UiT The Arctic University of Norway

Faculty of Biosciences, Fisheries and Economics

Green movements below the surface

Developments in the macroalgae cultivation industry in Norway

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Master's thesis in International Fisheries Management, FSK-3910, May 2021

Acknowledgements

I am lucky to have so many great people surrounding me and supporting me. My friends abroad, my friends here in Tromsø, my friends from UEA, my Oslo friends, my Stavanger friends, my extended family, my two brothers and my parents. In my life you support me in all of my endeavours, and without you, I would not have been able to embark on the journey that I have. Knowing that I have all of you in my life, I feel safe and free to do anything.

I would like to thank my caring supervisor Signe, who supported me and inspired me to do a project on a topic I wanted to write about, in a way I wanted to write about it, and Daniel, who could always provide me with hints and tips on how to manage the thesis writing. I would like to thank my fellow students at UiT. Together, and apart, we have endured studying and living together in unprecedented times.

Tromsø, 18. Mai, 2021

Abstract

Macroalgae can benefit society in a variety of ways, and there is a lot of potential for cultivation of macroalgae in Norway. A sustainable development of this industry is needed to make use of these benefits, today and in the future. Hence, it is asked which opportunities and barriers exist in developing the industry and how the barriers are affecting this development. Inspired by a Grounded Theory Approach, firms, municipalities and counties working with the industry are asked about their thoughts about future developments. It is found that there are a number of barriers and opportunities in the industry and that important barriers in developing the industry sustainably include profitability, production value, area use and research and innovation. It is suggested these barriers all play important roles in explaining the development. It is also suggested that there could be underlying reasons how the barriers are affecting this development.

Keywords: Macroalgae, Cultivation, Sustainability, Grounded Theory

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List of Abbreviations

BSI	Barentswatch Sustainability Indicator
IMTA	Integrated Multitrophic Aquaculture
MAC	Macroalgae Cultivation

1 Introduction

We are experiencing many challenges in our world today. The release of greenhouse gases such as carbon dioxide traps heat and causes global temperatures to rise (United Nations, 2016a), our oceans are threatened by deterioration and acidification is having an adversarial effect on the functioning of ecosystems and biodiversity (United Nations, 2016b), and it is estimated that 690 million of us go to bed hungry every night, with numbers increasing in 2020 (United Nations, 2016c). Seaweed production may have the capacity to mitigate several of these challenges simultaneously (Barbier et al., 2019). Seaweed binds carbon and produces oxygen and can therefore counter the release of greenhouse gases (Kraan, 2013). Seaweed absorbs organic waste, it can facilitate other ecosystems and it can be used as bioplastic (Norderhaug et al., 2020), all of which could contribute to cleaner, healthier and living oceans. Because it is a rich source of nutrition that can be grown rapidly, it can also contribute to combat world hunger (Barbier et al., 2019). Moreover, all these benefits could be achieved at a low cost, as seaweed production takes no chemicals, no fertilizer, no fresh water, and no land to grow (Kraan, 2013).

Through its updated Ocean Strategy (2019) the Norwegian government aims to secure a blue vegetation and blue forest in order to bind carbon and maintain marine biodiversity. In the Climate Plan for 2021-2030, the government states that “Norway aims to produce healthy, safe, sustainable and climate friendly food by 2030”. The Norwegian Prime Minister has accepted the role as Patron of the Ocean-decade-alliance and Norway is one of the biggest contributors to the UNs Decade of Ocean Science for Sustainable Development (Ministry of Foreign Affairs, 2021). These political visions are supported by realism as Norway has one of the longest temperate coastlines in the world with very good conditions for cultivation of seaweed (Norderhaug et al., 2020).

However, despite the many advantages and opportunities of macroalgae cultivation, the political visions, and the realism of such a development, there seems to be little actual development in the industry. Norderhaug et al., (2020) estimates that Norway could produce 20.000 tonnes of seaweed per km^2 along the coast. Yet, in 2019, only 117 tonnes were produced, with few actors taking part in production (Fiskeridirektoratet, 2020). Why is it so? Are the uttered goals merely empty words? Is the potential for seaweed an illusion? Why are we not making more use of this incredible resource?

The Oxford Dictionary (Stevenson, 2010) describes potential as something that can develop into something or be developed in the future. From this definition, it seems clear that a development needs to occur, and steps need to be taken, for the potential advantages of seaweed to be realised. In this explorative study the aim, therefore, is to explore why despite apparent great potential, the Norwegian macro algae industry, seems to lack development. To explore this, I will attempt to answer the following research questions:

1. Which opportunities and/or barriers exist in the sustainable development of the macroalgae cultivation industry in Norway?

2. How are the barriers affecting this development?

In answering these questions, I will first identify the opportunities and/or barriers that exist in Norway. Given the scope of this thesis, I will then focus on the barriers that are most important in understanding this development.

2 Background

2.1 Macroalgae

Macroalgae, a technical synonym for seaweed (Jiang et al., 2016, p. 48), is a macroscopic, multicellular plant-like organism comprising more than 10 000 species, often divided into green, brown and red whereby ca 1500 are green (also named Chlorophyta or Charophytes), ca 2000 are brown (Phaeophyceae) and ca 6500 are red (Rhodophyta) (Barbier et al., 2019).

Nutritional composition of seaweeds varies according to the type of species, geography, environment, season and also within populations (Barbier et al., 2019). However, they are often rich in minerals (Na, K, P, Ca, Mg, I, and Fe)-10-20 times of the amount usually found in land plants (Gupta & Abu-Ghannam, 2011) -and anti-oxidants (Cornish & Garbary, 2010). Seaweed generally contains quite small amounts of protein, (although this can reach up to 47% for some species, Barbier et al., 2019, p. 118). Seaweeds are rich in dietary fiber, fatty acids, essential amino acids, vitamins A, B, C, and E (Rajapakse & Kim, 2011). Seaweed can be a healthy substitute to salt (Rioux et al., 2017) and a source of iodine (Duinker et al., 2020).

Macroalgae generally live attached to rock or other substrata in the marine benthos (Raven & Hurd, 2012) of coastal areas (Barbier et al., 2019) where it grows by photosynthesis by absorbing dissolved nutrients (FAO, 2020, p. 27). Cultivation of seaweed can be carried out in a variety of ways and varies with the type of species (see, Guiry & Blunden, 1991). They show how the natural growth characteristics and fertility of the seaweed can be used in farming to attach the algae to certain structures, such as shells, nets, ropes and bundles from which the seaweed can grow.

2.2 Use

2.2.1 Human nutrition

As mentioned earlier seaweed is a rich source of important nutrients. Seaweed is a famous delicacy in parts of Asia and a source of important agar, alginates, and carrageenan (Rajapakse & Kim, 2011). Seaweed can be used in salads, sushi recipes, or as various food additives (Buchholz et al., 2012, p. 472).

2.2.2 Animal nutrition

The rich level of nutrient make seaweed a good alternative for feeding domesticated animals. Particularly valuable in this regard are the complex carbohydrates, pigments and polyunsaturated fatty acids and the all the essential amino acids that is rarer in other sources of feed (Barbier et al., 2019).

2.2.3 Pharmaceuticals

Macroalgae is being explored as a new and sustainable source of bioactive compounds for use in pharmaceuticals (Barbier et al., 2019). Pangestuti and Kim (2011) look into what they call "natural pigments" which exhibit antioxidant, anticancer, anti-obesity, and neuroprotective activities. Using Kim and Joh (as cited, p. 260) Pangestuti and Kim find that the natural pigments could play a significant role in mediating Parkinson's disease, Alzheimer's disease, multiple sclerosis (MS) and AIDS related dementia.

2.2.4 Cosmetics

Barbier et al., (2019) point out that different seaweed species may have different applications and therefore occupy a variety of niches within the cosmetics sector. They mention a variety of uses in cosmetics and list texturing stabilisers, colouring agents and bioactive extracts which they say have positive impact on the skin. The latter is also highlighted as an important application by Pimentel et al., (2018) who find that certain ingredients in seaweeds have particular skin-health promoting effects.

2.2.5 Bioenergy

Bioenergy can play a substantial role in supplying future energy demand in a sustainable way (Bauen et al., 2009). Given its potential for high levels of production, macroalgae has been considered a potential contributor to such energy (Goh & Lee, 2010). They find that carbohydrates derived from seaweeds are particularly suitable for developing ethanol for use in fuel.

2.2.6 Bioplastic

Bioplastics are the form of plastics derived from renewable biological sources (Rajendran et al., 2012). Because of its ability to grow when cultivated, seaweeds can serve as one of the alternatives for the production of bioplastics (Rajendran et al., 2012). Rajendrand et al., (2012) find that seaweeds as bioplastics are more resistant to microwave radiation, less brittle and durable in comparison to other bioplastics.

2.3 Early developments of the macroalgae cultivation industry

Using archeological findings, Dillehay et al., (2008), suggests that macroalgae has been used by humans for 14.000 years, whereas the earliest *written* records of seaweed usage can be traced back to China around 1700 years ago (吴都赋, as cited in Yang et al., 2017, p. 253). The *farming* of seaweed can be dated back to Japan in the 1600s according to Tamura (as described in Buchholz et al., 2012. p. 472) where the first specie to be cultivated was the red seaweed Porphyra or "nori" (Guiry & Blunden, 1991, p. 313). They find that one of the main reasons why cultivation of seaweed started, was high demand for it as a source of food and lack of supply from wild populations. Suitable substrata, in the form of "brushwood bundles" were set in shallow water to "facilitate settlement of spores" from natural populations (p. 313). Around the 1800s, cultivation of seaweed started in China, by cleaning stones, enabling growth at the appropriate season (p. 313).

Despite an aquaculture tradition of many centuries in parts of Asia, aquatic farming on the global scale is still a young sector (Buchholz et al., 2012. p. 471). Guiry and Blunden (1991) studied the use of seaweed resources in Europe and found that the Greeks collected seaweed from shore to give to their cattle around 45 BC (p. 21). They suggest that the lack of seaweed usage in Europe can be explained by economic development and less settlement along the coast because of industrialisation and reduced dependence and knowledge of local resources. European production of seaweed (harvest and farming) remained stable at above 350,000 tons until 2000 and has since decreased, with Laminaria and Ascophyllum as the main genera (Barbier et al., 2019). Until 1990 seaweed was not regulated as a source of food in Europe and that year, France became the first European country to establish a specific regulation concerning the use of seaweeds for human consumption (Mabeau & Fleurence, 1993). Stévant et al., (2017) find that in recent years, seaweed cultivation has received increasing interest in Europe supported by trends towards a bioeconomy based on natural resources. Europe has good conditions for seaweed farming (Barbier et al., 2019)with large exclusive economic zones, a high seaweed biodiversity and a leading role in research on macroalgae.

2.4 Global production

Total world production of macroalgae increased from 10.6 million tonnes in 2000 to 32.4 million tonnes in 2018 (FAO, 2020). In 2018 cultivation made up 97.1% and harvest made up 2.9% (FAO, 2020, p. 29). Harvesting wild seaweed could lead to potentially significant, negative ecological responses globally (Rebours et al., as cited in, Monagail et al., 2017). The main producing countries are China (18505.7 m/t), Indonesia (9320.3 m/t) and the Republic of Korea (1710.5 m/t) (FAO, 2020, p. 27). The most common produced specie is the Japanese kelp (Laminaria japonica) which constitutes more than one third of total production (p. 32). Globally there has been a slowdown in growth of farmed seaweed rates in recent years (FAO, 2020, p. 29). The reliability of these numbers must be considered with attention as they are not always properly consolidated and spread (Buchholz et al., 2012, p. 472) and due to confidentiality, data are limited by some producing countries (FAO, 2020).

2.5 Developments in Norway

The use of seaweed in Norway can be traced back more than a thousand years (Norsk Fiskenæring, 2020). In the Frostathing Law, it was specified who could eat seaweed, where and when (Hagland & Sandnes, 1994). Since the 1800s, seaweed has been mainly burned to produce ashes for production of glass and soap (Norsk Fiskenæring, 2020). This has been mainly done by harvest of wild caught seaweed. Norway started early in developing a large scale aquaculture industry of marine species in the 1970s (Edwards, 1978). Despite such traditions, the cultivation of seaweed is a rather new industry as cultivation of kelps at sea only started in experiments from 2005 (Stévant et al., 2017) and the first licenses for cultivation were granted first in 2014 (Fiskeridirektoratet, 2020). In the first year, 10 companies received a license, and the number grew steadily until 2019, when it fell from 172 to 166 (Fiskeridirektoratet, 2021). In this development it is also important to note that even though a license is held by a company, it doesn't mean that production is actually taking place there. According to Fiskeridirektoratet (2020), the total production of farmed algae was 117 metric tonnes in 2019. "Sea Belt" was the most produced specie (73 MT), followed by "Babberlocks" (44 MT). Other species which have been farmed include "Dulse" and "Nori nei".

2.6 Obtaining a license for aquaculture in Norway

From Kommunal-og moderniseringsdepartementet, (2018) we can read that several public bodies are involved in the process of approving a license for aquaculture. Until 2019 it was the Ministry of Trade, Industry and Fisheries that distributed and oversaw the allocation of licenses. Today it is the County Authority that distributes the application to the relevant public bodies involved and has the authority of allocation. The process must act in accordance with the Aquaculture Act which corresponds with the Ministry of Trade, Industry and Fisheries. The Act states that it shall contribute to the profitability of the aquaculture industry and competitiveness within the boundaries of a sustainable development, contribute to value creation along the coast and that one must have permission by the local spatial plan to conduct farming (§ 15). The local spatial plan is a document decided by the municipality in which the farming takes place. Mattilsynet and the County Governor must also approve aspects of the license in relation to the respective laws they are subjected to. In addition, Kystverket must approve the license, sometimes in instances requiring tapping of freshwater NVE must approve. Finally, Fiskeridirektoratet have authority to give their recommendations into the matter. A license can only be given if it adheres to fish health and welfare, the environment and the spatial plan and is approved by all the public bodies involved.

