier hetzelfde zijn." Original language

For interviewee 1, who lives in the Netherlands, some options for seaweed starter were possible. It is even possible to buy local seawater that's been filtered and UV cleaned. Wild harvesting is however illegal in The Netherlands. Interviewee 2's company provided seaweed themselves, but he can imagine people going to the beach to collect seaweed to start cultivating (although it is not always legal). Interviewee 3 gets the starter seaweed through research institutions such as *Ilvo* and *University of Ghent*. Interviewee 4 harvests her own seaweed at the French coast, where it is allowed to do so.

All interviewees state that energy consumption is rather high when cultivating on land. However, no exact amounts of electricity use were given. The water-use on the other hand depends on the size of the tank. Interviewees 3 and 4 use two times a four-litre tank. For the other interviewees, no exact information on water use is given.

5.2.1.2 Emissions and pollution (greenhouse gas emissions, chemical use, wastewater production, solid waste generation)

The environmental impacts discussed with the interviewees were mainly waste. All four agreed that the main source of waste is wastewater. For interviewee 1 and 4 this was rather minimal, around 1l-8l per week, the other interviewees did not specify the amount of wastewater. Besides wastewater, waste also includes plastic and gloves, especially interviewee 2 mentioned this.

Interviewees 1, 2 and 3 think cultivating seaweed at sea is greener than cultivating seaweed on land. Cultivation at sea however is weather-dependent. Interviewee 1 mentioned both sea- as land-based cultivation suffer from a lack of market, especially for lower grade seaweed. The advantage of growing seaweed on land is that it can provide year-round growth and has a cleaner production, but it is more expensive and requires diligent water management. To cultivate at home, water quality was seen as a primary bottleneck, including the difficulty of having a constant temperature, the management of unabsorbed nutrients to prevent contamination and the CO₂ balance.

Interviewees 2 and 4 believe the biggest advantage of cultivating at sea is the uptake of CO₂. They believe this is also possible at home, but more limited. Despite this advantage, the most important advantage for interviewee 2 remains the reliability of cultivation at home. Interviewees 1, 3 and 4 believe cultivation on land is good for the ocean because there is less wild harvesting and ecosystem services stay intact.

Interviewees 2, 3 and 4 use the standard F/2 medium as nutrient source. Interviewee 1 uses her own composted nutrients.

5.2.2 Economic dimension

This section provides an overview on the manufacturing aspects and financial aspects of cultivating seaweed and describes the related indicators.

5.2.2.1 *Manufacturing (energy costs, water costs, yield, essential material)*

Interviewee 1 used a DIY setup with a second-hand aquarium and freezer to grow seaweed at home. An *Inkbird* temperature controller and a pump to aerate the water were used. The water was cooled by pumping the water with pipes through the freezer. This is a fairly simple setup. They mainly grew sea lettuce (*Ulva*) and experimented with kelp. They estimated that the harvest was less than a kilo. This interviewee powered the house with solar panels, but energy remained one of the biggest issues and costs. To tackle the energy costs, and to assure a clean energy supply, this interviewee was thinking about installing a wind turbine as well. They stated that they discovered a way to grow it at home, but this is not fool proof.

The second interviewee used a professional land-based cultivation system. This required a substantial installation for water storage, UV filtration and cooling, making it a complex and a large-scale setup. The company he worked for cultivated all kinds of seaweed, including kelp, *Palmaria* and *Asparagopsis*. This is a large-scale commercial cultivation operation, so high yields are possible. He indicated that the biomass could double in a month but no specific information about the amount of yield was given.

The third interviewee uses two cylindrical PVC bioreactors of 4l. These reactors have an integrated lamp and air pump for recirculation. This is a small but well-equipped setup. They started cultivating a perforated variety of *Ulva* and harvests half of the tank every two weeks.

The fourth interviewee uses two flasks of 4l each to grow seaweed in. They are placed in a climate room with LED bulbs. There is also a pump used which is connected to the pipette. She explained it as a “DIY-PhD setup”. It is considered to be a small-scale but professional setup. The experiment only just started so yield could not be determined yet.

All four interviewees think cultivating seaweed with vegetative growth (ripping it apart to grow again) is feasible at home or on land. The second and fourth interviewee however stated that executing the whole life cycle might be tricky. Especially spore release might be hard to accomplish in home-based cultivation.

All four participants confirmed that a setup at home is possible without industrial tools.

All participants mentioned that the energy costs due to the cooling of the tank were high. Exact numbers however were not provided. The costs for water supply were not provided neither.

5.2.2.2 Financial (costs saved, material costs)

Especially interviewee 1 tried to minimize the costs on purpose, using mostly second-hand material. This resulted in a cheap setup of less than 100 euro. However, the electricity bills were remarkable higher during the time of this experiment. This interviewee suggested to lower the energy cost by building a small wind turbine at home. Interviewee 3 bought their small reactors for €1200–€1600 each. This interviewee summarized it well saying a small setup could cost a few hundreds of euros where a professional setup can cost up to hundreds of thousands of euros due to water treatment.

They all agree it is not currently profitable for small growers and is more of a passion or hobby. Interviewee 1 notes that space is probably a larger barrier than cost for most people. Interviewee 4 mentioned that compared to large scale cultivation, the costs per volume yield will probably be higher.

5.2.3 Social dimension

This section will discuss the needed skills and safety by discussing the indicators related to these topics, based on the available data from the interviews.

5.2.3.1 Skills (difficulty level, hours of work, space required, required knowledge)

When cultivating seaweed, time needs to be spent weekly. When starting to learn how to cultivate seaweed, up to four hours each day are needed, recording interviewee 1. Once you know how to cultivate seaweed, only five to ten minutes each day is required for maintenance, all 4 interviewees agree.

All four agreed that anyone can cultivate seaweed. While interviewees 1, 3 and 4 say one person is enough, interviewee 2 suggests two people for a semi-professional setup to handle daily tasks. When going on a holiday, someone else needs to be able to take over the tasks.

