DyPP

Exploring the future potential
of seaweed as bioplastic
through strategic use of design

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ABSTRACT

In the cold waters along Norway's rocky coast, we find what's predicted to be one of the most important resources in the future. This project is an exploration of the great possibilities of seaweed. More specifically, farmed seaweed.

Norway has set a vision for 2050; to produce 20 million tons of seaweed valued at 40 billion NOK. How do we get there?

This project aims to contribute to a national strategy of how Norway can reach this vision for 2050. Through a systemic approach we have mapped the situation today and important steps to upscale the industry, into a roadmap. The roadmap is designed to be a tool for discussion and reflection. Illustrating how cross sectoral collaborations and common goals are key to see the development needed.

To make a large-scale seaweed industry feasible, product development is essential. We have developed four future scenarios within one of the predicted usages of seaweed; biomaterials, to exemplify this development. Our focal point is how seaweed can be used as packaging. The main objective of the four scenarios is to inspire the emerging seaweed industry, especially the companies currently developing packaging material. Additionally we hope to challenge the way we think about packaging today.

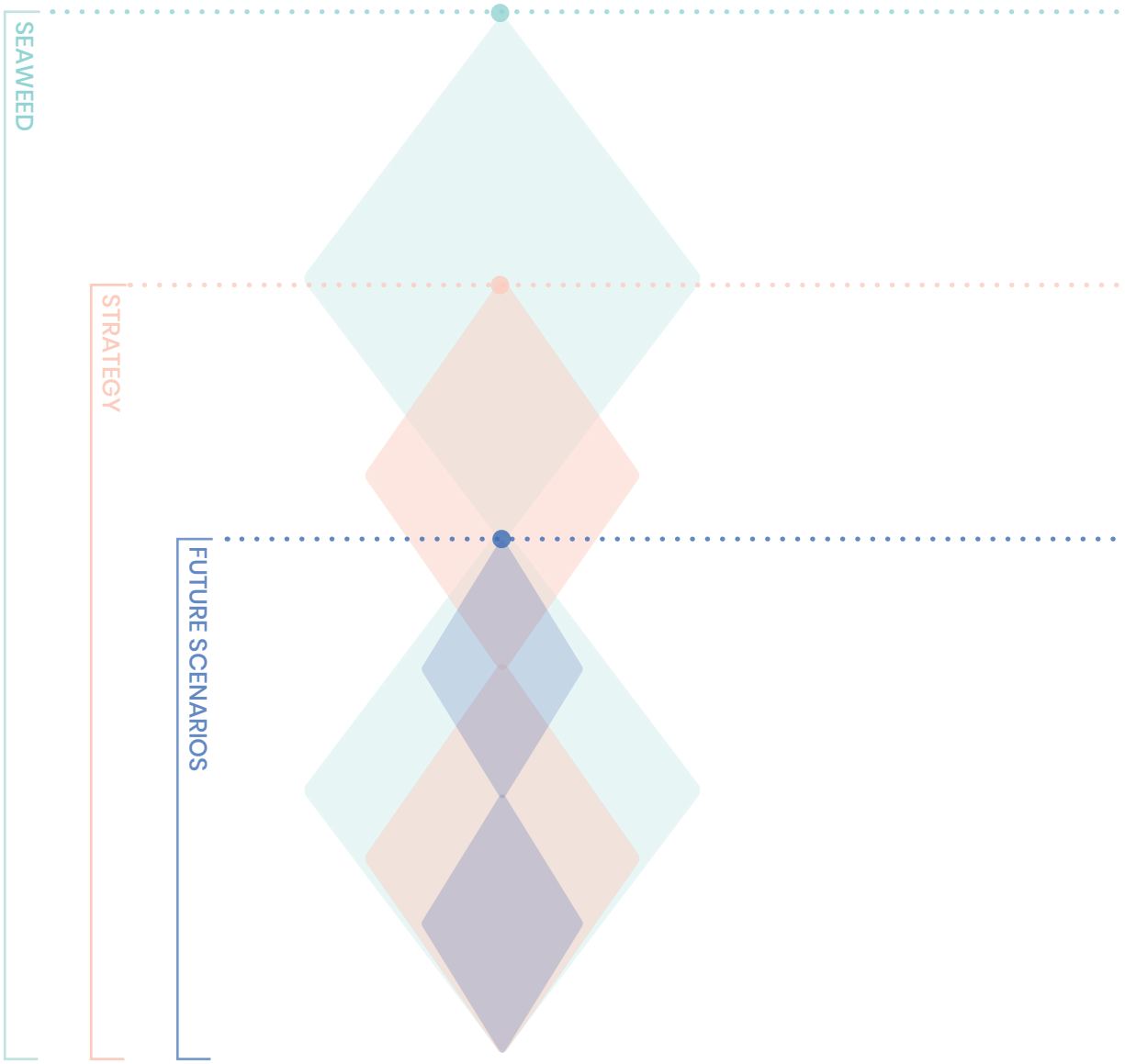
PERSONAL MOTIVATION

Our greatest motivation has been to make a difference. To develop design that may contribute to push for change. Through the opportunity of doing a design diploma, we wanted to work with a topic that would be both fun and complex.

During spring 2018, in collaboration with a global sports and lifestyle brand, and PhD fellow Claire Dennington, we did an eight-week project. The project we delivered, together with Michelle Chow, was called "*Run the Magic*". "*Run the Magic*" is a futuristic concept exploring how bacteria can be utilized to dye sportswear for urban runners. The objective of the project was to reduce water consumption by challenging traditional dyeing methods. We both found the project really inspiring and quite different from any design project we had previously done. Starting with a material and it's possibilities, and looking at trends to predict the possible future. "*Run the Magic*" has been a source of inspiration for our diploma.