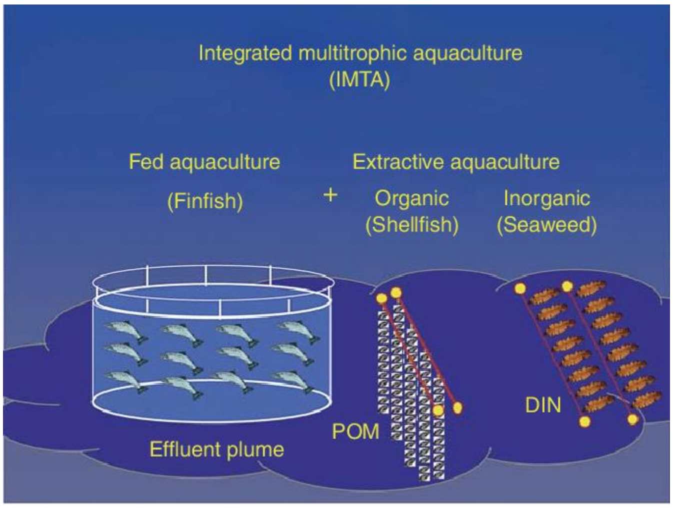
2.7 Future developments

2.7.1 Integrated Multitrophic Aquaculture

In a response to growing concerns of the environmental impact of intensive fed aquaculture Chopin et al., (2001) presented an idea of how species of different trophic levels could benefit of one another if placed in proximity to one another. He described what he called a "balanced ecosystem approach" (Chopin, 2006), a system that combines aquaculture of fed species with aquaculture of extractive species, that either consumes dissolved inorganic nutrients from the fed specie or particulate organic matter from the other species (see Figure 1). By placing these in proximity to one another, Chopin (2006) shows how the environmental processes at work may counterbalance each other. Seaweed can play an important role in such a system, by removing waste materials from fed species, and lower the nutrient load (FAO, 2020, pp. 27-29).

Figure 1

Integrated Multitrophic Aquaculture



Note. Illustration by "Multitrophic Integration for Sustainable Marine Aquaculture" (2021) Diagram illustrates the concept of Integrated Multitrophic Aquaculture where farming of a fed species (e.g finfish) is combined with extractive aquaculture in the form of one organic (e.g Shellfish) and one inorganic (e.g Seaweed) species. The process takes advantage of the particulate organic matter (POM) and the enrichment in the dissolved inorganic nutrients (DIN).

A real world example can be illustrated in a project in Steigen, where a company (Folla Alger) is undergoing the process of developing an IMTA system where salmon is farmed in combination with seaweed (Kyst.no, 2018). The waste from the salmon is used as fertilizer for the seaweed, and the seaweed will be used in feeding of the fish. An important step in the development of IMTA is up-scaling of the experimental systems and an establishment of the appropriate food safety regulatory and policy frameworks (Chopin, 2006). The food safety aspect is being addressed by Mattilsynet which is still not certain about the quality of such seaweed (see, for example, Fiskeridirektoratet, 2018). Despite these challenges FAO encourages more use of IMTA (FAO, 2020, p. 29).

2.7.2 Offshore

Another possibility that might be more developed in the future is offshore aquaculture of seaweed where large rafts of seaweed beds are left floating offshore, to allow efficient use of space (Notoya, as described by Buschmann et al., 2017). This is also discussed by Norderhaug et al., 2020, who shows that combining such activity with windmills could reduce the number of conflicts inshore.

3 Theoretical framework

3.1 Introduction

Sustainable development lays an important foundation as a reference point and framework for this study. In the following section I will discuss what sustainability is, and how and why it can help us understand the opportunities and barriers in the macro-algae farming industry in Norway.

3.2 Sustainable development

Sustainable development is a concept that became popular after it was described in the Brundtland Commission Report, "Our Common Future" in 1987 (Rogers et al., 2012). It was written by the "World Commission on Environment and Development", a body created by the UN General Assembly, headed by the former Norwegian prime minister Gro Harlem Brundtland (Rogers et al., 2012). Sustainability was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43). In the context of macroalgae cultivation (MAC), we could understand this as the potential for macroalgae to be produced in a way that doesn't compromise the ability of future generations to meet their own needs. Given the potential advantages of MAC, this would seem like a good source for sustainable development. In fact, if macroalgae have the potential that is described in the introduction and background chapters, it may even not be a question of development *without compromising* future generation's needs, but rather a development *enhancing* their ability of these needs. The definition, however, is quite open, and it is not straightforward to grasp what the "needs of the present" is, or what "compromising the ability for future generations" entails. Costanza and Patten (1995) write that we need consensus on "what we want to last" and for how long (p. 193).

Due to this complexity, many attempts have been made to better understand sustainable development. Costanza and Patten (1995) simply describes it as a system that survives or persist. Rogers et al., (2012) focuses on the interplay between environment and development saying that sustainability is meant to bridge the gulf between the two. Bartelmus (as cited in Barbier, 1987, p. 101) adds to this that the goal of both environment and development is to improve human welfare for present and future generations, whilst Repetto (as cited in Rogers et al., 2012, p. 22) states that sustainability is about increasing long-term wealth and well-being. Barbier (1987) adds to this that the problem with defining sustainable development is finding a universally acceptable definition that is also analytically precise. He finds that often, precision will be "sacrificed for acceptability" (p. 101) and goes on to describe sustainability as an interaction among three systems: a biological and resource system, an economic system and a social system.

Since this distinction, instead of defining sustainability, many have instead focused on each dimension of sustainability separately. For example, Spangenberg et al., (2002) describe the environmental dimension as the sum of all bio-geological processes and their elements, and Costanza and Patten (1995) focuses on avoiding extinction and living to survive and reproduce. In the context of MAC this could be about ensuring that the presence of aquaculture doesn't cause a negative impact on other biological processes or other forms of life in the ocean. Moreover, the process of MAC from production to consumption may also enhance sustainability, because of its carbon neutrality (see Kraan, 2013). The Agenda 30 (United Nations General Assembly, 2015) describes for example how we should protect the planet from degradation through sustainable consumption and production, sustainably managing natural resources.

Regarding the economic dimensions, Erdil et al., (2018) shows how this refers to practices that support long-term economic growth without "compromising other dimensions of sustainability" (p. 528). They show how often economic sustainability will be the outcome, either directly or indirectly, of social or environmental sustainability efforts such as recycling or energy conservation. Costanza and Patten (1995) argue that economic sustainability is about avoiding major disruptions and collapses, evading against instabilities and discontinuities. In the context of MAC this could perhaps be the possible efficiency in large scale production of macroalgae given the amount of input required, as long as external factors doesn't negatively impact on the stability of production.

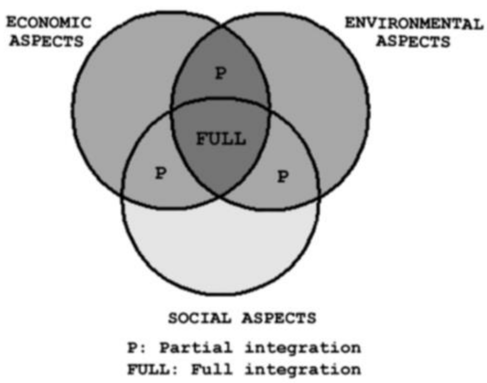
Looking at the social dimension of sustainability, Vifell and Soneryd (2012) considers this to be the most vague and least explicit in practical attempts to shape sustainable development. They argue however, that it should include both welfare aspects such as fair distribution of environmental bads and goods and democratic aspects such as empowerment of weak societal groups. In the context of macroalgae this could mean the effects of MAC onto employment and on local communities where production and job creation takes place. Because seaweed is more common outside of Norway, perhaps increased familiarisation and use of such a resource could generate closer cultural ties on its own? Maybe it could open up dialogue and cooperation across cultures in Norway?

It seems from these definitions that the sustainability dimensions will often be connected to each other. In the context of aquaculture Barentswatch (2021) write that in the same way that the environment, society, and economy are intertwined and mutually affect each other, the individual themes can also be relevant for several sustainability dimensions. Barbier (1987) argues that stressing these unique features of sustainability, is the first step towards an interpretation that is sufficiently "rigorous to provide the useful tools needed for practical analysis and policymaking" (p. 101).

In order to make the sustainability dimensions more coherent, many have illustrated how the three dimensions relate to each other. Lozano (2008) shows how the three dimensions of sustainability can be graphically illustrated using a Venn-diagram (see Figure 2).

Figure 2

Sustainability Venn diagramme



Note. Lozano's (2008, p. 1839) adaptation of the three sustainability dimensions showing the environmental, economic and social aspect of sustainability, where they partially integrate (P) and where they fully integrate (FULL) in a sustainable state.

From this diagram it seems that sustainability is often a trade-off (Rogers et al., 2012) between the economic, social and environmental aspect and it may look like achieving sustainability in all dimensions simultaneously is difficult. However, it is often assumed that that the three dimensions are "compatible and mutually strengthening" (Vifell & Soneryd, 2012, p. 20).

From what we have seen of the macro-algae industry it may seem that there isn't such a trade-off between the three dimensions and that aspects of sustainability should rather complement each other. For example, growing and selling macroalgae can create monetary returns, but this activity should also generate employment for harvesting and processing the algae, and the environmental dimension as macroalgae absorbs CO2. For this reason, in the context of macroalgae, perhaps the three dimensions would be better represented if they were closer, or to a larger extent complemented each other? Mitchell (as shown in Lozano, 2008, p. 1839) illustrates the three as concentric circles whereby the economic dimension lies within the social dimension, that again lies within the environmental dimension (see Figure 3).

Figure 3

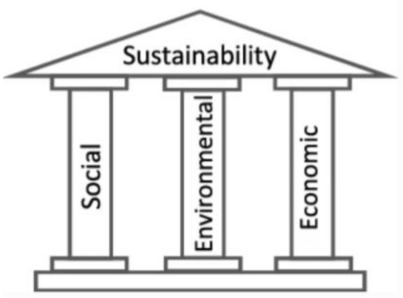
Sustainability concentric circles

Note. Mitchell's illustration (as shown in Lozano, 2008, p. 1839) of sustainability where the economic aspect is part of the social aspect, which again is part of the environmental aspect of sustainability.

A potential drawback from this illustration is that the difference in the sizes of the circles may indicate that the three dimensions should be emphasised differently, but as Barbier (1987) argues the three should be regarded as equally important. Another limitation with the above illustrations might be that it is difficult to know how to operationalise sustainability (Purvis et al., 2019). Figure 4 illustrates the three dimensions of sustainability as pillars that are equally important in order to hold or achieve sustainability.

Figure 4

Pillars of Sustainability



Note. Purvis et al., (2019, p. 682) illustration of pillars of sustainability shows the social, environmental and economic dimensions of sustainability represented as pillars that equally carry sustainability.

Perhaps this visualisation better illustrates the interconnection between the sustainability dimensions and how they must work together in order to develop the MAC industry in Norway? As Barentswatch (2021) write, an imbalance between the pillars will weaken the structure and limit the possibility for sustainable development.

3.3 Operationally

Multiple attempts have been made to make sustainability more applicable. Agenda 21 set out a plan to put the principles of sustainable development into practice (United Nations Conference on Environment and Development, 1992). The aim was for action to be taken both globally and locally in every area in which human impacts on the environment.

Agenda 30 builds from this and presents 17 sustainable development goals. The goals are specific such as “no poverty” and “zero hunger” and actions being taken are constantly listed and updated (United Nations, 2021), to shift the world on to a “sustainable and resilient path” for “people, planet and prosperity” (United Nations General Assembly, 2015, p. 5). Rogers et al., (2012) stress the difficulties in defining sustainable development operationally and suggests nine ways to achieve sustainability including possible options such as “let the markets take care of it”, “internalise the externalities” and “not overwhelm the carrying capacity of the system.” Parris & Kates, (2003) find more than 500 efforts have been devoted to developing quantitative indicators of sustainable development and conclude that there are no set of indicators that are both universally accepted, backed by compelling theory, data collection and analysis and are influential in policy.

In order to distinguish the three dimensions, while at the same time allowing them to carry equal weight in achieving sustainable development, and to facilitate operationalisation of the dimensions, it seems that “the pillars of sustainability” provides the best representation of sustainability is the best starting point for the following analysis in this thesis.

To find out which factors are influencing the sustainable development of the macro algae industry, and given the scope of this thesis, an initial foundation was needed to develop the methodology. To operationalise the sustainability development goals, the Barentswatch list of sustainability indicators were chosen as a point of departure to the method, and as a means for interpreting the results. Barentswatch is a portal administered from Tromsø, that collects, develops and openly shares information about Norwegian coastal and marine areas (Barentswatch, 2021). They are subject to the Ministry of Transport and Communications, while the Norwegian Coastal Administration is responsible for implementation of the programme, with ten ministries and 29 administrive agencies and research institutes as partners. Given Barentswatch’s geographical proximity and the fact that they have well known and reliable founders and supporters, it was believed that basing the theory in these indicators would yield comprehensive results. Barentswatch (2021) lists the following indicators for sustainable development of aquaculture:

(1) Environmental sustainability:

Disease, Emissions from fish farming plants, Escapes, Fish mortality and losses in production, Greenhouse gas emissions, Impact on wild salmon, Sales of pharmaceuticals, Salmon lice, Utilisation of residual raw materials

(2) Economic sustainability:

Costs, Feed composition and origin, From feed ingredients to produced fish, Production value, Profitability, Value added– contribution to GDP

(3) Social sustainability:

Area use, Certifications, Employment, Job absence, Nutrients and unwanted, substances, Occupational injuries, Societal contributions, taxes and charges

4 Methodology

4.1 Research design

In order to find out which barriers exist in the sustainable development of the macroalgae farming industry in Norway, an inductive qualitative research design was chosen. Creswell (2009) describes qualitative research as a means for exploring and understanding the meaning individuals or groups ascribe to social or human problems. He says that researchers who engage in this form of inquiry, support a way of looking at research that honours an inductive style, a focus on individual meaning, and the importance of rendering the complexity of a situation. Bryman (2012) adds to this that an inductive approach is a relationship between theory and research in which the theory is generated out of the research. Creswell (2009) describes research design as the plan or proposal to conduct research and says that a researcher must be aware of the worldview or theoretical perspective they bring to the study. If having to decide, I believe I would see myself as grounded in symbolic interactionism. Symbolic interactionism emphasises social interaction and views this as something taking place in the meaning actors attach to action and things (Bryman, 2012, p. 717).

4.2 Grounded theory

In order to answer the research question of this thesis, I have been inspired by Grounded Theory (GT). GT is a methodological approach developed by Glaser and Strauss (1967) in response to most sociological methods that was concerned with "how accurate facts can be obtained and how theory can thereby be more rigorously tested" (p.1). In GT the researcher derives a general, abstract theory of a process grounded in the views of participants. Theories are thus discovered from or "grounded" in data. They argue that such an approach would generate theory that is suited its supposed uses.