While everyone could do it, it is not a simple task to fulfill, bringing some struggles and uncertainties with it. Interviewee 1 stated:

“Why can't it just talk? Like, why can't we? Like, how do we communicate with this thing? Like, are we torturing it?”

Interviewee 4 mentioned that when harvesting marine seaweed, some physical fitness is required to reach the seaweed.

Interviewee 1 stated that the required space might be too much and difficult for people to cultivate seaweed at home.

Interviewee 4 also stated that the biggest advantage of growing seaweed is the fun you get out of it. You get a connection with the food you are eating, just like when people grow vegetables in the garden.

5.2.3.2 *Safety (personal protective and safety equipment, food safety and health)*

All interviewees indicated that some signs of unhealthy seaweed are fragility, see-through spots, rotting edges, excessive seed production and sliminess.

This person was also concerned about food safety. Interviewee 1 ate it themselves, but they did not feel it was safe enough for a public dinner or to give others. Compared to wild harvest, interviewee 2 and 4 considered it to be safer due to the possibility to control heavy metals. Interviewee 3 thought there was no safety hazard because of the usage of tap water and salt. Algae on the surface of seaweed could be rinsed off. Interviewee 1 and 2 also mentioned the fire risk or risk for electrocution when running a DIY seaweed cultivation 24/7.

Interviewee 2 is worried about the amount of iodine when eating a lot of seaweed. This is probably lower for home cultivation but should be kept in mind. Cultivation at home is probably safer and healthier.

To assure a health for both yourself as the seaweed, interviewee 2 recommend wearing gloves when entering the water. Basic hygiene is important. Interviewee 3 thinks due to the salinity, not a lot of bacteria will grow in the tank. Interviewee 4 believes the seaweed is safe to eat as long as the water looks healthy. The seaweed can be washed or dried, to minimize the risks. When collecting wild seaweed on the other hand, more uncertainty about the health arises. She states the risks are not higher than for example the growth of vegetables.

5.3 Case study

This section discusses the results of the case study, which were obtained by carrying out the steps involved in growing seaweed at home. This section is based on own experience.

5.3.1 Environmental dimension

This section provides information on resources, emissions and pollution and the related indicators, based on data available from the case study.

5.3.1.1 *Emissions and pollution (greenhouse gas emissions, chemical use, wastewater production, solid waste generation)*

First of all, looking at the greenhouse gas emissions, it's difficult to determine the exact emissions from the case study. The cultivation only emits indirect emissions from energy production, material production or other indirect steps. The electricity for the pump and the heat to warm the room emits indirect emissions that differ depending on the energy source. Although it cannot be determined how much greenhouse gases were emitted during the course of this case study, it is known that seaweed can also play a positive role in capturing CO₂ from the surrounded air. Literature even states that seaweed has a positive effect on capturing CO₂ (van den Burg et al., 2021). For the material, greenhouse gases are only released during production and transport of these materials. These emissions occur earlier in the production chain. When the used equipment reaches the end of their useful life, greenhouse gases may also be released during the processing of this waste.

During the case study, both plastic and paper waste were generated. Plastic was used to cover up the top of the aquarium, to avoid contamination as much as possible. When feeding the seaweed, the nutrients or adjusting the tank, the plastic needed to be replaced, causing quite some waste. During the time of this case study (3 months), almost a whole roll of plastic foil was used. This could be avoided by using a see-through lid instead. When performing actions on and in the aquarium, some water got accidentally spilled, so the surrounding areas had to be dried and cleaned. Paper towels were used for this purpose. Moreover, the used equipment such as the scale and salinity meter needed to be cleaned often. This caused half a roll of paper towels to be used. To clean the aquarium, besides the paper towels, a sponge was used. The aquarium needed to be cleaned before the start of the case study as well during, when trying to eliminate contamination on the side of the aquarium. This sponge is also considered waste and depending on the amount of cleaning needs to be replaced every couple of months.

However, the largest volume of waste was the salted wastewater. The water had to be changed once a week. Although only around 20% of the volume was changed each week, this resulted in approximately 21 litres of wastewater every week. At one point, the entire aquarium was replaced with fresh water to eliminate contamination, which produced almost 80 litres of wastewater. At the end of the experiment, the entire aquarium also had to be emptied. This salt water could not be reused during the case study. Consuming all the harvested seaweed produces no organic waste.

No chemicals were used in the design of this case study. To prevent soap from having a possible negative effect on the seaweed, the material was cleaned using hot water only. A feed mixture was used as feed. This mixture has not been specifically tested for human consumption, but following consultation with the company, it was determined that this would not pose a problem.

5.3.1.2 *Resources (Use and reuse of resources, energy consumption, availability of resources, water consumption)*

When looking at the resources, the biggest consumption was the usage of water. The aquarium with a capacity of 100 l was filled with approximately 86 litres of water. Each week, about 21 litres of water was replaced and once, the whole aquarium was replaced. During the whole period approximately 237.6 litre water was used

Twice a week, 5 ml of nutrients was added to the water. During the whole period of the case study, approximately 125 ml of nutrients was added.

To create a salty environment, *Instant Ocean* was used. The recommended amount of salt on the package was used. This equalled 1 kg of salt per 30 l of water.

The purpose of this case study was to only use available resources and materials. Everything therefor was easily available. Some materials such as the nutrients and salt needed to be ordered online but arrived only a few days later, making it very available. The seaweed on the other hand was much less easily available. For private individuals, no seaweed sellers exist in Belgium or near, making it very difficult to start cultivating seaweed at home. There is however a company in The Netherlands, *Hortimare*, who was willing to sell seaweed for this case study, but it was difficult, expensive and not for the general public. Thanks to the University of Ghent, who experiments with seaweed, some starter seaweed could be used for this case study. In general, seaweed availability is a huge issue for home cultivation.