In our design diploma we wanted to explore possible futures, new ways of using a material and build scenarios based on trends. From the very beginning we hoped that we would get the opportunity to experiment hands-on with seaweed as a material, as we both find this really exiting. For our diploma we wanted to use a strategic approach and methods from service design to create experiential touchpoints. Today's examples of new usage of seaweed made us curious to learn more about the predicted potential, and how design can be applied in the field.

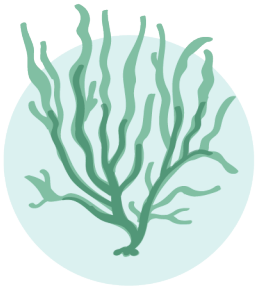
CONTENT:



PROCESS MODEL: *Through this diploma we have worked on many different levels, continuously zooming in and out of different fields. The model above shows the different stages of our process to gain a holistic understanding of seaweed. Our starting point was seaweed, then we zoomed in and mapped out a potential strategy towards the future. Furthermore, we developed future scenarios to exemplify one of many potentials seaweed can have.*

1. APPROACH

KEY MOMENTS & METHODS



EXITING MATERIAL

We chose seaweed because we already had some knowledge about it's potential. As soon as we started our research we understood that the possibilities were way bigger than we thought.

ADDITIONAL PERSPECTIVE

Meeting Julia Lohmann, in Finland, provided us with an additional perspective; to think about the whole ecosystem and all the non-human actors. She is a seaweed designer & professor of practice at the Aalto University.

DESKTOP RESEARCH

To get an understanding of seaweed and the current situation we read several reports and articles. The illustrations above show the most important reports for our project. Through this research we found relevant people to contact.

INITIAL INTERVIEWS

We conducted interviews with experts from the **industry**, **research** and at **governmental** level. The logos represent the different people we talked to.

By 2050 Norway can produce 20 mill tons of seaweed valued at 40 bill NOK

HOW?

BELLONA

Through our desktop research we discovered that one of Bellona's focus areas is seaweed. We contacted them, and their insights and angle was very valuable. They view seaweed farming as a climate action, to absorb CO^2.