Since the GT approach was presented, much work has been done to make the theory more applicable. Glaser (1978) offers an updated version of GT as he finds that "the techniques and thought involved in grounded theory have been advanced and elaborated since the original publication" and presents a more practical approach to grounded theory. Corbin and Strauss (1990) also offer an updated description where they present several criteria to evaluate studies when developing grounded theory.

4.2.1 Why Grounded Theory?

From my initial perspective, it seemed that there was some research going on in different fields of MAC. There was research about everything from the ecology of macroalgae to consumer preferences regarding such products. There was however, lacking an overview of this development, based on the thoughts of the stakeholders involved in the industry. I believed, the nature of GT would allow me to explore the topic in such a way that it would provide me with such an overview of the situation, "grounded in" the meanings of the stakeholders themselves.

There was also a more practical reason why it was decided to apply grounded theory. Given that the cultivation of macroalgae is such a new industry, there was a limitation to knowledge providing an overview in the industry's development, or the lack thereof. I believed there was a need to contribute to the development of such knowledge.

4.2.2 Criticism of grounded theory

Despite my hopeful vision towards GT, the approach has been criticised. Glaser and Strauss (1967) in their first description of GT state that the researcher should have no preconceived ideas when collecting data. Allan (2003) deems this unlikely saying there must be some sort of agenda for research in the first place and that time and resources would constrain such “unfocused investigation” (p. 8).

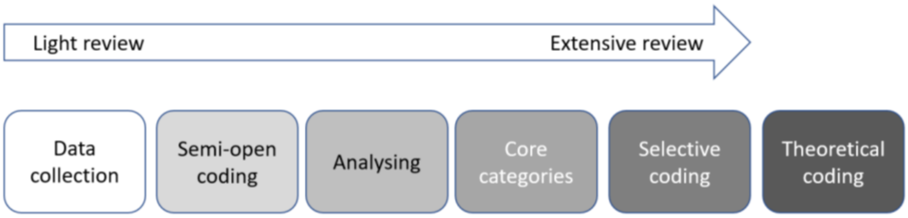
Another aspect of GT often criticised is the lack of guidance of the researcher when conducting analysis of data. Allan (2003) states that Glaser and Strauss do not instruct the reader “in a prescribed mechanism for performing the coding” (p.8). As a consequence there are several approaches to GT developed (see Timonen et al., 2018 for an overview). Timonen et al., (2018) find that the fact that there are so many theories, may cause a lack of trust in GT. They find that even experienced researchers wonder whether they have applied the GT method correctly, saying that GT can cause “confusion and apprehension” (p. 2).

4.3 My approach to grounded theory

One of the reasons for choosing GT was that I could start data collection early and that it would allow me to get an overview based on the respondent’s views. However, GT is a comprehensive and time-consuming process; Glaser and Strauss (1967) state that the researcher doesn’t know beforehand how long the process will last. Given the scope and the time constraints of this study there was a need for adjustments to better suit the scope of the thesis. This study is thus merely inspired by GT. Figure 5 shows the steps taken in my approach to GT, starting with data collection and ending with theoretical coding. Alongside this process, literature was continuously reviewed (see white arrow), in line with Corbin and Strauss (1967) who underlines the advantages of literature alongside the qualitative data collection. In the following I will describe the process in more detail:

Figure 5

Conceptual model



Note. Figure 5 is a conceptual model of the methodological approach used based on a GT

4.3.1 Light review

With an open, explorative mind I was eager to find out what the barriers were for developing a seemingly important industry with a high potential in Norway. I started looking into the macroalgae farming industry in the North of Norway. This is in line with Glaser and Strauss (1967, p. 47) who find that the initial decision for theoretical collection of data is based on a general sociological perspective and a general subject or problem area. I spoke to one of my professors who sent me some projects that had been conducted on the macroalgae farming in County 1. Matsson et al., (2019) had tried cultivation at three different locations here and had found that the ecological potential for cultivation in the area was very good and that there were possibilities for harvest all year around. I was eager to see how the administration facilitated this MAC and looked into the Coastal Zone Plan for Tromsø which was under development.

4.3.2 Data collection

Glaser and Strauss (1967) find that there should be no limits to the techniques of data collection as this will provide the most information possible. They argue that researchers should use the collection technique that best can obtain the information required. Because of the corona-pandemic and the social distancing required, it seemed that the main source of data collection was going to make use of the internet for collecting both primary and secondary data. My main approaches to data collection have been online interviews using snowball-sampling.

4.3.3 Qualitative research interview

According to Kvale and Brinkmann (2015) a qualitative research interview attempts to understand the world from the subjects' point of view, to unfold the meaning of their experiences and to uncover their lived world. Charmaz (2006) further illustrates that one for interviews in GT should devise, a few broad, open-ended questions. She argues that this allows for unanticipated statements and for stories to emerge. Follow-up questions are used to get the informant to articulate their true intentions or meanings (see Charmaz, 2006). Interviews were not recorded, but transcribed directly as the informant spoke. The downside of this approach is that it is not possible to hear again what has been said. However, according to Glaser (as cited by Hjälmhult et al., 2014, p. 27) it is not recommended to use recordings during an interview, one should rather note important aspects to prevent "drowning in data" and miss the overview.

A focus group interview was also conducted. A focus group is a type of group interview where a moderator guides the interview, while a small group discusses the topics that the interviewer raises (Morgan & Krueger, 1998.) Such an approach will allow the group members to share and compare their different ideas, and they can discuss what is likely and unlikely to happen (Morgan & Krueger, 1998, p. 10). The focus group interview was conducted as a Microsoft Teams meeting.

In total, 7 in-depth interviews (one being a focus group) were carried out in the period January to March 2021 (see Table 1

List *of informants*

Three interviews were carried out with people from the industry, two interviews with people from county management and two interviews with people from municipality management.

Table 1

List of informants

Description	Sector	Region
Municipality 1	Public administration	County 2
Municipality 2	Public administration	County 2
Firm 1	Industry	County 2
Firm 2	Industry	County 2
Firm 3	Industry	County 1
Senior-Advisor (County 1)	Public administration	County 1
Biology-advisor (County 1)	Public administration	County 1
Market-advisor (County 1)	Public administration	County 1
Senior-Advisor	Public administration	County 2

Informant selection was primarily done through snowball sampling. This is when a researcher gets access to informants through other informants (see Noy, 2008). Informants refer the researcher to other informants that then refer the researcher to yet other informants, and as such the "snowball" starts rolling. The snowball sampling started with my advisor at UiT recommending that I contact a senior advisor in County 1. The advisor contacted a biology advisor and a market advisor working in the field of macroalgae, initiating a focus interview. From this interview there seemed to be a general interest in facilitating cultivation of macroalgae in County 1, but few actors actually getting involved. In accordance with snowball-sampling, the senior advisor put me in contact with Municipality 1 and a senior advisor in County 2. The snowball kept rolling…

The initial review and early data collection had shown that there was only one firm in the macro algae industry (Firm 3) in County 1, which in addition was in the early research stages of cultivation. In other words, there was a need to gather informants from outside the region. New informants were collected, either by me asking specifically or by them offering to contact the informants. Contact was made using any means of communication (restricted by social distancing) such as email, phone and Teams Meetings. The interviews were carried out as semi-structured interviews (see “interview guide”) in appendix.

Based on the early “data collection” and “light review”, it seemed apparent that the next research area would be County 2 because there was more industrial activity here. This is in line with Glaser and Strauss (1967, p. 47) who state that the basic question to ask when collecting data, is what group to turn to next and for what purpose. Based on the experience and the difficulties in finding Firms in County 1, the decision was made to contact firms first. Unfortunately, I did not get an interview with a firm from Municipality 1. However, I got to interview two other firms in County 2. Contact was then initiated with the municipalities in which the firms were located (Municipality 2 and Municipality X), but no contact was made. An interview was made with a senior advisor in the aquaculture department of County 2.

In line with the snowball approach contact was made with the owner of Firm 1 to ask for informants in Municipality 2. I was put in contact with a representative from Municipality 2 and a telephone-interview was conducted. In the end contact was made with Firm 3 from County 1 which responded to the questions via email.

4.3.4 Semi-open coding and analysing

The next step was what Corbin and Strauss (1990) call open coding. In open coding, data is compared over and over again for similarities and differences. As the data is analysed it is given conceptual labels or coded and “similar events are grouped together to form categories” (p. 12). An important part of the analysis process is what Glaser and Strauss (1967) call “constant comparison”. This is a process whereby data is continuously analysed and evaluated in the category in which it has been placed. Corbin and Strauss (1990) say that incidents should be compared against other incidents for similarities and differences and that making such comparisons assist the researcher in guarding against any bias. Moreover, Corbin and Strauss (1990) find that open coding and the use of constant comparison enables investigators to break through subjectivity. They argue that fracturing the data in this manner, forces preconceived notions and ideas to be examined against the data themselves.

To meet the data in such an open manner and without any form of bias seemed difficult, and time consuming. Given the time and scope of this project, there was a need to obtain an initial framework to start the coding process. Therefore, instead of an "open" coding I have decided to name the initial coding process as *semi-open* coding. Using the sustainability indicators provided by the Barentswatch portal "Sustainability in aquaculture (2021), an initial starting point was used to lay a foundation and guide the rest of the coding process.

Because the Barentswatch Sustainability Indicators (BSIs) were created for aquaculture of salmon, many of them needed amendments to be suitable in the research question of this study and certain BSIs were not relevant and were removed. In order to create Grounded Theory Codes (GTCs), there was a need to study the data and to draw potential GTCs from it. Thus, in refitting the BSIs to the GT, the analysing process or "constant comparison" was automatically started. The data was analysed until certain core categories had been created. The result of this process can be seen in *Table 2* below.

A problem that was discovered when analysing the BSIs, was that many of the categories were very similar and sometimes overlapped, making the coding process difficult. For this reason, certain indicators were combined into one. For example, "Emissions from fish farming plants" was added to "Greenhouse gas emissions" and "salmon lice" and "diseases" were combined into "biofouling." Another difficulty was separating "production value" and "profitability" as "production value" was described as "the value that each stage in a value chain achieves through revenues in the market" (Barentswatch, 2021) which is closely linked to profit. Therefore, if the focus was more on the *process* of the production value such as the *process* of sale, it would be coded in "production value." If the focus was more linked to the revenue generated *from* sales, it would be placed in "profitability". Quotes that did not fit in any of the categories could either get their own table if often occurring (i.e. research and innovation) or be included in the "Others" table if less frequent. Quoted barriers and opportunities (table 7 and table 8) were also described in parentheses as I have worked with them for my own reference and to keep an overview of the decision behind that allocation. A potential problem with this approach was that when combining several categories, these could get a disproportionate value. However, I believed that the chosen approach would still provide me with relevant core categories for later discussion. Table 2 shows the amendment decisions.

(For a more detailed description, see Table 9 in Appendix for a more detailed summary describing these amendments.)

Table 2

Coding framework

Barentswatch indicators	Barriers	Opportunities
Environment		
Diseases	Changed to "biofouling"	Removed
Emissions from fish farming plants	Changed to "Impact on other ecosystems"	=
Escapes	Removed as unapplicable	=
Fish mortality and losses in production	Changed to "losses in production"	Removed
Greenhouse gas emissions	Unchanged	=
Impact on wild salmon	Added to "Impact on other ecosystems"	=
Sales of pharmaceuticals	Removed as unapplicable	=
Salmon lice	Added to "biofouling"	Removed
Utilisation of residual raw materials	Unchanged	=
Economy		
Costs	Added to profitability	Removed
Feed composition and origin	Removed as unapplicable	=
From feed ingredients to produced fish	Changed to "growth efficiency"	=
Production value	Unchanged	=
Profitability	Unchanged	=
Value added– contribution to GDP	Added to "production value" due to difficulty distinguishing the two	=
Social		
Area use	Unchanged	=
Certifications	Unchanged	=
Employment	Unchanged	=
Job absence	Added to "Employment"	=

Nutrients and unwanted substances	Unchanged	Changed to "Nutrients and *wanted* substances"
Occupational injuries	Added to "Employment"	=
Societal contributions, taxes and charges	Unchanged	=
Other categories		
Research and development	Adopted from quote by respondent "Firm 2"	=
Other categories	Any other barriers	Any other opportunities

Note. Coding framework, adapted from https://www.barentswatch.no/en/havbruk/

4.3.5 Selective coding

Corbin and Strauss (1990) describe selective coding as the process by which all categories are unified around a "core" category. They state that poorly developed categories are likely to be identified at this stage where such categories are those in which few properties have been uncovered in the data. The categories closer to the core was believed to be those that were mentioned the most. In order to do a systematic and thorough analysis using the Barentswatch Framework, I first looked further into the categories mentioned the most, which eres believed to be close to the core, before suggesting what the core might be.

When coding, I realised that many quotes could be grouped in several of the categories. I realised that in order to get a systematic analysis I had to assume that a quote could only take one category, and that I would have to choose the one I believed was the most suitable category. Consider for example the quote "we don't know how much (seaweed) will fall to the bottom". Looking at the quote it could be grouped in several categories such as "loss of biomass", "negative impact on other ecosystems", "growth conditions" and "profitability." Without any restrictions I realised that it may be difficult to get a clear and systematic overview of the relevant categories and that an analysis based on such an approach may expand undesirably and lack the wanted "edge". I decided therefore, to make individual decisions for each quote. My decision would be based on the quote itself, the context in which the quote was spoken, the wording and tone of the informant and my own interpretation. In the above example, my understanding was that the respondent was focusing on the potential impact on other ecosystems and I therefore believed that the most appropriate category would be the "negative impact on other ecosystems" category.

4.3.6 Theoretical coding

Glaser (1978) finds that theoretical codes conceptualise how codes may relate to each other as hypotheses to be integrated into the theory. He states that coding gets the researcher off the empirical level by fracturing the data, then conceptually grouping it into codes that then become the theory which explains what is happening in the data. In order to get a visual understanding of how categories were related to each other, the quotes in each category were counted as described above, and a heat map was created. Based on this heat map, the four most important categories could be looked at more closely, in order to come a step closer to the "core."