Research mentioned a high energy consumption for large scale industrial production, causing high costs and, depending on the energy source, a significant environmental impact (Dinesh Kumar et al., 2023). Although the consumption at home is lower compared to industrial scale anyway, the costs and impact are further avoided by only using a pump for this case study. Resulting in a reduced energy use compared to industrial scale. The pump used 3.5 watt (Eheim, n.d.). During the period of this study, energy consumption was estimated to be 6.972 kWh. Due to some exceptional technical issues with the pump, also iron wire and tape were used to reinforce the pump.

None of the resources were reused during the case study.

5.3.2 Economic dimension

This section provides an overview on the manufacturing aspects and financial aspects of cultivating seaweed and describes the related indicators.

5.3.2.1 Manufacturing (energy costs, water costs, yield, essential material)

In 2025, the energy price was on average 0.38 euro/kWh, this however changes over time (Eneco, 2025). The pump used for the case study has a power of 3.5 watt (Eheim, n.d.), which equals 2.65 euro during the period of this case study.

Water costs between 4.7 and 6.7 euro average per household for 1 m³ (Vlaamse Milieumaatschappij, n.d.). During the period of this case study, the cost of water is estimated on 10-15 euros.

At the beginning of the case study, 611g seaweed was placed into the aquarium. After three days, 32g was taken out due to possible contamination. All the seaweed was harvested after six weeks, and the amount of seaweed then totaled 655 grams. In combination with the seaweed taken out earlier, the seaweed gained 76g. After harvesting part of the seaweed, the other part was placed back into the aquarium to grow. After another six weeks, a second harvest took place. For this harvest, yield could not be determined due to a mistake during the previous harvest. The weight of the seaweed after the second harvest was lower than the weight of the seaweed left in the aquarium after the first harvest. This would assume seaweed being taken out, which was not the case. The seaweed looked healthy after the second harvest, so degradation of the seaweed is unlikely. The most likely scenario is that during the first harvest of the seaweed, only the seaweed intended for consumption was weighed. The seaweed that was returned to the tank after harvesting was not weighed separately. The harvesting process took a very long time, causing all the water to drain out. The weighed seaweed was therefore dry, which means it weighed less. The assumption was made that the amount of seaweed in the aquarium was equal to the total weight at the start of the harvest minus the weight removed. This turned out to be incorrect due to the water. It was however visual that the seaweed grew a bit because there were more branches visual (see figure 15).



Figure 15: Branches after second harvest

As mentioned in the methodology (see section 4.2.3.1) an as simple as possible setup was used. Only an aquarium, pump, salt and nutrients were used. No freezer or heater to regulate the water temperature.

There were a few issues with the equipment during the case study. The pump kept coming loose, which meant the tank wasn't being aerated. This was sometimes spotted and fixed quickly, but if I was away for the weekend or even a week during the holidays, the tank would be without air for anywhere from a few hours to a few days. The scale malfunctioned also a couple of times, causing delaying the water change.

5.3.2.2 Financial (costs saved, material costs)

Most of the material for this case study were provided by the university. This results in an estimation of the costs based on the data available on the internet. These costs might differ depending on the moment and place you buy the material. All equipment has cheaper or more expensive options.

The most expensive cost is the seaweed starter. *Hortimare* asks around 300 euro + shipping for a starter sample of *Ulva*. To the best of my knowledge, no other seaweed providers for private customers were available. Another expensive cost is the aquarium. For a 100l aquarium, you easily pay at least 150 euro with most options ranging between 180-200 euro up to a couple of hundreds of euros. The salt costs about 52 euro for 10kg. Other equipment like the pump and nutrients cost around 15 euro with most pumps going to 20-25 euro. The pump used in this thesis costs around 35 euro.

The table below summarizes the costs.

Table 2: Cost estimation

Product	Price	Source
Aquarium	180-200 euro / 100 l	(Bol.com, 2026a)
Salt	52.5 euro / 10 kg	(Bol.com, 2026b)
Pump	34.99 euro	(Bol.com, 2026c)
Seaweed	300 euro	(Hortimare, n.d.)
Nutrients	16.25 euro	(Easy-life, n.d.)
Plastic foil	1.05 euro / roll	(Albert Heijn, 2026a)
Paper towel	2.99 euro / 2 rolls	(Albert Heijn, 2026b)
Thermometer	4.89 euro	(Bol.com, 2026d)
Scale	9.99 euro	(Bol.com, 2026e)
Refractometer	50 euro	(Bol.com, 2026f)
Water	10-15 euro	(Vlaamse Milieumaatschappij, n.d.)
Electricity	2.65 euro	(Eneco, 2025)
Extra	9 euro	(KBouwmat, 2026)
TOTAL	699.01 euro	

As shown in table 2 is the estimated total cost to start cultivating seaweed for the first couple of months around 700 euro. This can be lower or higher in reality.

5.3.3 Social dimension

This section will discuss the needed skills and safety aspects based on the indicators.

5.3.3.1 Skills (*difficulty level, hours of work, space required, required knowledge*)

When setting up and cleaning your tank, it takes about two hours. Twice a week, you need to provide some nutrients to the seaweed. At the same time, you can monitor and observe the seaweed, to check if the seaweed is in good conditions: no bleached spots, or weird colours and forms. This only takes about 10 minutes each week. Once a week, some water needs to be refreshed and salt needs to be added for the new water, taking about 30 minutes each time. The weekly time spend is comparable to the care of other plants at home and is not extraordinary. Once it is time to harvest however, a lot of time is needed. If you want to continue growing seaweed after harvesting, you need to cut off the tops of the seaweed and place the tops again into the water. This way, each seaweed plant needs to be cut separately, using a lot of time (up to 2.5 hours). If you do not want to continue growing seaweed, you can just take out the whole plant, which takes about half an hour. The picture below shows the process of harvesting where on the right side the cut-off tips are shown. These parts go back into the aquarium. On the left side, the harvested seaweed is shown. This part will be processed afterwards.



Figure 16: The harvested seaweed

The table below shows a clear overview of the spend time for each step of the cultivation process.