MAPPING RESEARCH

To understand connections and cluster main findings

1. FINDING

Low demand for seaweed = market gap

2. FINDING

Increased interest for farming seaweed, but lack of product development

3. FINDING

Predicted future potential: food, agriculture, biofuel & **biomaterial**

4. FINDING

Need for **common strategy** & shared milestones

FIRST EXPERIMENTATION

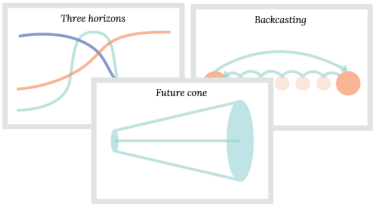
After choosing to focus on seaweed as biomaterial, we went to forage seaweed in the Oslofjord. We tried to follow a recipe for making paper of seaweed. It turned out to be both smelly and difficult.

To see pictures go to
Appendix A
separate document

ALGINATE BIOPLASTIC

We chose to focus on how seaweed can be used as a bioplastic for packaging in the future. Out of the predicted future potentials, this was the area where we felt we could contribute the most as designers and design inspirational examples for the future.

During a workshop in Sweden we learned how to make bioplastic of seaweed, from Martin Sterner, postdoc, KTH.



FUTURE METHODS

As one of our main findings was the need of a common strategy, we wanted to explore this further. Through future methods we tried to map out key steps needed to reach the vision of 2050. We talked to Jomy, Claire and Josina at AHO to learn more about how the methods could be applied.

VALIDATING FINDINGS

We met Jon at Seaweed Energy Solutions to discuss our mapping and get the perspective of an actor within the industry.

B'ZEOS

The meeting with Jon led us to Guy Maurice at B'zeos. This is a startup working with bioplastic of seaweed, more specifically straws.

UNDERSTANDING PACKAGING

We used the probes in interviews with Øya, Bama, Fursetgruppen and A-packaging. We interviewed these people to understand the current situation of packaging, challenges and alternative materials.

PROBES

After many attempts we managed to create structures and shapes that did not break. We used the experiments as probes in interviews. This triggered questions about the material properties and interesting reflections on how it could be used.

EXPERIMENTATION

The workshop in Sweden made it possible for us to continue to experiment at AHO. We had a lot of fun experimenting with this strange alginate material. This exploration inspired many ideas

FUTURE IDEA WORKSHOP

We invited fellow students to join an idea workshop. The goal was to ideate on what packaging might be in the future.

To see pictures go to
Appendix B
separate document

To see pictures go to
Appendix C
separate document

ITERATING ROADMAP

We have gathered different perspectives to be able to illustrate the complexity of a potential development.

Meeting with Seas of Norway, a startup working on how seaweed can be used for packaging

Meeting with Asbjørn Stavland, Norwegian Seaweed Farmers

TESTING IDEAS

The discussions during interviews lead to many new ideas and to more targeted testing of the material.