4.3.7 Extensive review

The four core categories were then explored closer in an extensive review. Literature was centred on each category to better understand how they affect the development of MAC and in order to discover a theory. Here I would choose the literature and theories that seemed most relevant in describing the categories under consideration. Glaser (1978) states that the "code conceptualises the underlying pattern of a set of empirical indicators within the data" (p. 55) and describes how one can discover a theory by developing the relationships between categories and properties.

4.4 Validity

Leung (2015) describes validity in qualitative research as "appropriateness" in research question, choice and design of methodology, sampling and data analysis, and results and conclusions valid for the sample and context. Simplifications have been made in methodology in order to fit the scope of the study. Despite this, and seeing as the results are mirrored in literature, I believe it is still a valid approach that can answer the research question of this study.

4.5 Reliability

Leung (2015) finds that the essence of reliability in qualitative research lies with consistency and that a margin of variability for results is tolerated in such research. I believe that the reliability of this study has increased due to the constant comparison of data, and because the results are compared with other research. In addition, I believe that the use of tables has made it possible for future researchers to replicate the approach. The fact that much of the data analysis is based on the BSIs, can mean that the foundation for the study is grounded upon a reliable source of information and therefore increase its reliability.

4.6 Generalisability

This study has been limited geographically and doesn't explore all of Norway, and it might be misguiding to make generalisations about all of Norway from this. Moreover, there are many things that doesn't apply to other parts of the world. From the ecology of Norwegian waters, to Norwegian maritime policies. This being said, as the results are based on both primary and secondary data, the patterns unveiled are expected to be applicable outside the context of this thesis as well.

4.7 Representativity

Whether or not the group that I have interviewed would represent other stakeholders in the industry is not easy to say. Because farming of macroalgae is such a new and underdeveloped industry, there are few actors involved. It may therefore be possible that each stakeholder has their unique way of doing things, and that achieving representativity from such sample would be unlikely in this context. Moreover, it could be the case that the firms, although different, still see many of the same barriers and opportunities as others would.

4.8 Credibility

Cope (2014) finds that an audit trail; “a collection of materials and notes used in the research process that documents the researcher’s decisions and assumptions” (p. 90), can enhance the credibility of a study. She says examples of study materials include interview transcripts, data analysis and process notes. In this study it has been attempted to describe thoroughly what was done in the data analysis. In addition, the interview guide and the result of the interview are included in the appendix for transparency. Moreover, multiple informant groups were interviewed, in line with Barney and Strauss (1967), who find that multiple groups for comparison “make the credibility of the theory considerably greater” (p. 231).

4.9 Trustworthiness

In addition to credibility, Lincoln and Guba (as cited in Cope, 2014, p. 89) present three criteria to develop trustworthiness in qualitative research: dependability, confirmability, and transferability. Cope (2014) finds that dependability can be achieved when another researcher concurs with the decision trails at each stage of the research process. In the process of this study my supervisor has helped me through each of these stages and secondary literature has been used to confirm or reject findings. Cope (2014) finds that the researcher can demonstrate confirmability by describing how conclusions and interpretations were established, and exemplifying that findings were derived directly from the data. I believe that with the examples provided when making decisions about the approach to data collection the study has increased its confirmability. When it comes to transferability, Cope (2014) finds that a qualitative study is transferable if the results have meaning to people not involved in the study and readers can associate the results with their own experiences. She further states that researchers should provide sufficient information on the informants and the research context to enable the reader to assess the findings’ capability of being “fit” or transferable. A dilemma was encountered here. Because there are so few actors involved in the cultivation of macroalgae, I was afraid that too much information about the stakeholders involved may reveal their identity, which would not be in line with the agreement concerning anonymity (see interview guide in appendix Figure 6). Still, I believe that enough information about the context has been provided for the reader to assess the transferability of these findings.

4.10 Ethical considerations

Kvale and Brinkmann (2015), find that ethical problems in interview research can arise because of the complexities of researching private lives and placing accounts in the public arena. For this study it has been the latter aspect that has been most important. As this thesis will be made publicly available, it was important to make sure that the respondents could not be identified. The original transcripts of the interviews have therefore been excluded from this study and the names of firms, municipalities and counties have been anonymised. The study has been conducted in accordance with the regulations of the Norwegian Centre for Research Data (NSD).

5 Results

5.1 Barriers and opportunities in cultivation of Macroalgae in Norway

In the following, the barriers and opportunities in the sustainable development of the MAC-industry are presented. First, the barriers will be considered, organised in four sections, three of which are the sustainability dimensions, followed by other categories. The sustainability dimensions and the categories with the most quotes will be presented first. Afterwards, the opportunities will be presented in a similar sequence. In general, the quotes from each of the three stakeholder groups will be mixed and compared irrespective of background. Emphasis in the chapter is put on what the stakeholders said.

5.2 Barriers in cultivation of Macroalgae in Norway

Table 3 shows the barriers in the cultivation of Macroalgae in Norway, as mentioned by the Firms, Counties and Municipalities, with respect to the Environmental, Economic and Social sustainability dimension and any other categories. This shows the overall pattern of the mentioned barriers categorised by the sustainability dimension in which the quotes have been coded. Darker shade indicates that the category is more frequently mentioned. The direct quotation can be found in Table 7 in the Appendix. In Table 3 we see that the economic dimension had the most frequent barriers, followed by the social dimension, whereas the environmental dimension contained the fewest.

Table 3

Barriers to cultivation of macroalgae by sustainability dimension

	Environment	*Economy*	*Social*	*Other*
Firms	2	26	16	10
Counties	6	16	12	6
Municipalities		6	6	3
Total	8	48	34	19

Table 4 shows the barriers in the cultivation of Macroalgae in Norway, with respect to the specific categories. The barriers are presented with respect to the respondent. Darker shade indicates that the barrier is more frequent. Green barriers are environmental, blue are economic, orange are social and black are barriers that emerged irrespective of the BSIs. From Table 4 we can see that the barriers turned out to have a wide range of frequencies. "Greenhouse gas emissions" and "Utilisation of residual raw materials" did not appear at all, whereas "Profitability" was the most frequent, followed by "Area use", "Production value" and "Research and Innovation". From Table 4, we see that the firms and the municipalities were mostly concerned with profitability, whereas the counties were mostly concerned about the use of area. To see the barriers with respect to each respondent, see Table 10 in Appendix.

Table 4

Barriers to cultivation of macroalgae by category

	Biofouling	*Impact on other ecosystems*	*Losses in production*	*Production value*	*Profitability*	*Area use*	*Certifications*	*Employment*	*Nutrients and unwanted substances*	*Societal contributions, taxes and charges*	*Research and innovation*	*Other categories*
Firms	1	1		9	17	3	3	3	7		9	1
Counties		4	2	7	9	10				2	3	3
Municipalities				1	5	4	1		1		3	
Total	1	5	2	17	31	17	4	3	8	2	15	4

5.2.1 Environmental sustainability barriers

The environmental barriers were seen to be the least frequent and were coded only 8 times. The counties were mostly engaged with this dimension, whereas the municipalities did not mention these barriers once.

5.2.1.1 "Biofouling"

From the data there was only one response coded in the "Biofouling" category. This was Firm 1 who mentioned that seasons and fresh product is difficult to deal with.

5.2.1.2 "Impact on other ecosystems"

The most frequent category in the environmental dimension was the "Impact on other ecosystems" barrier. Firm 2 and County 2 both expressed concern about what might be left on the bottom of a farm and Firm 2 noted how this could potentially be harmful. County 1 stated that if you have large farms, this may prevent sunlight from reaching ecosystems below the surface. County 1 also expressed concern about what might happen to lumpfish when first facilitating an ecosystem through cultivation of macroalgae before removing it. County 2 said more generally that one would have to do analysis of the nature surrounding the macroalgae farms.

5.2.1.3 "Losses in production"

The second most frequent code in the environmental category was the "Losses in production" code. This was mainly due to County 1 who mentioned that there could be some problems with falling seaweed in large farms, for example due to "bad weather". Additionally, they stated that seaweed rots quickly and that it therefore need to be quickly processed after harvest.

5.2.1.4 "Greenhouse gas emissions" and "Utilisation of residual raw materials"

"Greenhouse gas emissions" and "Utilisation of residual raw materials" did not appear from the data.

5.2.2 Economic sustainability barriers

The barriers within the economic dimension were the most coded barriers for the development of the MAC industry. There were two codes that really stood out as very frequent within this dimension of sustainability. Despite economy being the most popular barrier, no firms appeared to be concerned about economic category: "growth efficiency." Meanwhile, "production value" and "profitability" were very frequent. "Profitability" was the most coded category overall, with firms being particularly focused on this matter. When looking at the barriers by group in Table 4 we can see how firms mentioned profitability 17 times, compared to County who mentioned it 9 times and municipality who mentioned it 5 times. The "profitability" category was the most frequent category and all apart from two respondents were found to have profitability as their most important barrier.

5.2.2.1 "Profitability" (firms)

The firms said there was currently lacking profitability achieving an economically sustainable development of the MAC industry. Firm 2 wondered whether there were any firms at all with profitable production (quoted barriers are presented in Appendix, Table 7). Firm 1 confirmed this and said all it required was to see profit margins at zero. Firm 2 added that automatization could help in achieving profitability.

The firms also talked about the difficulties in conducting production in an unprofitable market. Firm 1 stated that you can't have seaweed production as a "left-hand activity" and that one must have the "knife to the throat" every day in order to produce. Moreover, it noted that a barrier might be that some firms conducted seaweed production as a "side activity" and illustrated how, for these firms, the incentive may be centred towards production of fish instead of macroalgae. Firm 2 said that it is easy to spend too much money in a new industry and concluded that it was trying to "take things slowly" because of this. It added investment was needed for developing production and that there was a need for "risk-willing capital." The Firms also discussed the importance of the market noting that a market for seaweed hasn't developed yet (Firm 2), that we need to start from the needs of the market (Firm 3), and that if demand increases, more firms will start with seaweed production (Firm 1). Firm 2 added that market and sale must go "hand in hand" and recalled the shell industry where "they managed to grow shells but didn't manage to sell them". The firms also stressed the need to develop macroalgae products for achieving profitability. Firm 1 described their seaweed product as "disruptive" and found that people aren't used to it such products today. Firm 3 explained how it was attempting to find market niches that would make it possible to "develop products".

The counties and municipalities also focused on the importance of profitability in developing the MAC industry. Municipality 1 listed production cost as an important barrier and County 1 specified that one should aim to lower the investment costs required in production. Furthermore, it suggested that a way to do this would be to focus on a few actors with "a spine." They further discussed the importance of the market. Municipality 1 said it believed the market is the biggest barrier and Municipality 2 described the market as too small. County 1 stated that there isn't a market and that the economic barriers, therefore are "hard to ignore". County 1 said that if you can't sell it, "it is not so easy" whereas County 2 compared the macroalgae industry to larger industries and asked whether it would develop without a demand for macroalgae products.

The respondents also talked about aspects of production. Here they emphasised having sustainability. County 1 stated that there is no need to produce if it is only left lying around afterwards. County 2 recalled the former blue shell cultivation activity and described how many had started farming, but since there was no market, many of the blue shell pens were left lying around in the ocean.

5.2.2.2 "Production value"

Production value was also considered an important barrier in the industry. Many firms were concerned about the sales process. Firm 3 said there is a need to find new ways to sell seaweed out in the market, Firm 2 said there is a need for "good sales channels", and Firm 1 expressed concern that a lot of added value of products are exported out of Norway. Firm 2 stated that there is quite a large market for seaweed products in Europe, but that most of these products are imported from Asia ("Østen"). Firm 2 said that similar to farmed salmon, it wants a common sales company for the seaweed industry. Firm 2 added to this a need for marketing through the Norwegian Seafood Council. Moreover, Firm 1 said there was need to find a business model aimed at production of seaweed, whilst Firm 3 noted that developing reception and production centres ("apparat") would help.

The Counties and municipalities were also concerned about production value. The County said that we need to find out how to process the seaweed and that most of the production is happening in the "south of Norway." The County also discussed the link between the market and the industry, saying that "it seems that the industry is waiting for the market while the market is waiting for the industry" and "what makes it hard is that there are many X-es on the production side and many X-es connected to the market." County 1 stated that there are many things that need to go right in order to succeed when developing a new value chain. It drew a parallel to the blue shell industry where "nobody managed to produce".

5.2.2.3 Growth efficiency

"Growth efficiency" did not appear from the data.

5.2.3 Social sustainability barriers

The Social dimension was the second most coded dimension (see table 3). "Area Use" was the most popular category in this dimension and was the second most popular category overall (Table 4).

5.2.3.1 "Area use"

County 1 said that if you were to develop a large scale industry of macroalgae you would need to find ways to grow macroalgae that make efficient use of area. They said this was a prerequisite for allocating space for such activity. County 1 highlighted the need to allocate "good space" and said there may be a lack of shallow waters. County 2 said that there was a need to have access to areas that are good and with enough space. County 1 gave an example with a firm that was planning to produce bioenergy, where it turned out that they needed the whole areal plan. The County said this illustrates how much space macroalgae production requires. They also showed how space could potentially be allocated disproportionately and gave an example where an applicant applying for IMTA was blamed for using macroalgae as a cover for expanding fisheries production. Additionally, County 2 argued that a lot has to do with the planning work in the municipalities. Municipality 1 underlined the need to make sure this planning process is not in conflict with other considerations. County 2 noted that there may be several interests in these areas and Municipality 2 said that there may be competition over space. Municipality 1 emphasised the need to balance the space for these activities. County 1 agreed to this and argued that there may be a lot of outdoor life conflicting with potential areas for MAC. Similarly, Firm 3 wanted an overview of the different natural advantages in different parts of the country and found that locating these differences would be necessary. Municipality 1 asked how much buoys and blinking lights would be tolerable from the cultivation sites.

5.2.3.2 “Certifications”

Firm 2 described that its working to get a nutrition declaration. “Mattilssynet says we have to wait on documentation on iodine levels” adding that this would have “helped in getting products through customs.” Firm 2 also explained how it’s trying to work with the Norwegian Seafood Council for marketing advice. It stated that this was difficult because “they are not allowed to do this with macroalgae due to lack of documentation.” Municipality 1 emphasised quality of products and recalled the blue shell industry and the problem with the quality of these shells.

5.2.3.3 “Employment”

Only a couple of firms mentioned employment. Firm 1 explained how there was a need for year-round jobs in order to develop the industry. Firm 2 said that salaries may become a problem. It added that it would need a 100% position exclusively working with macroalgae in the future.