Table 3: Time spend

Activity	Time in minutes	Frequency
Cleaning aquarium before starting	60	Once at beginning
Putting water in aquarium	40	At beginning and after totally emptying
Salt calculation and stirring	10	At beginning and every week
Adding seaweed	1	At beginning
Weighting	2	At beginning and when you want to harvest
Technical problems	60	Exceptional
Cleaning contamination	30	Every 2 weeks depending on contamination
Refreshing water and salt	30	Every week
Nutrients + parameters	5	2 times/ week
Checking aquarium	5	2 times/ week
Cleaning aquarium	60	Exceptional, once
Emptying aquarium + clean	90	Exceptional, once
Harvesting seaweed	140	Depending on growth (here every 6 weeks)

The setup only needs the space required for the aquarium, no additional space is needed. It is however beneficial if the setup is not too far from a sink or shower and placed on a surface that can handle some water. The water needs to be refreshed once a week and the closer to a sink, the easier it is to do so.

Cultivating seaweed at home turns out to have quite some benefits. First of all, the practice of doing so is fun and watching the seaweed is calming. It gives fulfilment to be able to cultivate your own food. Another benefit of cultivating seaweed at home is the amount of people interested in the process. I had some very interesting conversations with people close to me on cultivating seaweed, but also with strangers like on the train. It offered nice perspectives and conversations. It also offers a nice opportunity to make people more conscious about the food they eat and where it comes from.

As well as being enjoyable, it also offers many nutritional benefits and possibilities. It provides your own source of protein, making you less reliant on supermarket suppliers. You also know what you are eating, and which ingredients you have and have not used. Unfortunately, growing your own food also carries certain risks. It is not easy to check at home whether the food is safe to eat.

The study revealed that every stage of seaweed cultivation is feasible, making the process viable. The seaweed was able to grow, although slowly. *Palmaria palmata* prefers cold temperatures, which makes cultivation at home more difficult. The case study took place between February and May. During this period, there were a few warmer days, resulting in a significantly higher water temperature. The temperature during the beginning this period was low enough (averaging below 20°C) but later on the temperature was rising (average between 20-22°C). Cultivation during the summer and heatwaves could make cultivation impossible during these periods. This could not be tested for this thesis.

When starting to cultivate seaweed at home, it was quite difficult to know what to do. This can cause uncertainty or stress. It is recommended to read up to the subject. Information on how to grow seaweed at home is not easily found. The websites mentioned above provide a simple step-by-step

guide, but this does not feel sufficient. Additional information on the selected seaweed species is recommended. Even after reading a lot of literature research, it is not easy to know what to do and how to handle signs of an unhealthy culture. Knowledge on food safety also stays out. Once you know what to do, no additional knowledge, considerations or calculations are needed.

5.3.3.2 Safety (personal protective and safety equipment, food safety and health)

Seaweed cultivation does not seem to be dangerous in any way. No real safety equipment or personal protection is required.

Food safety could not be tested during this case study. Due to the use of other nutrients than described in literature and due to visual algae growth on top of the seaweed, it is not sure if the cultivated seaweed is safe to eat. There has been eaten from the seaweed without any noticeable complications but eating self-cultivated seaweed might always be a risk.

The cultivation of seaweed did not cause any personal trouble. There was no smell present, only when refreshing the water, a little smell set free. This smell can be compared to the smell of the ocean. The sound of the pump could be experienced as annoying but could be easily replaced with a more silent alternative. All these parameters are of course personal and could differ between people.

When cultivating at home, it is difficult to prevent contamination. As it is impossible to work in a sterile environment, the risk of contamination is high. A researcher from Ghent University suggested countering this by using a higher density of seaweed, so that it outcompetes the other algae responsible for contamination. Administering half the nutrients recommended on the packaging, and doing so twice a week instead of once, is another possible way to prevent contamination. Plastic film placed over the top of the aquarium can also prevent contamination. Due to the amount and frequency with which nutrients are added, combined with the less-than-ideal conditions, the seaweed grows more slowly, meaning it requires more time and resources to reach a certain level of growth. The frequency makes it more labour-intensive for people to cultivate. If one goes on holiday, a solution must be found.

While cultivating *Palmaria palmata*, contamination was found. Followed by literature research, this could be *Acrochaetium secundatum* (Guiry, 2004), but determination is needed to be sure. Once this was noticed, an attempt was made to remove the debris with a sponge and rinse the seaweed with some salt water to loosen the remaining seaweed residue. The tank was successfully cleaned, but the contamination on the seaweed itself remained. After a couple of days to a week, the contamination on the tank was visible again. While harvesting all the seaweed, emptying and cleaning the whole tank was tried to remove the contamination and give the young seaweed the best chance to grow again. Unfortunately, this wasn't effective enough. Combined with the fact that the system may not have been aerated for a whole week and the warmer weather at the time, the contamination increased significantly (see Figure 17). The pictures below were taken at the beginning and end of this week, showing significant contamination growth. The third picture shows the situation two weeks after cleaning the tank.



Figure 17: Tank at beginning vs. end of week vs. 1 week later

Not only on the walls of the tank the contamination was visible, also on the seaweed itself. As can be seen on Figure 18, some greenish hair-like growth is visible on top of the *P. palmata*. Even after washing off, these 'hairs' remained.



Figure 18: Contamination on seaweed

As mentioned in the paper before, seaweed tends to bleach when under stress or not ideal circumstances. This was visible on small parts of the seaweed but was not a major problem, as can be seen on Figure 19. In general, even tips with a fresh red colour were visible, suggesting that the seaweed was in quite good condition and was growing.



Figure 19: Bleaching

This is only visible contamination, other, not visible, contamination was impossible to notice so could not be monitored.

As can be seen in Figure 20 was the contamination very severe at the end of the case study.