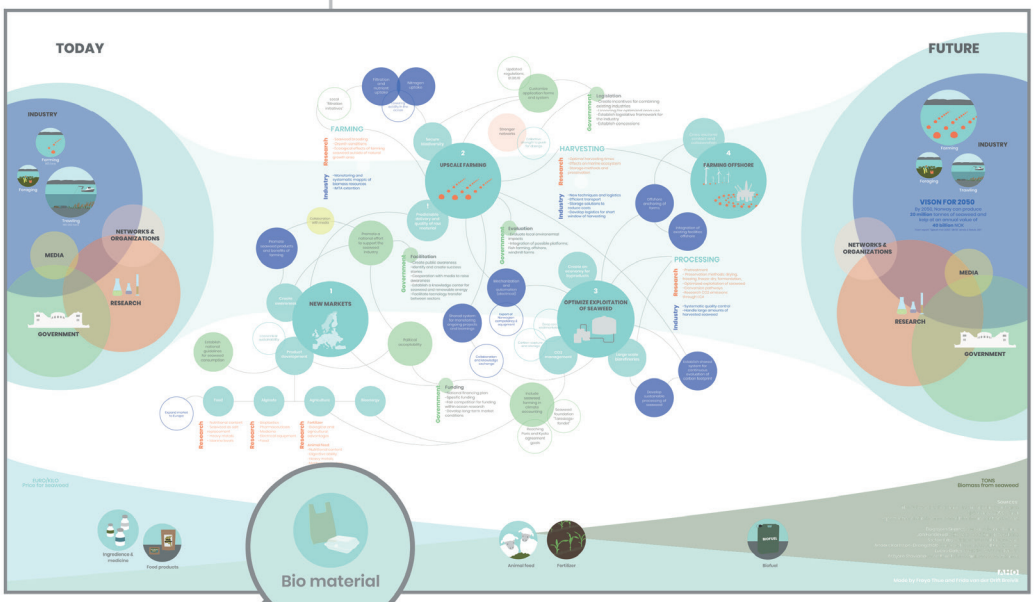
FUTURE TRENDS

To help imagine possible future scenarios we used trends as inspiration.

To see pictures go to
Appendix D
separate document

ROADMAP

to establish common goals &
ensure sustainable development



4 x FUTURE SCENARIOS

to exemplify a potential development

Introduce material

Challenge
unneccessary
use of plastic

Challenge imbalance

Challenge packaging

OVERVIEW OF PROJECT

APPROXIMATELY 70% OF THE EARTH'S SURFACE IS WATER. TO MEET THE NEEDS OF FUTURE POPULATION GROWTH AND CLIMATE CHANGE, WE HAVE TO LOOK TO THE OCEAN. HOW MIGHT WE USE THE INHERENT POTENTIAL OF SEAWEED TO TACKLE SOME OF THESE CHALLENGES?

"DYPP" is a design diploma exploring the future potential of seaweed as bioplastic through strategic use of design. The overarching goal of our design proposal is to make a contribution to upscale seaweed farming in Norway, and move towards a green shift. Through an explorative- and systematic approach, we have identified key challenges and opportunities within the seaweed industry today. Our design proposal is a result of research through design. The proposal consists of a roadmap and four future scenarios.

ROADMAP: The roadmap illustrates a potential development within the seaweed industry. One of the main findings from our research and interviews is the need for a national strategy, common goals and shared responsibilities within the industry. The aim of the roadmap is to create an overview and highlight the importance of multiple focus areas, collaborations across industries and investment in local resources.

FUTURE SCENARIOS: The four scenarios illustrate how alginate from farmed seaweed can be used as bioplastic, more specifically packaging. The main objective of the four scenarios, is to inspire the emerging seaweed industry, especially the companies currently developing packaging material. We envision the scenarios as possible steps going from introduction of a new biomaterial to potentially challenging packaging as we see it today. Our scenarios are based within the next ten years, as we believe this timeline is enough to envision radical changes, but still be relevant for the stages of development needed today.

We are at the beginning of a potentially large industry; seaweed farming. When upscaling seaweed farming, it is crucial to consider how the industry can be developed in a sustainable way, avoiding overexploitation and harmful interference with the marine ecosystem.


SEAWEED
PRODUCTION TODAY
PREDICTED POTENTIAL

2. INTRODUCTION

Picture from the Northern Company

SEAWEED

BELOW THE SURFACE WE HAVE COUNTLESS SPECIES OF ANIMALS AND ORGANISMS, WHERE SEAWEED IS AN ESSENTIAL PART OF THE ECOSYSTEM. SEAWEED IS ONE OF THE OLDEST SPECIES ON EARTH, YET MOST OF US DON'T KNOW ABOUT IT'S IMMENSE POTENTIAL.

Seaweed forests is home to many organisms as well as a safe place for breeding. Seaweed also works as a filter for the oceans, absorbing nutrients, nitrogen and CO^2. World wide we know of 11 000 different types of seaweed, and in Norway alone, we have registered 450 different types (Rueness 1998).