5.2.3.4 “Nutrients and unwanted substances”

“Nutrients and unwanted substances” was the second most popular category in the social dimension. The Firms said they were concerned about what products would contain of unwanted substances. Firm 1 said the problem with seaweed is that you “don’t know the level of heavy metals.” The Firms were also concerned about iodine levels. Firm 2 stated that people are afraid that there could be “too much iodine in the products”. Firm 1 said that “we are not used to such high levels of iodine”. Additionally, Firm 1 added that it had problems with removing shellfish allergens from its product. Respondents also spoke about people’s food habits. Firm 2 stated we have tried selling together with salmon producers, but these are afraid that the seaweed will “harm their reputation”. Municipality 2 said that “countries in Asia are more used to this taste”.

5.2.3.5 "Societal contributions, taxes and charges"

"Societal contributions, taxes and charges" was coded two times and was the least coded social category. Only the counties were concerned about this. County 1 said the biggest challenges regarding seaweed production is connected to the economy and the society. County 2 wondered what the total benefit to society would be.

5.2.4 Other barriers

Some codes also emerged in the "Others" group. These were "Research and innovation", "Sustainability", "Passive administration" and "Extreme rainfall" (see appendix Table 7.) Despite emerging irrespective of BSI, the categories within the "Others" group actually summed up to more than the "Environment" dimension.

5.2.4.1 "Research and innovation"

"Research and innovation" was so frequent that it was decided to make an own table for this category.

Many respondents said there was a need for research and innovation on how to make new products. Firm 3 said it's important to develop new products and Municipality 1 mentioned food, medicine and alginate as important products. County 2 said it is "exciting to see" how these products can be used. Firm 1 stressed the need to make "mainstream" products that would actually sell.

Firm 2 was more interested in research licenses (FOU-konsesjoner) in order to test and research. Firm 2 said such research institutions should be used to put forward "reliable analysis of the nutrient content." Firm 3 added that such resources could be used for building competence in cultivation. Municipality 2 said there is little research and development on what is actually the optimal growth condition for macroalgae. Firm 2 expressed a need to use research and innovation to build constructions for production. It said "we could consider those in China", but added that "we can't have these because their salaries are too low" also suggesting that Norway would need to automatise more than China.

County 1 and Municipality 1 emphasised knowledge in the development process, County 1 saying that the macroalgae production must "start from the knowledge that is available" and that "any action needs to be based on knowledge." Firm 3 talked about the knowledge in business networks and said these can be challenging when the distances are too long between participants. It said "I feel quite alone here."

5.2.4.2 "Sustainability"

Sustainability was an independent code which was based on the comments from County 1 and County 2. This barrier did not seem to fit into any of the other categories, and it was therefore decided to make a new category. The sustainability barrier emerged when the counties were asked about the sustainability dimensions. County 1 said, "personally I am a little fed up with the term sustainability. Like, everything is supposed to be sustainable. You're supposed to make money, create jobs and production where people are. It is such a big concept, and everything is connected." County 2 described sustainability as a "well-used word". "What is sustainability exactly?" it said. "What is the definition of sustainable again? It's a little hard to relate to sustainability. It has a definition, but I don't remember what it is. It is something about production not affecting negatively beyond what is being produced?"

5.2.4.3 "Passive administration" and "Extreme rainfall"

Two other codes emerged irrespective of the BSI. "Passive administration" was adapted from Firm 3 when it said "the County is more passive here" and "Extreme rainfall" was adapted from County 1 saying that "extreme rainfall causes challenges due to darkening ("formørking") of the ocean."

5.3 Opportunities in cultivation of Macroalgae in Norway

Table 5 shows the opportunities in the cultivation of Macroalgae in Norway, as mentioned by the Firms, Counties and Municipalities, with respect to the Environmental, Economic and Social sustainability dimension and the other categories. This shows the overall pattern of the mentioned barriers categorised by the sustainability dimension in which the quotes have been coded. The direct quotation can be found in Table 8 in the Appendix.

Table 5

Opportunities in cultivation of macroalgae by sustainability dimension

	Environment	*Economy*	*Social*	*Other*
Firms	7	12	12	2
Counties	1	4	5	4
Municipalities	4	6	7	
Total	12	22	24	6

Table 6

Opportunities in cultivation of macroalgae by category

	Impact on other ecosystems	*Greenhouse gas emissions*	*Growth efficiency*	*Production value*	*Profitability*	*Area use*	*Certifications*	*Employment*	*Nutrients and wanted substances*	*Societal contributions, taxes and charges*	*Research and innovation*	*Other categories*
Firms	2	5	5	2	5	2	1	4	4	1		2
Counties		1	1	1	2	3			1	1	1	3
Municipalities	2	2	2		4	4		1	2			
Total	4	8	8	3	11	9	1	5	7	2	1	5

Respondents also mentioned many opportunities in the MAC industry. From Table 5 we see that “Profitability” was the most coded opportunity. This was followed by “Area use", "Growth efficiency" and "Greenhouse Gas Emissions." From Table 5 we can see that the "Social" dimension was the most coded dimension, followed by "Economy" and "Environment." Other categories that appeared from gathering data was "Research and Innovation", "Sustainability" and "Settlement". To see the opportunities for each respondent, see Table 11 in Appendix.

5.3.1 Environmental sustainability opportunities

Environment was the least coded of the sustainability dimensions. "Greenhouse gas emissions" was the most coded and "Utilisation of residual raw materials" was the least coded environmental opportunity.

5.3.1.1 "Impact on other ecosystems"

Respondents mentioned a variety of ways in which the cultivation of macroalgae could benefit ecosystems. Firm 1 argued that there is no freshwater needed, which benefit ecosystems requiring this resource. Firm 2 said they can contribute in cleaning the fjord systems and Municipality specified saying that they can clean the waste material ("avfallsstoffer"). Municipality 1 also said that cultivation of macroalgae could contribute in creating a more diverse ecosystem and facilitate biological diversity, as for example, a habitat for juvenile fish.

5.3.1.2 "Utilisation of residual raw materials"

No respondents were found to mention "utilisation of residual raw materials" as an opportunity.

5.3.1.3 "Greenhouse gas emissions"

Greenhouse gas emissions was the environmental category that was coded most times. The respondents seemed to be very aware the opportunities regarding macroalgae's and carbondioxide. Municipality 1 and Firm 3 said that seaweed binds carbon, County 1 named it “the blue forest” and Firm 1 added that macroalgae binds carbon to the same degree as the rainforest. Firm 2 discussed the indirect greenhouse gas emissions that would be prevented by the fact that they processed the product where it was produced and therefore wouldn’t require any emissions from transportation. Municipality added that there should be more focus on cultivation specifically because “wild harvest may interrupt with carbon storage.”

5.3.2 Economic sustainability opportunities

Economy was the second highest coded sustainability dimension. “Profitability” was the most coded opportunity within this dimension and overall. “Production value” was the least coded category in the economic dimension.

5.3.2.1 “Growth efficiency”

Firm 2 noted that macroalgae doesn’t need fertiliser or feed in order to grow. Firm 1 added that this may contribute to sustainable production. Municipality 1 said that it “doesn’t require chemical substances” and said that the process is all natural. Firm 1 agreed and added that “society uses chemicals everywhere.” Firm 1 said it believed macroalgae could be “made efficient” in Norway. County 1 specified geographically and said there are “favourable conditions in Northern Norway.” Firm 2 discussed IMTA, and said that macroalgae grows more rapidly when placed in proximity to a fisheries net pen.

5.3.2.2 “Production value”

Concerning “Production value” there were a few but different responses. County 1 called cultivation of macroalgae an “exciting production process.” Firm 2 said that is was hoping to see something “similar to the salmon industry” where “the owners owned both production and sales”. Firm 1 also compared it to the salmon industry and said it didn’t see any reason why Norway shouldn't be one of the countries focusing production process on macroalgae. "We are good at salmon. Why can't we be good at seaweed?" It said.

5.3.2.3 "Profitability"

All except from one respondent were found to mention "Profitability" at least once. Municipality 1 said seaweed is less energy demanding and has less emissions so it should be profitable. Respondents were interested in the opportunities regarding cost of seaweed. Firm 1 added that dry seaweed has many years of durability and Firm 3 said it can be a cheap alternative to animal feed. Firm 3 also discussed the risk of costs saying that it was hoping the public would "provide risk loans that could be changed to grants" if something were to go wrong. County 1 noted that if you place macroalgae pens in shallow waters, the investment in construction "would be a lot cheaper." Municipality 1 added that it was important to have a deposit in place so that costs would be covered in case one had to clean up after production.

Many respondents were also focused on the opportunities regarding demand for seaweed. County 1 said that there is a lot of interest both from private people and from large companies. Firm 2 said it expected healthy food and feed to become more important in the future. Municipality 2 also talked about food and said, "we need more sources of food" and added it was expecting people to "view seaweed as a valuable resource" in the future.

5.3.3 Social sustainability opportunities

The social dimension was the most coded sustainability dimension of the opportunities.

5.3.3.1 "Area use"

"Area use" was the most coded social dimension and the second most coded category overall. Many respondents brought up macroalgae in relation to other interests.

Municipality 1 said macroalgae is rarely in conflict with other activities and Firm 1 noted that farming of macroalgae requires no land (list of quoted opportunities are presented in Appendix, Table 8)

Municipality 1 talked about how macroalgae may facilitate for and complement other activities and mentioned fish stocks possibilities of growing in seaweed. Similarly, Firm 2 said it had applied for a permit to start IMTA with a salmon company. County 2 found that the low conflict level made macroalgae applications less complicated and easier to approve. Municipality 2 said that in principle all areas are were open for MAC and that they would exclude those areas that happened to be unavailable. It said “we are a small municipality, but we have a lot of ocean.”

5.3.3.2 “Certifications”

“Certifications” was one of the least coded opportunities and was only coded once. This was Firm 1 who mentioned the opportunities of Mattilsynet’s instruction to facilitate helping firms with documentation of their products.

5.3.3.3 “Employment”

Concerning “Employment” it was Firm 1 that was very interested in this aspect of MAC. It talked about dry seaweed can last for many years and how this may facilitate jobs all year-around. It said that if jobs are placed near resources and products, it should contribute in creating more jobs in Norway. It noted that it wanted to see a different development than what has occurred in the fisheries industry where the production process involves workers far away from the resource. Municipality 1 was also hopeful for the industry’s chances of creating jobs locally. Firm 2 the development of macroalgae farming could create jobs in processing on land, sales and marketing.

5.3.3.4 “Nutrients and wanted substances“

Firm 1 said it believes in the long run that seaweed will become a common source of food similar to rice and potato. County 1 talked about the new generation and that this might have new perspective concerning environment and sustainability and didn’t “have to eat meat every meal.” Municipality 2 added that there is an increasing number of vegans and vegetarians today. It also looked to the past and said that 10 years ago few people ate sushi but today it is a lot more common. Firm 1 said many are interested because of the iodine and Firm 2 said there are no additives during production.

5.3.3.5 “Societal contributions, taxes and charges“

“Societal contributions, taxes and charges” was coded two times. This was Firm 2 who claimed that the government is very eager for this to become a big industry and County 1 which stated that MAC can contribute in strengthening local communities.

5.3.4 Other opportunities

Some codes emerged as other opportunities. These were “Research and innovation”, “Sustainability” and “Settlement.”

5.3.4.1 “Research and innovation”

There was only one coded “research and innovation.” County 2 talked about the possibilities when doing research and innovation and said when it comes to product development it will be exciting to see how these products can be used.

5.3.4.2 “Sustainability”

There were also multiple opportunities that concerned sustainability and therefore this category was created. Firm 2 said it’s “absolutely sustainable” about MAC and County 2 said that it’s easier to “do sustainable environment” in macroalgae farming than in fisheries farming. Firm 1 described how “we must establish an economy in Norway that is economically sustainable” and said such an economy should be made for “everlasting resources”. We can’t have an economy that is based on petroleum anymore it said.

5.3.4.3 “Settlement”

Another category that emerged irrespective of BSI was “Settlement.” This was developed from County 1 who stated that MAC could generate settlement and County 2 who stated that without an industry “no one will want to live there.”

6 Discussion

In the following I will discuss the barriers that were found from the data collection. Given the scope of this project I will focus the discussion on the most quoted barriers and results that diverged from the literature. Where needed, I will make use of the opportunities to discuss how the barriers are affecting the development of the MAC industry in Norway. The results suggest that the 4 most relevant barriers were “Profitability”, “Production value”, “Area use” and “Research and Innovation”. Thus, when going through the sustainability dimensions I will focus the discussion on these barriers. In the discussion I will also attempt to discover the “core” underlying these barriers, in order to understand how they are affecting the sustainable development of the macroalgae-farming industry in Norway.

6.1.1 Environmental sustainability

Environmental sustainability turned out to have the fewest barriers. Some respondents mentioned biofouling as a potential barrier. This finding is in line with Matsson et al., (2019) and Stévant et al., (2017). Biofouling can be described as the unwanted deposition and growth of biofilms (Flemming, 2002), where Biofilms are microorganisms capable of growing, on a surface (Bremer et al., 2015). The respondents did not seem to regard biofouling as an important barrier. This is in contrast to Matsson et al., (2019) who find that biofouling is an important factor in developing the macroalgae industry. A reason could be that the Firms that were asked in this analysis happened to be located at a place with limited biofouling. This could also be explained by Matsson et al., (2019) who find large variations in the amount of biofouling at different localities. The respondents of this study seemed to emphasise the potential impact from seaweed cultivation onto other ecosystems. This is confirmed by Stévant et al., (2017), who lists this as in developing the industry, and Barbier et al., (2019) who explains how cultivated populations represent a small part of existing seaweed species and that if they manage to cross with wild populations, they risk spreading reduced genetic diversity to wild populations.

The fact that the stakeholders in the industry are less concerned about the barriers in the environmental dimension does not necessarily mean, that there should be less focus on this aspect when developing MAC industry. The theoretical framework showed that the environment is often considered a foundation needed in order for the other sustainability dimensions to be achieved (recall for example Mitchell's illustration (Figure 3) where sustainability is presented as concentric circles in which environment encloses the other two). The stakeholders might be more occupied with day-to-day activities, rather than the underlying sustainability dimension, and therefore these barriers might be more visible to them. As Lozano (2008) describes, the environmental dimension of sustainability can be thought of as the system in which the economic dimension can operate. Hence, it could be that environmental sustainability through "impact on other ecosystems" is the underlying theory.