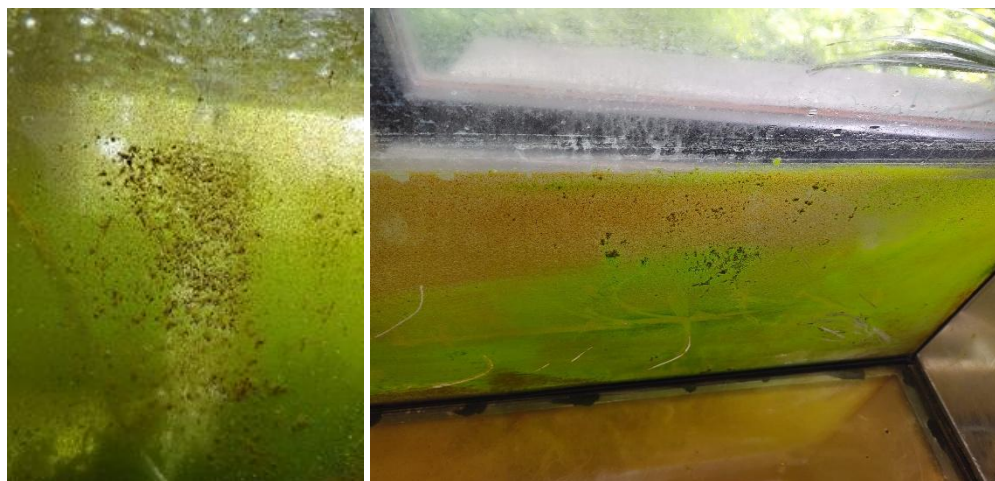


Figure 20: Contamination end of case study

5.3.4 Ulva

The cultivation of Ulva at school also showed some difficulties. Firstly, the air bubbles from the air stone caused the sea lettuce to shift to one side of the bucket, which can lead to uneven growth. Weighing the sea lettuce also proved difficult, as the material got stuck on the sieve, affecting the accuracy of the measurements. Working sterily presents an additional challenge. In a school setting, it is difficult to completely avoid contamination, which may affect growth and the reliability of the results. Because it is difficult to weigh the seaweed 'dry' identically, the measurements show variation unrelated to actual growth. The results are therefore indicative.

Although there were some difficulties, the cultivation of the sea lettuce was successful. The seaweed remained alive and showed a measurable growth of 8.22 grams over six weeks. The cultivation is highly suitable as a didactic tool to teach students about seaweed, as an application for food projects and to demonstrate growth processes in the classroom or in a laboratory environment. However, this cultivation is not suitable for consumption. Due to the challenges in maintaining a standardized, hygienic environment at school, the product is not safe enough to serve as food.

5.4 Cross-method results

The results from the different methods are brought together in this section. This way, the research questions concerning the advantages, limitations and feasibility of cultivating seaweed at home can be further answered. Table 4 shows a summarized cross-method overview of the results.

Table 4: Cross-method overview for home cultivation

	Literature review	Interviews	Case study
Opportunities	- Easily monitored and adjusted environment - Potential for high-quality biomass - High value co-products possible	- Strong awareness aspect - Personal satisfaction and engagement with food - Hobby - Kitchen compost could be used	- Increased awareness and connection to food - Enjoyable activity - Start conversations on sustainable food - Grow own food/protein - Educational

	- Fish and shellfish could be combined - Alternative energy sources possible - High yield - New species all year - Food safety assured - *Climate change mitigation, CO₂ absorption, limiting eutrophication	- Depending on scale not much wastewater - Year-round cultivation - No or limited organic waste → fertilizer or salt recovery - CO₂ uptake - Fun and connection with food - Heavy metal concentration reduced	- Energy consumption limited - Captures CO₂ - Easily available equipment
Barriers	- Labor-intensive maintenance tasks - Skilled workers necessary - High energy and material need and cost - Bleaching, diseases and epiphytes - Residual streams might be low-value - Depletion of fossil fuels and climate change - Substantial initial investment	- High energy costs (especially cooling) - Limited profitability - Availability of starter material is a barrier - Uncertainty about food safety - Regular maintenance needed - Requires basic knowledge - Whole life-cycle difficult - Space required - Fire risk and risk for electrocution	- Contamination difficult to control - Uncertainty about food safety - Slow growth and low yield - High water use - Practical issues and technical failures - Noise from pump - Expensive setup cost - Availability of starter seaweed - Requires knowledge
Feasibility	- Technically feasible under controlled conditions - Often used at industrial or lab scale	- Vegetative growth possible at small scale - Not feasible as economic activity - For everyone possible - Simple setup possible	- Depending on species - Depending on specific environmental conditions needed - Technically possible with basic setup - Depending on season
*It is assumed this benefit is lower for home cultivation compared to marine cultivation			