Historically seaweed has been an important and precious resource. In one of Norway's oldest laws, Frostatingsloven we found that seaweed belonged to the farm, and in rich occurrences, it would increase the value of the estate. (Øverland et al,.2018). According to Zoe Christiansen, founder of the Northern Co., the Vikings ate seaweed to prevent seasickness and took it as a supplement. Additionally, during the Viking time, a barrel of seaweed would be considered so valuable, that it could be used to pay once taxes. For generations farmers have used seaweed to improve land and feed livestock. During the Second World War seaweed was one of the few available food resources for livestock along the coast, and therefore, used on a large scale.

Today we are at the beginning of a seaweed renaissance, where seaweed can play an essential part in the push for sustainable alternatives for food, feed, materials and energy. Technology enables new ways of farming and utilizing this valuable resource, without unnecessary interference with nature.

BY 2050 NORWAY CAN PRODUCE 20 MILLION TONS OF SEAWEED VALUED AT 40 BILLION NOK

Paraphrased from report: "Value creation based on productive seas in 2050", SINTEF, 2012

Based on the report from Sintef, "*Value creation based on productive seas in 2050*", Norway has set a vision of how technology and competency will contribute in developing new ocean industries. Norway has the world's second longest shoreline and almost 2 million square kilometers of ocean (Thuesen, Nils P., et al. 2019). High competency within fishery and offshore industries like shipping, oil and gas, is proof that a large scale seaweed industry in Norway is feasible.

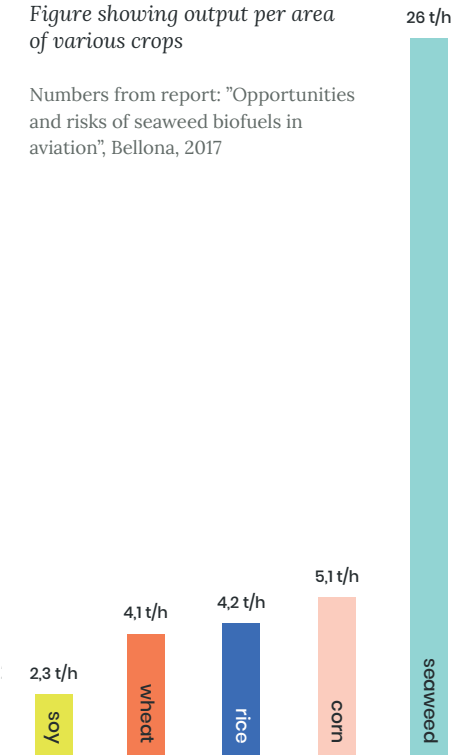
> ***"Norway has the biggest opportunity to farm seaweed in Europe"***
>
> Quote from interview with Job Schipper, business development advisor, Hortimare

Cultivation of 20 million tons of seaweed will require an area of approximately 6,000 km², this corresponds to only 3,3 ‰ of Norway's sea areas (Almås and Ratvik 2017, 33). To reach the goal of 2050, Norway must upscale seaweed farming and increase wild harvesting.

Farming is often considered a harmful interference with nature. Areas with great biodiversity are turned into large scale monocultures, where fertilizers, pesticides and chemicals are added to boost productivity. If we compare agricultural industry and seaweed farming, the agricultural industry requires significantly more area to produce less biomass than seaweed does. Seaweed is a rapid growing organism which use sunlight, CO^2 and nutrients in the water to grow. Seaweed is self-growing in it's natural environment, therefore, when farming seaweed, no unnecessary interferences with nature is required.