6.1.2 Economic sustainability

6.1.2.1 Profitability

Profitability turned out to be the most common barrier in the economic sustainability and overall. The respondents focused on various aspects of profitability. Profit can be explained as Total Revenue (TR) minus Total Cost (TC), where TR=Price x Quantity and TC = Total Fixed Cost + Total Variable Cost (see Mattessich, 1961). Thus, in order to have profitability TR must be higher than TC. Looking at the TR and TC, low profitability can either be explained by low prices, low quantity sold, high fixed costs, high variable costs or a combination of these. As Mattessich (1961) shows this will be the case for any firm and therefore also for firms cultivating macroalgae. Another explanation of low Profitability could be the “Q”, Quantity Sold, as the stakeholders in the industry said that demand for macroalgae products is currently low. From Fiskeridirektoratet, (2020) we can read that sales numbers for seaweed are quite low at only NOK 4.4 million in 2019. However, respondents said they expected demand for healthy and sustainable food to become more important in the future (Municipality 2, 2021). This development seems to have started as the total sales value of seaweed has increased from NOK 0.7 million in 2017 and NOK 1.3 million in 2018. There seems to be a development in this respect. 30 years ago, the scepticism towards seaweed as a source of food was higher, as found by Guiry and Blunden (1991) who stated that one “shouldn’t be too optimistic about seaweed as a source of food” (pp. 21-22). Today however, Future Market Insights (2021) estimates that the global macroalgae market will grow 8% from 2018–2028, adding that increased awareness about the nutritional value of macroalgae is expected to push the global demand for macroalgae. In the Norwegian context a recent survey found that most Norwegians are willing to eat seaweed (Govaerts, 2021). This will depend on the opportunities that respondents mentioned concerning for example seaweed as a more popular source of food in the future. The demand for seaweed thus seems to be closely connected to barriers within the social dimension of sustainability such as “certifications” and “nutrients and unwanted substances.”

Another possible explanation for low profitability could be the “price.” The price reflects the markets willingness to pay, as demand is a function of price (see for example, Judd & Scadding, 1982) and currently there seems to be little willingness to pay for seaweed. The respondents mentioned the importance of the market and demand where the overall message seemed to be that there is a lack of market for seaweed today. This is in line with Norderhaug et al., (2020) who finds that the market is one of the main challenges in developing the industry. There seems to be little use in selling seaweed if the prices are low. One way in which one could overcome this barrier is through a subsidy. In Norway, subsidising agriculture is common to ensure profitability in an otherwise unprofitable market to “ensure food availability” (Landbruks-og matdepartementet, 2020). If seaweed becomes a more available resource for human consumption, maybe we could have the same argumentation in the case of such farming as well? Given the potential of seaweed in

Norway (Norderhaug et al., 2020), this should ensure food availability and would also generate employment and contributions through taxation. The price thus seems to explain other categories, such as “nutrients and unwanted substances”, “employment” and “taxes.”

Looking at the Total Cost, low profitability can either be explained by high total variable costs, or high total fixed costs. It seems that the stakeholders are aware of the challenges with high costs, stating that production cost is an important barrier (Municipality 1) and that there is a need for investment and “risk willing-capital” (Firm 3). At the same time, they give promising trajectories regarding the development of the costs, stating that seaweed requires little energy and the that seaweed can have many years of durability and that future demand for products may lower the costs (Firm 1). Looking at the fixed costs specifically, it seems that the stakeholders require investment in production by for example focusing on a “few actors with a spine” (County 1), and an automated production system (Firm 2). With such a system in place, one would be left with the variable costs (at least in the short run), which may make costs more predictable. The need to have strong actors to lower the costs and produce profitably can also be explained using the concept of “economies of scale.” This theory suggests that there is a correlation between the profitability of a firm and the size of its production (see, Bain, 1954). Because fixed costs are a one-time investment, the per-unit fixed cost of production will fall for each additional unit produced. Instead of having many small actors perhaps one should focus on a few large ones in line with the suggestions of County 2. However, the question then arises, how a firm can profitably grow to a sufficiently large size? A solution to this question is to focus on actors that are already strong, such as large companies doing aquaculture of more profitable species. However, the problem with incentives may then arise, as Firm 1 emphasised, how to do seaweed farming as a “left hand activity?” How to develop the seaweed cultivation industry if you don’t have the “knife to your throat?” (Firm 1, 2021). A possible compromise here may be found in what Firm 3 suggested, if the state could provide investment to small firms, that could be amended to loans if the firms made profit that may incentivise smaller firms to risk growing solely on seaweed.

6.1.2.2 Production value

Production value was also considered an important factor in developing the industry and was the second most coded barrier. The stakeholders seemed to focus on the whole production process, from processing to selling. The fact that the number of firms that received a license fell from 172 to 166 in 2019 (Fiskeridirektoratet, 2021) may indicate that something is holding back the development. One of the more concrete examples of factors holding back the development are public bodies such as the "Norwegian Seafood Council" (Firm 2) and "Norwegian Food Safety Authority" (Firm 1) which could contribute in the development by giving targeted market advice and approve macroalgae products. Meanwhile, there seems to be reasons why these actors are holding back such approval as content levels such as heavy metals and allergens (Firm 1) and too much iodine (Firm 1; Firm 2) is still a challenge in macroalgae products. This is confirmed in a recent report, which found that the labelling of, and declaration of content, were inadequate or inaccurate, and that iodine levels were too high for several macroalgae products (Aakre et al., 2021). At the same time, several researchers have looked into how one can overcome these barriers, such as Stévant et al., (2017) who find that for certain species, iodine levels can be reduced by exposure to heated water, and Duinker et al., (2020) who found that for certain species, the iodine levels were more stable than for others. "Production value" is therefore linked to "certifications" and "nutrition and unwanted substances", again hinting to the connection between these barriers are. Moreover, the stakeholders emphasised that a future development should happen in a sustainable manner, drawing parallels to the former blue-shell cultivation. This is described by Johnsen, (2003) who argues that low profitability, low investment and bankruptcy caused huge challenges in the industry. Production value thus seems to be closely connected to profitability as well. This is perhaps not as surprising considering the methodological decisions considering profitability and production value described earlier. Anyhow, seeing as production value is closely linked to both social categories and economic categories, it could be the case that "production value" is the underlying theory affecting the development of the cultivation industry in Norway.

In order to understand better how production value may affect the development of the macroalgae industry, a relevant theory could be "blue growth." According to Eikeset et al., (2018) blue growth can be described as holistic management of complex marine social-ecological systems. Cultivation of macroalgae could be considered such a system, especially given the fact that there are so many unknowns in this development. The need to think holistically about such a development could be illustrated by all these unknown factors. A finding that can help illustrate the complexity and the unknowns in this regard is County 1, in saying that there are X's on both sides of the production process. This is also in line with the findings of Norderhaug et al., (2020) who state that production is one of the main challenges in developing the macroalgae industry in Norway. FAO (2021), is perhaps more specific in describing blue growth, showing how one must balance economic growth, social development, food security, and sustainable use of aquatic living resources. It seems that macroalgae development is complex, but that blue growth could allow for sustainable growth despite of or in line with such complexity. Moreover, the respondents seemed to see the potential of such a development saying that they didn't see any reason why Norway shouldn't be one of the countries focusing on production of macroalgae (Firm 1).

6.1.3 Social sustainability

6.1.3.1 Area use

The respondents said that seaweed cultivation would require a lot of space (County 2) and may therefore be in conflict with other considerations (Municipality 1; Municipality 2; County 2). This is also pointed out by Stévant et al., (2017) who state that an economically viable aquaculture sector will require large areas for cultivation which may lead to conflicts with other users of that area. Meanwhile, Stévant et al., (2017) find that MAC can be combined with other activity such as IMTA. As seen, this was confirmed by the respondents (Municipality 1, 2021; Firm 2, 2021; County 2, 2021) as long as that activity was not used a cover for other activity (County 1, 2021). In addition, Norderhaug et al., (2020) suggests offshore windmills as an example for multiuse and shows how this could reduce conflicts in marine areas. It seems that the characteristics of macroalgae can be a disadvantage, in that it requires a lot of space, but at the same time, an advantage, as it is easily combined with other activity (Norderhaug et al., 2020; Stévant et al., 2017) This duality is evident also in the aquaculture act § 16 where it is stated that one shall put weight on “the applicants need for area for planned aquaculture” and “alternative use of the area for other type of aquaculture”. Aquaculture of macroalgae will “need” a lot of space, but space may also be “alternatively used” in combination with other activity. Perhaps policy makers are rigid to allocate licenses because they are unaware of how to weight this balance? The respondents said that these applications were easier to approve (County 2), and that in principle all areas were open for MAC (Municipality 2). Based on this it seems that policymakers mean the benefits outweigh the costs. Yet, in order for them to approve applications, there needs to be applications and recently that has been falling (Fiskeridirektoratet, 2020).

It seems that there is a need to balance many activities in marine space when facilitating cultivation of macroalgae. The way in which area use may affect the sustainable development of MAC could be illustrated using the concept of Marine Spatial Planning (MSP). Greenhill (2018) describes MSP as a framework that aims to guide and support management of multiple and competing demands on marine resources for achieving economic, social and ecological objectives. Although this may hint to sustainable development in line with the sustainability dimensions, Kidd et al., 2020 argues that there is a lack of clarity and consensus in practice regarding sustainability in MSP. They ask whether we should conceive the environment as another sector with interests to be negotiated, or as a boundary that limits possibilities for maritime activities. In this regard Douvere (2008) recalls how the initial intention for MSP was to achieve sustainabile development in the form of marine protected areas. She shows how “zoning” can be a useful tool in achieving such goals, saying that it is about dividing marine space into “functional zones” (p. 767) to regulate and guide “rational use” of those areas. The features of marine space, however, may cause externalities from one zone to easily impact on other zones. For example, marine transportation may reduce the quality of seaweed, and seaweed cultivation might prevent marine transportation. A theory that might be useful when discussing space allocation in relation to such externalities is the Coase theorem. The theory shows how an efficient allocation of resources will be reached as long as property rights are allocated, assuming that agents can bargain freely over any externalities (Cooter, 1989). In the case of MAC this aspect could be linked to the potential impact that seaweed cultivation may have on other activity conducted and ecosystems in adjacent areas. Placing a farm in a certain “area” may therefore “impact on other ecosystems”, it could cause “unwanted substances” in products, it could generate “employment” in that area, and impact on “profitability.” In other words, it seems that a grounded theory could be developed from area use as well.

6.1.4 Other

6.1.4.1 Research and innovation

The fact that that research and innovation is such a frequent barrier is in line with the findings of Norderhaug et al., (2020). What distinguishes this category from the other categories is the fact that it is not rooted in a certain dimension of sustainability. Instead, it can be thought of as a means, to achieve the other sustainability goals. As Nordehaug et al,. (2020) recommends, one should «initiate research and innovation” that can stimulate *development of* a “profitable and sustainable seaweed-cultivation-industry.” In the same way, Innovation Norway (2021) states that one wants to use innovation to “contribute to” sustainable growth. More specifically their Business Model Canvas (Innovation Norway, 2020) lists a description of what is required in order to have a business model for successful innovation. They mention “cost structures” and “revenue streams” which is in line with the economic categories, “key resources” and “key activities”, both encompassed in the environmental dimension. In the context of macroalgae it seems that an sustainable, efficient business model would ensure a sustainable development of the industry, as noted by Firm 1. Without research there seems to be little sustainable development of the MAC industry. Isaac Newton (1675) describes how he is standing on the shoulders of giants that allow him to see further. Without research it would be difficult to get an overview of and see further in the development of the MAC industry. Furthermore, there seems to exist certain features in this particular research that seem to hold back the development. As noted by the stakeholders, there are “unknowns on both sides of the equation” (County 1) and in order to solve X, you first need to solve Y, that again is dependent on the development of X. An example of this can be demonstrated in a recent rapport by Hancke et al. (2021) that looked into the ecological impacts from seaweed and the potential spread of alien or threatened species. They concluded that the question would require more research if cultivation were to develop into large scale production in Norway. In contrast, Norderhaug et al., (2020) found that in order to develop the macroalgae farming industry, one should first conduct research concerning the impact on other ecosystems of such a development. Moreover, seeing as research and innovation is so closely linked to the other dimensions of sustainability, it could be that they themselves are the theory of this development. It would be hard to imagine any significant sustainable development in the industry without these factors.

6.1.4.2 An alternative theory?

Having gone through the most coded barriers it seems that they can all be relevant in developing a theory. But could the theory be something less visible? According to Glaser and Strauss (1967) one may have to look beyond the data to discover a theory. In the following I will consider an alternative theory on how the barriers are affecting the sustainable development of the macroalgae industry.

An unexpected finding when talking to the stakeholders in the industry about sustainability, was the uncertainty about what sustainable development entails. These dialogs were mostly unsolicited and arose when asking the informants about sustainably developing the industry. Today there is an increasing focus on sustainability as firms, state and governments should conduct activity that is in line with UNs development goals (United Nations General Assembly, 2015). Could it be that the complexity of sustainability, together with the increased focus on the concept is actually causing baseless caution? Could it be that the definition of sustainability itself, is a barrier for sustainably developing the macroalgae industry? Maybe stakeholders are afraid to start a sustainable development of MAC simply because they don't know what this would entail? As shown in the theoretical framework, many researchers struggle to grasp the concept of sustainability and many attempts have been made to understand it. Costanza and Patten (1995) say that reasons people critique sustainability is because it cannot be "adequately defined" (p. 193) and Purvis et al., (2019) find that even representing sustainability graphically is a complex task. Perhaps we would need to develop a new term or theory of sustainability that is more comprehensible before we can start sustainably developing the industry? Perhaps this is particularly relevant in the context of macroalgae, being so complex, and it that has the potential to impact so many aspects of society, from food habits, to marine area use, to profitability, to bioenergy, to pharmaceuticals, to demand, to impacts on other ecosystems.

6.2 The “core” of the underlying theory

As seen, each of the four most barriers considered could be relevant in developing a theory. It turned out that although they were initially defined as separate categories, they were connected to each other and to other categories. The underlying theory may therefore be a combination of these four barriers that were discussed. Such a theory could be: “research and innovation into production of macroalgae that make efficient use of area in a profitable, sustainable way.”