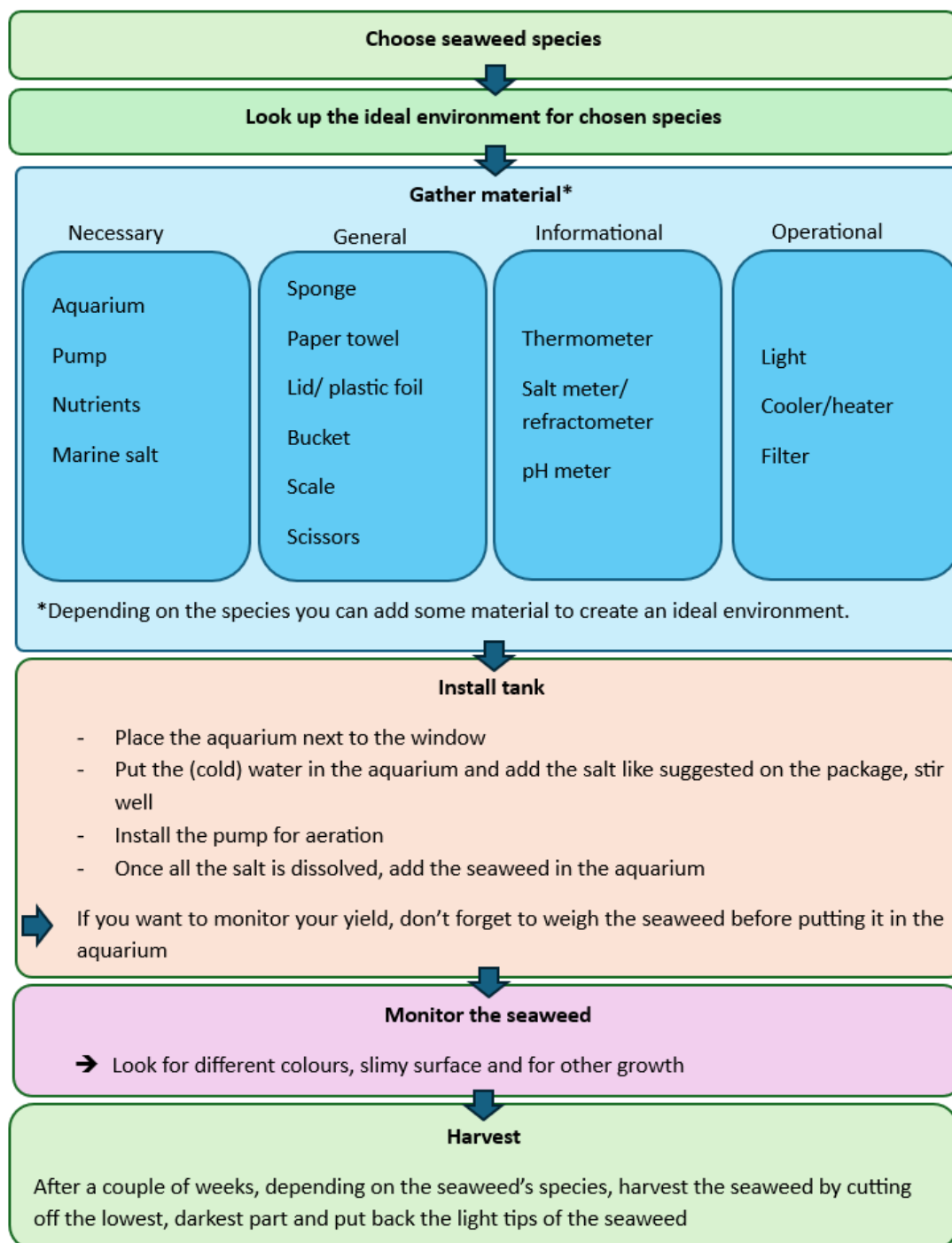
The different methods give the same conclusions for certain topics, as can be seen in the table above. The literature offers some more insights on how it is successfully being executed on industrial scale, while the interviews and case study offer a better overview on the social value of cultivating seaweed. All three methods agree on the feasibility and the role in CO₂ uptake. Diseases and contamination are put forward as concern for all three methods, however, literature states it is easy to reduce contamination on an industrial scale. For all methods, energy use and the related cost seem to be a major concern and knowledge on the topic seems to be important. However, the energy and the chemicals required for processing will decrease as the process is scaled up.

Based on the gathered information from the different methods, a simplified step-by-step plan was conducted. This offers a first stepping stone towards sharing information on how to cultivate seaweed at home. It also demonstrated the feasibility and offers the opportunity to facilitate cultivation in the future. Due to the limitations of this study and because there is not (yet) developed one specific

method to cultivate seaweed at home, this step-by-step plan is rather limited and should be supplemented when additional information is gained.

The basis for this plan is drawn from all the available information obtained through the three research methods. The list of materials draws primarily on the case study and the interviews, as the literature provided less in-depth insight into general and informative material that could be used for this purpose. The instructions for installing the tank are based mainly on the experiences gained from the case study.

Table 5: Step-by-step plan



6. Discussion

This report studied the opportunities and barriers of cultivating seaweed at home through a literature review, case study and interviews. This section provides a deeper understanding of the results from the perspective of each sustainability dimension.

Both the case study and the interviews showed that seaweed can be grown at home. It can be kept alive and slightly grow with a DIY set-up and material. The amount of growth and yield, however, depends on a lot of factors making it difficult to manage.

From an economic dimension, it appears difficult to cultivate seaweed at home profitably. The interviews and case study show that start-up costs (aquarium, salt, pump, seaweed starter, ...) can be high, which is also stated by (Titlyanov & Titlyanova, 2010). For this case study, it should be noted that the material used was provided by the university, so cost estimations were made based on online available information. When choosing a seaweed species with difficult-to-maintain environmental conditions, or conditions different than the normal conditions in the country of cultivation, additional material might be needed to cool or heat the tank. This results in extra costs and might result in a long list of material needed when replicating laboratories-like set-ups. Independent of the seaweed species, a constant energy and water cost is present. Given the scale, this could be seen as an acceptable cost. However, when adding additional equipment such as a cooler, heater or filters, the start-up cost and electricity cost increase, making cultivation at home less interesting. This is in line with what literature stated. Khan et al. (2024) mentioned the cost for electricity is the most expensive part to cultivate land-based seaweed. From the case study, only 76g of seaweed could be harvested over a period of six weeks. Additionally, the interviews and cultivated *Ulva* showed limited yield. Because of the costs and yield, cultivating seaweed at home turns out not to be able to outweigh the costs. All interviewees indicated that home cultivation currently should be seen more as hobby and not as a way of making profit or saving money. Moreover, the limited availability and high cost of starter seaweed might form a barrier. Where industrial systems struggle with high energy costs, investment costs and disease risks, they benefit from professional monitoring and higher yields. It can be concluded that growing seaweed at home is not economically viable, as it does not result in any cost savings and the yield does not outweigh the costs.