Figure showing output per area of various crops

Numbers from report: "Opportunities and risks of seaweed biofuels in aviation", Bellona, 2017



> "[...]FUTURE GROWTH IN THE OCEAN ECONOMY REQUIRES THAT WE MANAGE TO HARVEST RESOURCES SUSTAINABLY, AND THAT WE SEE THE OCEAN HOLISTICALLY."
>
> From report: "New Growth, Proud History", The Norwegian Government's Ocean Strategy, 2017

It is important to thoroughly research the consequences of large scale farming of seaweed and continuously monitor the effects when the industry is scaling up. The biodiversity close to the shore might be influenced in several ways, one of them being seaweed covering the surface and blocking sunlight. Seaweed farming can also increase biodiversity, by creating new habitats and food for fish and organisms. However, further research needs to be conducted to identify potential consequences of harvesting seaweed. This is one reasons as to why large offshore farms might be the solution for the future.

Including seaweed in other ocean industries can also be highly beneficial. Today, there are some integrated multi trophic aquaculture (IMTA) projects being piloted. IMTA is a co-culture of various species; farming fish, mussels and seaweed together (Bellona 2013). The mussels and seaweed filters the water from the fish farms and benefits from the nutrients, reducing the waste from the fishery industry. This also creates a habitat for more species, but companies have struggled to create a market for the raw materials produced by IMTA.

Farming seaweed can also be used to filter local areas, by absorbing CO^2 and nitrogen seaweed can help to lower the acidity of the ocean. The acidity in the ocean has increased during the last decade and is now at a historically high level. One of the main contributors to this acidification is soil from agricultural farms containing nitrogen and pesticides being washed away with the rain into the ocean.

Farming seaweed can also be used to capture CO^2, and researchers from SINTEF and advisors in Bellona predicts that this can be a way for Norway to reach the climate goals in the future.

Seaweed cultivation can remove CO^2, both efficiently and quickly: After just a few months in the sea, the seaweed has grown large enough to be harvested – and at the same time absorbed CO^2.

Paraphrased from article in Gemini by Jorunn Skjærmo, Researcher and biologist, SINTEF Ocean

SACCHARINA LATISSIMA: In Norway and other nordic countries the most commonly farmed seaweed is Saccharina Latissima, also called sugar kelp. It's fast growing and can be applied in many ways (Andersen 2015). Spores are seeded onto ropes and placed out in the sea during fall. After just 5-6 months they can reach up to 2 meters in length. Today sugar kelp is mainly used for food, as it has a sweet taste and in the future it's predicted that it can be used in a variety of ways.

PRODUCTION TODAY

TODAY; TRAWLING AND FARMING ARE THE MAIN METHODS OF EXPLOITING SEAWEED IN NORWAY. FOR PRIVATE AND SMALL COMPANY USE, THERE IS ALSO AN INCREASED INTEREST IN FORAGING WILD SEAWEED.

Trawling of wild seaweed is the dominant method used in the industry today. The annually harvesting amount is 160-170 000 tons, valued at approximately 1.4 billion NOK(Almås and Ratvik 2017, 32). The biggest actor is FMC Biopolymer AS, owned by Dupont, trawling for Laminaria hyperborea, a large brown kelp mostly used for extraction of alginate. Other actors like Algea is harvesting Ascophyllum nodosum, or more commonly named knotted kelp to produce animal feed and fertilizer. New technology within harvesting makes the interference on the seabed less harmful, however, there are ongoing discussions and uncertainty around how this affects the environment.

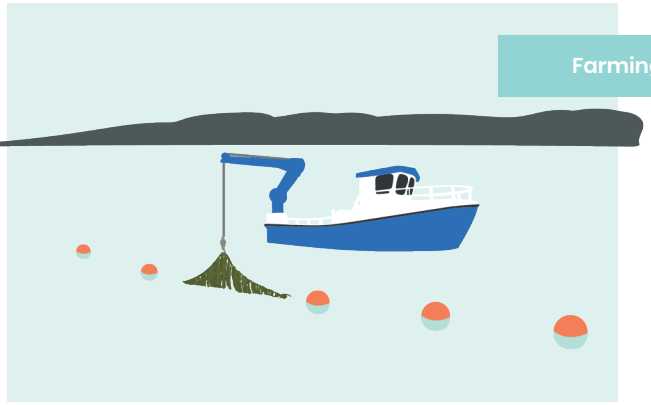
New methods to preserve the kelp during transportation needs to be developed. Today formalin is used to prevent the kelp from decaying, however a consequence is that it leaks out during transport. Moreover, FMC Biopolymer AS has not been able to create a market for the by-product from alginate extraction. Only 15% of the kelp is used to extract the alginate, the rest is thrown back into the sea. Changes must be done throughout the process to make it a sustainable industry.