The fact that the theory is a combination of several barriers could be supported by Barentswatch (2021) who write that the categories can be relevant for several sustainability dimensions at the same time. The theory also seems to be similar to the findings of Norderhaug et al., (2020) that recommend initiating research and innovation that can stimulate development of a profitable and sustainable industry.

Whether it is an interplay between the most important barriers or whether there is something else, being the theory of this study is not easy to conclude. It seems difficult deciding on one theory. But perhaps this is sufficient? Timonen et al., (2018) find that it’s a myth that GT should produce fully elaborated theory. They find that the most common outcome from a GT study is greater conceptual clarity, or a conceptual framework, to fully explain or predict something.

6.3 Limitations

There are a number of limitations to this study that should be mentioned. First, the scope of the study in time and resources forced a considerable simplification in the application of Grounded Theory. It has been attempted to draw the most important elements out of the theory. Yet, in doing this, important steps may have been overlooked. Moreover, in such an explorative and open methodology, research may have been unintentionally directed in a certain direction. The snowball sampling method is a good approach for finding informants, but what about those informants that didn't appear? Perhaps these responses would have provided valuable data that has now been overlooked? The time resources have also forced this study to be quite superficial and there hasn't been enough time to consider all barriers in depth.

The subjective nature of the analysis, where the decision to draw meaning out of the data has been up to me, may have caused this study to be biased. Adding to this that I have considered the data through my own worldview may add to this subjectivity.

Throughout the study there has been little physical contact with respondents as most of the communication has occurred online. Although such an approach has opened many doors in the research it may have also caused limitations in terms of clear communication which is crucial in qualitative research (Kvale & Brinkmann, 2015). When considering data collection, yet a possible limitation could be that the data have been collected in different ways (email interview, telephone interview and teams meetings) which may have caused them to be less comparable.

Given the size of the MAC industry in Norway, it has been difficult to set clear boundaries when conducting this study. Also, the scope of this study has not allowed me to explore the industry in all of Norway. This may have made it more difficult to replicate this study for future research. The size of the industry has also limited the number of potential respondents. This has forced this study to choose informants that are not necessarily speaking about the same exact industry.

6.4 Future research suggestions

Although looking into both the opportunities and barriers, this study has focused the discussion on certain barriers. There should be important factors in developing the MAC industry in Norway that can be revealed if looking closer into the other factors as well. Moreover, this research did not focus on how to *overcome* the barriers. This is something that future research may look into, which would be important in further understanding the sustainable development of the MAC industry. In addition, this study only focused on certain parts of the macroalgae industry. Future research could investigate other parts of the industry such as the perspective of consumers or scientists, or the equal stakeholders, based in other parts of Norway.

7 Conclusion

The aim of this study was to identify the opportunities and barriers in the sustainable development of the MAC industry in Norway, and how the barriers affect this development. It was found that in an industry with a lot of potential, barriers were present in all dimensions of sustainability, and often they seemed to be linked in the way they affected the development. The complexity and close links between the barriers made it difficult to conclude on a one theory explaining the development on its own. Adding to this, there could be other, less apparent aspects that may influence on such a development.

What seems to make this development difficult is that that there is a lot of complexity in many different aspects of a sustainable development. The industry itself is full of X's and Y's, and often solving one side of an equation requires solving of another unknown of that same equation. In addition, the industry itself has the potential to impact society, in ways that are difficult to predict or even imagine. To make use of the potential of seaweed farming, we first need to understand these barriers better and learn how they will affect the sustainable development of the industry. I hope this study has contributed in making the future of this industry visible. Perhaps it can provide stakeholders with a reference point that is grounded in the views of those involved. Maybe macroalgae will grow closer to the surface one day?

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9 Appendix

Figure 6

Interview guide

Intervjuguide: *Navn på bedrift/kommune/fylkeskommune*

Dato:

Introduksjon: Dette intervjuet omhandler oppdrett av makroalger og hva slags barrierer og muligheter det er og vil være for industrien i fremtiden.

Problemstilling: Målet med oppgaven er å finne ut hvilke muligheter og barrierer som finnes i en bærekraftig utvikling av industrien og på hvilken måte barrierene påvirker denne utviklingen.

Anonymitet: Navnet til intervjuobjektet vil bli referert til som «en representant fra næringen.» Identiteten til personen vil kun bli synlig gjennom personens ytringer, gjennom samtykke av disse.

Datainnhenting: Intervjueren vil benytte seg av notater samt eventuell avklaring med intervjuobjektet for å innhente data.

Tid: Ca. 30 minutter

Bli kjent med bedriften/organisasjonen	**Kan du fortelle litt om bedriften/kommunen/fylkeskommunen?**

Barrierer/Muligheter	**Hvilke barrierer og/eller muligheter mener du er de viktigste når det gjelder oppdrett av makroalger?**
	På hvilken måte mener du disse barrierene er med å påvirke utviklingen av industrien?
Bærekraft	**Hvordan mener du algeproduksjon kan bidra til bærekraftig utvikling?**
Annet	**Er det noe mer du har lyst å si?**

Table 7

Quoted barriers

	Biofouling	Impact on other ecosystems	Losses in production	Greenhouse gas emissions	Utilisation of residual raw materials	Growth efficiency	Production value	Profitability	Area use	Certifications	Employment	Nutrients and unwanted substances	Societal contributions, taxes and charges	Research and innovation	Other categories [category in brackets]	
Firm 1	Sesonger og ferskprodukter er vanskelige å forholde seg til (attacks)		.				… mye av merverdien av produkter eksporteres ut av Norge (production process) Vi trenger en forretningsmodell som kun handler om produksjon av tare (sales	Det går ikke å ha tareproduksjon som venstre håndsarbeid. Vi må ha kniven på strupen hver dag, hvis ikke går det ikke (cost) Markedet er der ikke (profit) Dersom etterspø	Konsesjon har tatt litt tid, men det har gått greit (application)		Helårig arbeidsplasser (need for year-round jobs)	Problemet når man plukker tare er at man ikke vet hva innholdet av tungmetaller er (heavy metals) Vi er ikke vant til å ha så høye nivåer		Produktene som har vært der lenge er gode på å produsere, men vi mangler produkter. Vi så at det var mye tilgjengelig tare, men ikke så mange produkter som lages av det (product development)		

							process)	rselen tar seg opp, kommer det til å komme flere tareoppdrettere (demand) å finne risikovillig kapital for å utvikle bedriften. Dette er generelt en utfordring i Nord-Norge (cost) Med tanke på bedriftsøkonomi må vi se at marginene går i null og at vi kan få til en positiv omsetning (profit, cost)				av jod som det tare inneholder (iodine) Mye risiko knyttet til tungmetaller (heavy metals) Vi har også en utfordring med skalldyrallergi. Vi klarer ikke å få dette bort fra produktet (allergies)		Hvordan kan vi lage produkter som andre vil ha og skjønte at vi måtte få produktet over i noe «mainstream» (product development) Produksjonen av tare er der, men produktene er der ikke. Investeringene i å lage nye produkter av tare mangler. Det er det viktigste (product development)		

								Det er et disruptivt produkt -folk er ikke vant til det (demand) Tror en barriere er at en del av de bedriftene som driver med tare driver med andre ting ved siden av, at insentivet ligger i fiskeproduksjon (cost, profit)								

Firm 2		…vet man ikke hva som blir liggende på bunn. Det må i så fall være et slikt stort bunnfall som kan være skadelig (bottom impact)					[Vi trenger] gode salgskanaler (process) Det er et relativt stort marked i Europa, men her importeres det meste fra Østen (process) Ser også at det kan komme et felles salgsselskap for algenæringen, på samme	Vi tar det sakte og rolig fordi fra erfaring vet vi at det tar tid. Det er fort gjort å bruke for mye penger (cost) I tillegg er det dette med marked og salg som må gå hånd i hånd hvis ikke risikerer man det samme som skjedde med skjell der man fikk til å dyrke, men ikke selge (demand)		Vi trenger god dokumentasjon (documentation) Jobber med å få på plass innholdsdeklarasjon. Dersom vi hadde dette hadde det hjulpet oss mye i få produktene gjennom toll Mattilsynet sier vi må vente på dokumentasjon på	…fått plass til en 100 % stilling som kun jobber med tare delen av IMTAen (need for employment) Lønningene er altså et problem (salaries)	Folk er redde for at det kan være for mye jod i produktene (iodine) Vi har prøvd å selge sammen med andre lakseprodusenter, men disse er redd for at taren kan skade ryktet deres (substances)		I tillegg trenger vi flere FOU-konsesjoner for å teste og forske (research) Mye er ukjent. For eksempel hvordan vi skal bygge anlegg. Vi kan jo se på anleggene i Kina, men vi kan ikke har slike produksjonsanlegg fordi lønningene der er så lave. Vi må automatisere mer		

							måte som det finnes dette for lakseoppdrett (sales process) Dette er nytt produkt og vi har ikke noe salgsapparat som er forberedt (process) Vi trenger markedsføring gjennom norsk sjømatråd (process)	Vi har ikke opparbeidet noe marked enda (demand) Trenger å bli automatisert for å bli lønnsom (cost) Tror at nå er det få som har lønnsomhet eller overskudd til dette (cost)		om det kan være for mye jod for eksempel. Vi trenger en god oversikt med jevnlige analyser (documentation) Vi har spurt norsk sjømatråd om markedsføring av makroalge. De markedsfører fisk, men har ikke lov å ta inn tare enda (due to lack of documentation)		Det er viktig å berolige markedet med at det vi selger er bra (substances)		enn det de gjør (research production) Vi har med forskningsinstitusjoner som skal legge fram betryggende innholdsanalyser (research)		

Firm 3							[Det må jobbes med] nye måter å selge tare ut i markedet (process) …i tillegg må det også på plass mottak og produk	Håper at jeg finner markedsnisjer som gjør det mulig å videreutvikle bedriften (market, cost/profit) Lønnsomme produkter (cost/profit)	For meg som dyrker handler det også om arealer (lack of area) Det er ikke tvil om at vi har ulike naturlige fortrinn for dyrking av tare rundt i landet,					Her kan det settes av FoU-midler som kan brukes for å bygge opp kompetanse på dyrking (research competence) Bedriftsnettverk er nyttige, men utfordr	Fylket er mer passive her [passive administration]	

							sjonsapparat (process)	Skal vi få opp en industri må det ta utgangspunkt i markedsbehov (demand) Dette er såpass store investeringer at det må inn andre investorer. Alternativt må man bygge det opp sjøl, - noe som jeg ikke tror er så realistisk (cost) I løpet av de neste 2-3 år må det inn risikokapital for å bygge	og det er viktig å få kartlagt disse (lacking overview of area)					ende når det blir store avstander mellom næringsaktørene. Føler meg nokså ensom her (cooperation, research) Samtidig må det jobbes frem ulike produkter (product development)		

								opp et rasjonelt dyrkings, høstings- og produksjonsapparat (cost)								

County 1		for eksempel finner vi mye rognkjeks i tareanlegg og det er jo bra at det er med på å skape økosystemer, men det område det vil jo forsvinne når man til slutt skal høste taren (uncertain impact) Det kan også være en fare, dersom du	hvis du får store anlegg kan du risikere at det detter av tare på grunn av uvær for eksempel (fall off) Tare råtner fort. Det kan gå bare noen timer før den				..det vi må finne ut handler om hvordan man skal prosessere taren (process) Det er mye som skal klaffe når man skaper en verdikjede. Det erfarte vi også fra blåskjellsatsingen. Alle visste at markedet var der, men ingen klarte å produsere. Det er mindre politisk vilje på grunn	Hvis du ikke tjener penger, er det ikke så lett å overleve (cost/ profit) ..produsere så mye du vil, men får du ikke solgt det så er det ikke så lett (profit) få ned investeringskostnadene i produksjonen (cost) Jeg tror man, for å kunne drive med tareoppdrett må satse på noen få aktører som har ryggrad (cost,	Tror det blir viktig å utvikle måter å dyrke tare på som er arealeffektivt, hvis du skal ha storskala-industri i fremtiden (area efficiency) Interessen er der, men i planfasen har man ikke klart å knekke kodene. Skal man avsette areal må man vite hvordan det skal produseres. (planning area)				Jeg mener de største utfordringene ved tare-produksjoner knyttet til økonomi og samfunn.	Mye i tareoppdrett vil måtte være basert på antakelser og ta utgangspunkt i den kunnskapen man har tilgjengelig (research knowledge) Enhver handling må med andre ord basere seg på kunnskap (research knowledge)	Personlig er jeg litt metta på begrepet bærekraft. Alt skal liksom være bærekraftig. Du skal tjene penger, skape arbeidsplasser og skape produksjon der folk er. Det er så stort, og alt henger sammen (sustainability)	

		får store anlegg, at dette skygger for det som lever under (shadow)	begynner å lukke og det er vel enten 12 eller 24 timer fra man tar opp tar en til den må være prosessert (on land)				av denne erfaringen (prduction process and political will) Det virker litt som at næringa venter på markedet, mens markedet venter på næringa (process) Jeg tror det som gjør satsingen utfordrende er at det er mange X-er på produksjonssiden og mange	profit, economies of scale) De økonomiske barrierene er vanskelige å komme forbi, fordi det ikke er noe marked (cost, profit) ikke vits å produsere masse hvis det bare blir liggende (lack of demand)	Mangel på grunneområder (lack of good area) det er mye friluftsinteresse knyttet til disse områdene (lack of available) X skulle hvert fall inn her og produsere bioenergi til bruk i biler. Da de mottok sjøarealet, trengte de hele arealplanen! Det er et bilde på hvor mye plass slik produk						… ekstrem nedbør Det skaper utfordringer gjennom formørking av havet (extreme rainfall)	

							X-er som er knyttet til markedet (process) per nå skjer meste parten av produksjonen i sør (lack of process) Tror det er viktig at vi legger produksjonen av hele verdikjeden i Norge slik at vi skaper ringvirkninger lokalt og regionalt (value chain, local process)		sjon krever (size) Denne saken ble politisert fordi man mente at tareproduksjon ble brukt som et skalkeskjul for å kunne drive med lakseopdrett. (following lack of spacel)							