From an environmental dimension, home cultivation offers both potential benefits as clear disadvantages. The positive aspects include the low direct emissions and the limited requirement of agriculture land and material. It also offers opportunities to raise awareness regarding a more sustainable food system, putting less pressure on resources. Both literature and interviews showed opportunities for nutrient recovery and circularity. This, however, was not further examined in detail within the scope of this thesis but could increase environmental sustainability and decrease the impact. When cultivating seaweed, a relatively high amount of wastewater can be created, mainly due to the weekly water changes but dependent on the set-up size. Because of the salt level, this water could not be reused within a household. Installation of filters might however reduce the chance of contamination and therefore the need to change the water weekly. To cultivate seaweed at home, some plastic foil, gloves and disposable materials were used, causing waste. Besides the wastewater, the waste could easily be reduced by replacing the single-used products with other products. The emissions originate from the transport and production of all the equipment. Addition, electricity consumption produces emissions, causing a negative environmental impact. The exact amount is

difficult to calculate for home cultivation, depending on the energy source. When implementing renewable energy sources such as solar energy or wind energy, the indirect emissions related to electricity use can be reduced. Compared to industrial marine cultivation, home cultivation lacks the ecosystem benefit, stated by (Directorate-General for Maritime Affairs and Fisheries, 2025). It can be concluded that the environmental impact of home-based aquaculture depends on the scale of the operation, energy consumption and wastewater. A small-scale setup has a relatively limited impact. In general, home-based aquaculture does not offer the same environmental benefits as marine cultivation.

The social dimension highlights some positive impacts and possibilities. Besides being fun, it also offers educational opportunities both at school and in a private context. It can make people more conscious about their food choice and the current food systems. Cultivation at home can be carried out by anyone with a basic fitness level. The interviews and case study show that cultivating seaweed is not perceived as physically or mentally demanding. However, knowledge of the subject is required. Home cultivation differs from industrial cultivation in terms of material, scale and efficiency. Especially the lack of control over food safety and contamination is a big issue for cultivating seaweed at home compared to industrial scale. This contamination is a big issue when cultivating at home and is difficult to solve. Whether or not home cultivation can be seen as food safe could not be concluded in this thesis. The pump also makes some noise, which could be seen as annoying. It can be concluded that cultivation primarily offers opportunities for leisure and enjoyment, but solutions for food safety are needed.

Solutions can be found for many of these obstacles. For example, renewable energy sources can be utilized, different species can be cultivated and information can be made available. As regards contamination, there is currently no clear solution available, which causes a problem for food safety. The ability to consume seaweed is an essential aspect of home cultivation. A solution to this problem must be found. Even the use of a laboratory-like setup offers no guarantee of food-safe cultivation.

This research stated that it is possible to keep the seaweed alive, that is step one, the next step is to examine how and if the barriers could be overcome, with main focus on food safety. Because everyone could cultivate seaweed, it is especially interesting to examine this further.

This report was subject to some limitations. Due to resource constraints and the lack of eligible candidates (who had cultivated seaweed), only four interviews took place, which is a rather small amount to draw strong conclusions. More interviews are needed, especially with people cultivating seaweed at home. In Asia, the knowledge on home cultivation seems to be more evolved, especially this knowledge could be of high value. Within the case study, only limited species and configurations were tested, limiting the reliability. More species under different environmental conditions should be tested and evaluated. This should be complemented with research on setup possibilities. Much more research on the economic viability of cultivation at home, the environmental impact and the social benefits is needed to fully understand the value of home-cultivated seaweed. Regarding the technical aspects, some difficulties with the proper functioning of the pump and scale might have influenced the results. Repetition of the case study or larger-scale experiments are therefore recommended.

While it cannot compete with industrial cultivation in terms of efficiency, yield, or food safety control, it fills a niche in food awareness. Despite the difficulties, seaweed cultivation certainly offers potential

if further research is carried out. Especially the process needs to be optimized in order to strengthen and realize the opportunity to cultivate plant-based proteins at home.

Further research could provide valuable insights into which seaweed species are most suitable for home cultivation and which setups are required for each species. For example, exploring greenhouse cultivation could be promising, as it may reduce energy costs and help maintain more stable temperatures compared to indoor systems, particularly during autumn and winter. The integration of renewable energy sources could further lower energy costs and improve overall sustainability.

In addition, future studies could investigate ways to minimize wastewater production, such as through wastewater reuse or the implementation of filter systems. Such systems may not only reduce water use but also play a role in limiting contamination. More research is therefore needed to identify best practices for safe and efficient home cultivation setups.

Other potential solutions, such as introducing algae-eating fish, could offer accessible approaches to controlling contamination. Likewise, improving water circulation may help reduce contamination levels, although this still requires experimental validation.

Given the scope limitations of this thesis, future research could also examine a wider range of cultivation systems and seaweed species in order to determine more optimal and practical setups for home use.

Policymakers could contribute by providing clearer guidance and accessible information on home seaweed cultivation. At the same time, industrial stakeholders could support this development by supplying starter seaweed and tools to assess food safety. These efforts, however, must be grounded in robust scientific research.

7. Conclusion

This research aimed to examine the opportunities and barriers of growing seaweed at home through a literature review, a case study and interviews, with specific focus on economic, environmental and social dimensions. From the results can be concluded that growing seaweed at home appears to be technically possible but still has to overcome some challenges.

Based on all the research methods used, it can be concluded that it is technically possible to cultivate seaweed at home. The interviews and case study showed that especially vegetative growth can take place in a domestic environment using relatively simple materials. Setting up a laboratory-style setup even increases the feasibility. However, this leads to a long list of required materials and higher energy consumption but also offers opportunities for good growth and a high yield.

Although feasible, cultivation still faces a number of obstacles, particularly when the ideal setup is not implemented and, as a result, the ideal environmental conditions are not present. Uncertainty regarding food safety, available information and the availability of seaweed present difficulties when starting to cultivate seaweed at home. If a laboratory-like setup is not implemented, slow growth and a limited yield must be taken into account, as growth is highly dependent on environmental conditions. These conditions are difficult to control and maintain at a stable level with minimal equipment. When using minimal equipment, cultivation becomes highly species-dependent. For example, to achieve a higher yield with *P. palmata*, more stable environmental conditions appear to be required. The main by-product is wastewater and can currently not be reused in a domestic setting. Furthermore, home cultivation requires regular time commitment, basic knowledge and continuous monitoring, which may act as a barrier for some people. From an economic perspective, it can be concluded that home cultivation is currently not profitable. The combination of relatively high start-up costs, energy and water costs and a very limited yield make cultivation not interesting. The low yield from the study confirms that small-scale seaweed cultivation is not a realistic alternative to commercial production or self-sufficiency.