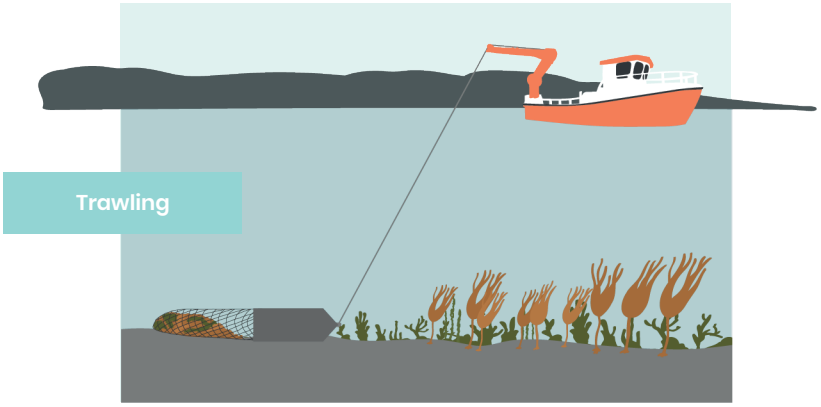
The last five years there has been an increase in companies applying for concessions to farm seaweed. Today there are about 30 companies licensed to farm, but only half are active. Saccharina latissima, also called sugar kelp, is the most commonly farmed species. Sugar kelp is easy to cultivate and provides a variety of usages, where most of the raw material is dried or frozen and sold to restaurants. The main focus within farmed seaweed is food products, as it requires little processing, giving high value products.

Norway has the capacity to potentially farm 2000 tons of seaweed. However, the annual production today is only approximately 200 tons, due to a small and immature market. More research needs to be conducted before farmers can upscale the production to reach new markets, and bigger actors within food and ingredient industry. In an interview with Dagbjørn Skipnes, senior researcher at Nofima, we learned that the smaller farmers are still dependent on research collaborators.

"Today we have an immature value chain; yet - the potential for it's development is enormous"

Translated quote from interview with Annelise Chapman, Marine biologist and founder of Tango Seaweed


Farming


Trawling


Foraging

Picture from the Northern Co

FARMING SEAWEED FOR FOOD IS THE ONLY FEASIBLE PRODUCTION TODAY.

Quote from interview with Jon Funderud, CEO at Seaweed Energy Solutions

FOOD AS MAIN FOCUS: By mainly focusing on developing food products, we believe the focus area is too narrow. The recommended daily intake should not be more than 10% of your dinner, therefore the Norwegian market is too small. Expansion to Europe and other markets will be necessary in near future to reach the production goal. To make the industry sustainable both economically and environmentally, we believe that there needs to be a more diverse focus on product development than than just food.

TO BOOST THE MARKET WE NEED TO BE MORE CONSCIOUS AND APPLY SEVERAL DIFFERENT BUSINESS MODELS FOR SEAWEED (E.G. FOOD AND FEED PRODUCTS AND ECOSYSTEM SERVICES)

Translated quote from interview with Annelise Chapman, Marine biologist and founder of Tango Seaweed

WE HAVE TO INVEST MORE AND LOOK FURTHER THAN FOOD.

Quote from interview with Anders Karlsson-Drangsholt, Senior adviser-aquaculture, Bellona

Food

Picture from the Northern Co

Agriculture

Photo by Bence Balla Schottner on Unsplash

PREDICTED POTENTIAL

THE THREE MAIN AREAS OF USE WE SEE TODAY ARE ALGINATE, FOOD AND AGRICULTURE. AS MENTIONED ALGINATE EXTRACTION IS THE BIGGEST INDUSTRY TODAY, BUT ALL THE APPLICATIONS ARE PREDICTED TO GROW AND ALLOW FOR NEW FIELDS TO DEVELOP, CREATING MORE POSSIBILITIES FOR THE SEAWEED INDUSTRY.