County 2		Det kan vel være en fare med noe nedfall av organismer (impact bottom) hvor ofte man må gjøre analyse av den omkringliggende naturen (impact cost)					Markedstilgang (process)	Viktig at det man driver med er lønnsomt også. Jeg tenker at man her må gjøre en avveining (profit/cost) Lurer personlig på dette med marked. Store næringer er jo veletablerte, med mye penger og har jo kommet seg her på grunn av etterspørsel (demand) Hvis du tenker tilbake på da	…arealtilgang og klarering av lokaliteter (availability) Finne gode nok og tilstrekkelig med areal (good area) I tillegg kan det jo være flere interessenter på ett og samme område (competition) Handler mye om planarbeidet i kommunen (area planning)				..hva er egentlig den totale samfunnsnytten?	Når det kommer til produktutvikling, er det jo spennende å se hva disse produktene kan brukes til (developing product)	Hmm bærekraftig er jo et velbrukt ord. Hva er egentlig bærekraft? Produksjon skal jo være bærekraftig. Hva er definisjonen på bærekraft igjen? Det er litt vanskelig å forholde seg til det der - bærekraftig. Det har jo en definisjon, men	

								blåskjellindustrien vokste frem for noen år siden var det jo mange som startet opp med oppdrett av dette. Men her var det jo ikke noe marked og i dag ligger mange blåskjellanlegg forlatt, og man har måttet ha en stor innsamlingsaksjon for å samle de inn. (market/profit)							husker ikke hva det er. Handler vel noe om at produksjonen ikke skal påvirke negativt utenfor rammene av det som produseres? (sustainability) .	
Municipality 1								Virker som marked er den største barrieren (demand)	Vi må passe på at vi har en planleggingsprosess som ikke er i konflikt med	Mange hev seg med fordi de så at det gikk så godt i laksenæringen, så				Kunnskap (knowledge research) hva alger		

								Produksjonskostnader tror jeg er en viktig barriere (cost) Vi er nødt til å ha lønnsomhet og tjene penger (profit/cost) viktig at markedet er der (demand)	andre hensyn (area planning) visuell forurensing: hvor mye tåler vi av blåser og blinkende lys fra oppdrettsanleggene? (visuality) Kan se for seg at det blir en utfordring å balansere plassen med andre aktiviteter (competition)	de heiv seg på med blåskjellproduksjon. Men her sleit de med kvaliteten på skjellene og markedstilgangen. (approving quality)				kan brukes til blir jo viktig å finne ut: mat, medisiner, alginat osv (product development)		
Municipality 2							Vi trenger nye strukturer og løsninger (	for lite volum og marked (market, profit)	rift om områder (competition)			Land i Asia er mye mer vant til å spise		lite forskning og utvikling på hva som er det		

							proces s)					denne type mat, med denne typen smak (lack of traditi on)		optimal e vekstgr unnlage t (researc h growth)		

Table 8

Quoted opportunities

	Impact on other ecosystems	Greenhouse gas emissions	Utilisation of residual raw materials	Growth efficiency	Production value	Profitability	Area use	Certifications	Employment	Nutrients and wanted substances	Societal contributions, taxes and charges	Research and innovation	Other categories [category in brackets]
Firm 1	Ingen ferskvann (no need freshwater)	ingen CO2 utslipp (carbon dioxide) tare binder karbondioksid like mye som regnskog (carbon dioxide) produserer et produkt uten å sette avtrykk (no greenhouse gas emissions)		Algeproduksjon kan bidra (til bærekraftig produksjon) fordi det er ingen gjødsling (grows without fertiliser) Samfunnet bruker kjemikalier overalt, det gjør vi ikke ved algeproduksjon (grows withou	Det gjenstår bare å se om Norge klarer å bli en av dem som produserer det. Jeg ser ikke noen grunn til at vi ikke kan bli det. Vi er jo gode på laks- hvorfor kan vi ikke være det på tare? (production process)	Tørket tare har flere år med holdbarhet (cost/profitability)	ingen landjord (no need land)	Mattilsynet har en bestilling fra myndighetene om å tilrettelegge for å hjelpe bedrifter i Norge (documentation)	Tørket tare har flere år med holdbarhet. Dette gjør at det er lettere å skape arbeidsplasser hele året rundt (year-round jobs) Jeg tror vi kan bidra til å få flere arbeidsplasser i Norge (job availability)	Flere er interessert bla på grunn av jodinnholdet (iodine). Jeg tror på lang sikt at tare kommer til å bli et vanlig, næringsmiddel, likestilt med ris og potet (food substitute)			I et større perspektiv må vi etablere en økonomi i Norge som er økonomisk bærekraftig og som er laget for evige ressurser. Vi kan ikke ha en økonomi som baserer seg på petroleum lenger

				t chemicals) Makroalger er et råstoff som kan bli gjort effektivt i Norge (growth efficiency in Norway)					Arbeidsplasser må lages i nærheten av ressursene og produktene som produseres. Her har vi gått på en smell når det gjelder hvitfisk (Demand for workers) Jeg tror flere vil ønske å jobbe med tare i fremtiden (demand for work)				. Vi må inn i et skifte i Norge, som vi ikke har sett siden krigen [sustainability]
Firm 2	De kan også være med å rense fjordsystemen	Vi videreforedler stort sett der		Bruker ikke gjødsel og forer ikke.	…noe liknende lakseindustrien der eierne til slutt	Helsekost og fôr vil bli viktigere i fremtiden (demand)	I samarbeid med X (lakseselskap) har vi søkt hos		Men det vil bli mange arbeidsplasser i land-	Ingen tilsetning underveis av stoffer i	Myndighetene er veldig gira på at dette		Absolutt bærekraftig [sustai

	e for næringssalter (improve ecosystems)	vi tar det opp (little transportation)		(grows without fertiliser) Vi setter ut i sjøen og så vokser det der. Vi prøver å få til i IMTA her. SINTEF Ocean har gjort flere forsøk som har vist at det er mye større vekst dersom de ligger nært et fiskeopdrettsanlegg. (efficient when IMTA)	eide både produksjon og salg (production process)	Matmarkedet er en viktig mulighet i fremtiden (demand)	fiskeridepartementet om konsesjon til å starte IMTA (IMTA)		prosessering, salg og markedsføring. (job availability)	produksjonen (no additives)	skal bli en stor næring (taxes)		nabilit y]
Firm 3		Tare binder CO2				Her kan det offentlige gå inn				Kunne brukes til huma			

		(carbon dioxide)				med risikolån som kan endres til tilskudd om det «skjærer» seg (cover cost) (kunne brukes til) dyrefor				nt konsum (wanted substances)			
County municipality 1		En annen dimensjon er klimadimensjonen og den blå skogen som binder CO2 (carbon dioxide)		gunstige forhold i Nord-Norge (growth conditions in north)	spennende produksjonsprosjekt (process)	Det er mye interesse fra privatpersoner men også fra store selskaper (demand) Plassere tareanlegg i grunnvannsområder- da ville investeringen i konstruksjonsdelene være mye mindre				I den nye generasjonen har man kanskje et nytt perspektiv på miljø og bærekraft, slik at man for eksempel ikke må spise kjøtt til hvert	Det kan være med å bidra til å styrke lokalsamfunn (taxation)		generere bosetning [settlement]

						(cost, space)				måltid (wanted substances)			
County municipality 2							Fylkeskommunen er i ferd med å utviklen en ny arealplan der tema om havbruker mer og mer aktuelt (area planning) Algesøknader er mindre kompliserte, og det er gjerne færre konflikter med andre aktører (competition) Det går mye raskere med makroalgesøknader fordi miljødelen er						Når det kommer til produktutvikling, er det jo spennende å se hva disse produktene kan brukes til (possibilities)	Enklere å drive med bærekraftig miljø innenfor makroalger enn ved fiskeoppdrett. [sustainability] Uten næring er det ingen som vil bo der. [settlement]

							lettere å godkjenne (space access)						
Municipality 1	kan være med å skape et mer mangfoldig økosystem og føre til økt biologisk mangfold. For eksempel kan det være oppvekstområde for yngel (biological diversity) renser avfallsstoffer (cleaner ecosystems)	binder det CO2 (carbon dioxide)		ikke trenger å legge til noen kjemiske stoffer og at prosessen foregår helt naturlig (no chemicals) Ved algedyrking utnytter man det som er der naturlig (grows efficient with little facilitation)		tare er jo mindre energikrevende og har mindre utslipp så det vil kunne være lønnsomt (profit) X (kommune) var en av kommunene som spilte inn at det var viktig å få på plass et depositum for oppdrett, slik at kostnaden for eventuell opprydning var dekket (costs covered)	gode muligheter her fordi tare i liten grad er i konflikt med andre aktiviteter (competition) fiskebestandene øker på grunn av taren og at det ikke blir plassmangel, men at disse utfyller hverandre (complement)		Skape arbeidsplasser lokalt (local employment)				

Municipality 2		mer fokus på oppdrett, da vi har hørt fra næringen at plukking kan ødelegge for CO_2 lagringen (carbon dioxide when cultivating)				Jeg tror at det kommer til å være flere som ser på tare som en viktig ressurs og derfor også at det blir mer behov for tare (demand) Vi trenger flere matkilder (demand)	Vi er en liten kommune, men vi har mye hav (spacious) I utgangspunktet er alle områder åpne for oppdrett og så utelukker vi istedenfor de som ikke er tilgjengelig (space availability)			For 10 år siden var det få som spiste sushi, men nå er dette mye mer vanlig (habits) Økende mengde veganere og vegetarianere (food preference)			

Table 9

Decisions behind amendments

Barentswatch indicators	Barriers	Opportunities
Environment		
"Diseases changed" to "biofouling"	"Biofouling" is not directly transferable from "diseases." However, it was believed that it is a similar, suitable description for macroalgae	Removed because didn't seem like an opportunity
"Emissions from fish farming plants" changed to "Impact on other ecosystems"	It was believed that this was a more fitting description for macroalgae cultivation.	Kept because may have positive impact as well
"Escapes" removed as unapplicable	Macroalgae can't escape in the sense of the word, and potential losses in biomass is captured by "losses in production"	Removed
"Fish mortality and losses in production" changed to "losses in production"	It was considered unfitting to talk about mortality when considering macroalgae.	Removed because didn't seem like an opportunity
"Greenhouse gas emissions" unchanged	Maybe applicable to macroalgae	Kept in case of positive impact
"Impact on wild salmon" added to "Impact on other ecosystems"	It was believed that "other ecosystems" would be a more fitting term	Kept in case of positive impact
"Sales of pharmaceuticals" removed as unapplicable	The use of pharmaceuticals such as antibiotics did not appear to apply to macroalgae	=
"Salmon lice" added to "biofouling"	More applicable for macroalgae	Removed because didn't seem like an opportunity
"Utilisation of residual raw materials" unchanged	Unaware if this could be applied to macroalgae and it was therefore kept	May have positive impact as well
Economy		
"Costs" added to profitability	Profitability=Revenue-Cost (see Mattessich, 1961). It was believed that anything related to cost, would be directly connected to profitability as well	Removed because didn't seem like an opportunity

“Feed composition and origin” removed as unapplicable	It didn’t seem fitting to consider this category in the case of macroalgae	=
“From feed ingredients to produced fish” changed to “growth efficiency”	From Barentswatch it is said about this category “How efficiently the feed ingredients are converted into fish” Several options were considered for macroalgae such as “Growth input” and “Growth conditions.” An important aspect in choosing the word “efficiency” was due to allow the economic perspective of the indicator to shine through.	=
“Production value” unchanged	Expected to be applicable as is. However, it was difficult to separate from profitability. Therefore, if the focus was on the process of the production value such as the process of sale, it would be coded in “production value.” If the focus was more linked to the revenue generated from sales, it would be placed in “profitability”. I considered combining production value and profitability, but it was believed that distinguishing the two categories from each other would generate more precise results.	=
“Profitability” unchanged	Expected to be applicable as is	=
“Value added– contribution to GDP” added to “production value” due to difficulty distinguishing the two	It was found difficult to distinguish these two indicators and the first was therefore added to the second.	=
Social		
“Area use” unchanged	Expected to be applicable as is	=
“Certifications” unchanged	Expected to be applicable as is	=
“Employment” unchanged	Expected to be applicable as is	=
“Job absence” added to “Employment”	Firm 1 expressed a need for year-round jobs in the Aquaculture Industry of Macroalgae. It was believed that in	=

	order for the jobs to be year-round it was explicitly meant that employers would need to be present at the job.	
"Nutrients and unwanted substances"	Unchanged and expected to be applicable as is	Changed to "Nutrients and *wanted* substances" to allow for a positive sounding
"Occupational injuries" added to "Employment"	It was believed that the employment category would be sufficient in capturing any aspects of occupational injuries. In addition, these were expected to be difficult to distinguish	=
"Societal contributions, taxes and charges" unchanged	Expected to be applicable as is	=
Other categories		
"Research and development" adopted from quote by respondent "Firm 2"	Adopted from quotes by respondents	=
Other categories	Any other barriers	Any other opportunities

Table 10

Barriers by respondent and category

	Biofouling	*Impact on other ecosystems*	*Losses in production*	*Greenhouse gas emissions*	*Utilisation of residual raw materials*	*Growth efficiency*	*Production value*	*Profitability*	*Areas*	*Certifications*	*Employment*	*Nutrients and unwanted substances*	*Societal contributions, taxes and charges*	*Research and innovation*	*Other categories*
Firm 1	1						2	7	1		1	4		3	
Firm 2		1					5	5		3	2	3		3	
Firm 3							2	5	2					3	1
County 1		2	2				6	6	6				1	2	2

County 2		2					1	3	4				1	1	1
Municipality 1								4	3	1				2	
Municipality 2							1	1	1			1		1	
Total	1	5	2	0	0	0	17	31	17	4	3	8	2	15	4

Table 11

Opportunities by respondent and category

	Impact on other ecosystems	*Greenhouse gas emissions*	*Utilisation of residual raw materials*	*Growth efficiency*	*Production value*	*Profitability*	*Area use*	*Certifications*	*Employment*	*Nutrients and wanted substances*	*Societal contributions, taxes and charges*	*Research and innovation*	*Other categories*
Firm 1	1	3		3	1	1	1	1	3	2			1
Firm2	1	1		2	1	2	1		1	1	1		1
Firm 3		1				2				1			
County 1		1		1	1	2				1	1		1
County 2							3					1	2
Municipality 1	2	1		2		2	2		1				
Municipality 2		1				2	2			2			
Total	4	8	0	8	3	11	9	1	5	7	2	1	5