Home cultivation also offers a number of opportunities. It can be made circular by using homemade compost, and the (limited) organic waste produced can be used as fertilizer. Cultivation also offers many opportunities for education, raising awareness, leisure activities, brings people closer to their food and encourages discussion about sustainable food. Additionally, the environmental impact is limited and the cultivation is accessible to a wide audience due to the limited complexity.

In conclusion, home cultivation of seaweed is currently not a practical solution for large-scale protein production or self-sufficiency. Nevertheless, it may represent a meaningful step toward a more sustainable and diversified food system.

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9. Synthesis report

Synthesis report 10/9/2025

During this meeting, we discussed possible thesis topics and research. We planned a new meeting and agreed on the following steps. She asked me to do some research on circularity by the following week. I completed the requested preparation.

Meeting 10/23/2025

Agreed that I would continue researching the barriers to growing seaweed at home. In addition, other avenues would be explored further. Namely, inquiring about LCA possibilities and requesting topics from colleagues and my supervisor. I completed the requested preparation.

Meeting 10/29/2025

Agreed to continue with Seaweed at home. Interesting points to explore: comparison, costs, time, impact, is there a demand for this, industry comparison, challenges. Also agreed that I would further investigate whether it is possible. Concrete agreements about methodology.

Informal meeting after class

Co-promotor suggested not to include literature research in methodology but make a separate chapter instead. Also, the framework for interviews is not necessarily, instead a framework for the indicators might be more interesting. I implemented all the feedback as good as possible. I learned that different researchers have slightly different approaches.

Feedback draft 1: problem statement and introduction

Both supervisors provided feedback on the first draft. I incorporated all suggestions and supplemented the text where necessary. The suggestion to merge the introduction and the problem statement could not be implemented due to the guidelines. I learned a lot on the structure of both parts.

Feedback questionnaire:

All suggestions to combine or rephrase questions were followed. It made me realise that not everyone understands scientific terminology and that the questions need to be adapted to the interviewee.

Feedback interim paper:

Almost all of the suggestions were used. Only a few were changed due to a slightly different approach and order for the following version. I gained a lot of insights on the best way to structure thesis. The feedback was very valuable.

Feedback on whole paper:

Some parts that seemed clear to me turned out not to be clear for readers, offering very valuable insights. The comments were as good as possible adapted, with a focus on making it understandable for everyone.

Conclusion and discussion:

some clear directions on the placement of some paragraphs were implemented as suggested by supervisor. The different paragraphs changed place as suggested.

10. Attachments

10.1 Interview questionnaire

1. GENERAL

This research is about cultivating seaweed at home. It is part of my master's thesis in Environmental Science. The purpose is to gain information about your experience. I will compare this information with my own case study and with the literature. At the end of my research, I would like to have another short talk about my findings and whether you agree with them.

11. Introduction

- I would like to start with asking to introduce yourself.
 - Name
 - Link with seaweed
- Why did you try to grow your own seaweed and where did you get the idea?
 - Nutrition, experimentation, sustainability, income?
- What is the main reason you started cultivating seaweed?
- How long have you been growing seaweed/ How long did you grow seaweed?

12. Home cultivation

- How does your installation look like and which infrastructure do you use?
 - (Pump, heater/cooler, ...)
- Which species do you use and are they suitable for home cultivation? Why did you choose these species?
- Where did you get your starter seaweed?
- What should a beginner definitely take into account and are there any important considerations
 - (placement, hygiene, odour, water replacement, safety)?
- Did you have concerns about food safety or health?
- Have you been successful at growing seaweed?
- If yes: How much biomass can realistically be harvested on a small scale?
- What are typical signs of an unhealthy culture?

13. Life cycle

- Can all stages of the life cycle (sporulation, seedlings, growth, harvest) be carried out on land?
- Which stages cause the most problems?

14. Advantages/disadvantages

- What do you consider to be the advantages and disadvantages, or limitation of on-land farming compared to farming at sea?
- What are the advantages and disadvantages of growing seaweed at home?
 - What are the potential bottlenecks when cultivating seaweed in a domestic environment?
- What are the factors influencing successful growth the most?
 - Which external factors are difficult to control?
 - (Light intensity/spectrum, Temperature, Nutrient balance, pH and water quality, Salinity, Flow/aeration)
- What are the main challenges you faced?
 - What technical challenges are there (infrastructure, water quality, sterilisation)?
 - Did/do you experience problems with materials or availability?
 - Have you encountered any issues regarding contamination?
- What would you do differently?

2. PEOPLE

- How many hours a day or week do you spent taking care of seaweed?
 - Which phase is the most time- consuming?
- How physical intensive are the different phases?
 - (start-up, maintenance, harvesting)?
- Can anyone do it, or is specific prior knowledge required?
- How many people are needed for a small-scale setup?
- Are there any safety aspects that people need to take into account?

3. PROFIT

- Can you give me an estimation of the costs related to cultivating seaweed?
 - How expensive is it to start on-land or small-scale cultivation?
 - What are the fixed maintenance costs (water, nutrients, filters, lighting, electricity)?
 - What hidden costs?

- What are the highest costs in on-land farming?
- Did growing your own seaweed saved you any costs?
- Can small growers make seaweed cultivation profitable?
- Could costs be a main barrier for people to start cultivating seaweed at home?

4. PLANET

- How much waste is generated during growing seaweed and maintenance?
 - How much water did you need for growing seaweed?
 - What step/action causes the most waste?
- Do you think organic kitchen waste could ne used as nutrients/food to grow seaweed?
- Do you think the organic waste of seaweed can be composted or used in circular systems?
- Is it possible to use all materials at home without industrial tools?
- What do you think are the ecological benefits or risks of small-scale on-land cultivation