FOOD: During the last years the main product focus for the newly established seaweed companies has been high quality food products such as; salt, seasoning and raw material for restaurants. Our impression is that these new companies have a more sustainable drive, and use farming or small scale foraging as methods to harvest seaweed. In collaboration with researchers, these companies work to develop more products and create standards and certifications to be able to expand the market.

"Everything with salt in it is a market for seaweed"

Quote from interview with Jon Funderud, CEO, Seaweed Energy Solutions

Seaweed has high amounts of proteins, vitamins, antioxidants and minerals making it an interesting food resource for multiple purposes in the future. Seaweed can be used as salt replacement, supplements and vegetarian alternatives.

AGRICULTURE: There are many interesting projects exploring the benefits of using seaweed as supplements in animal feed and as fertilizer. Farming seaweed for agriculture is predicted to be the most effective way to upscale the industry. Incorporating seaweed in fertilizer and animal feed would generate a large demand for seaweed. According to Job Skipper, business development advisor, at Hortimare, research studies have shown that seaweed is beneficial for animal health when used in feed, and even reduces methane emissions from livestock.

As seaweed absorbs large amounts of nitrogen and phosphorus it's well suited as fertilizer, as it provides important components needed in the soil to improve crops, according to Algea. There are several research projects looking into how seaweed can be used to feed smaller organisms and insects. During an interview with Bente Torstensen, Executive Director at Nofima, we learned that fish cannot break down the large amounts of carbohydrates found in seaweed. Therefore the insects are bred to further feed farmed fish.

Biomaterial

Algae Water Bottle by Ari Jónsson

Biofuel

Photo by Jose Lebron on Unsplash

MOST OF TODAY'S PRODUCTS MADE OF NON-RENEWABLE MATERIAL (PETROLEUM) CAN BE REPLACED BY PRODUCTS MADE OUT OF ALGAE.

Citation from report: "Tradisjonelt og Integrert Havbruk", Bellona, 2013

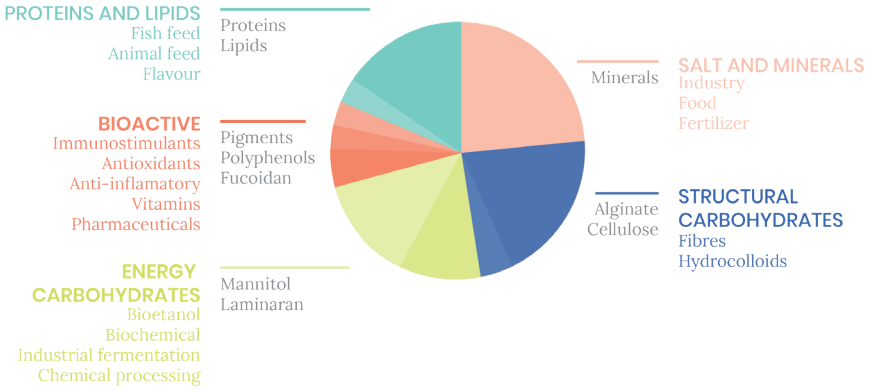
ALGINATE: One of the substances making seaweed unique, compared to land based plants, is alginate. Alginate is mainly found in brown kelp, it's a polysaccharide which is the structure that binds the seaweed together. Alginate provides the flexibility and strength seaweed needs to withstand waves and strong currents in the sea (Rueness 1998). It is used in over 600 different ways and we consume it almost every day in products such as; jam, ice cream, medicine and in electrical car batteries. There is a constant demand for alginate in the world and the areas of use are predicted to increase. One of the new usages of alginate is in biomaterials.

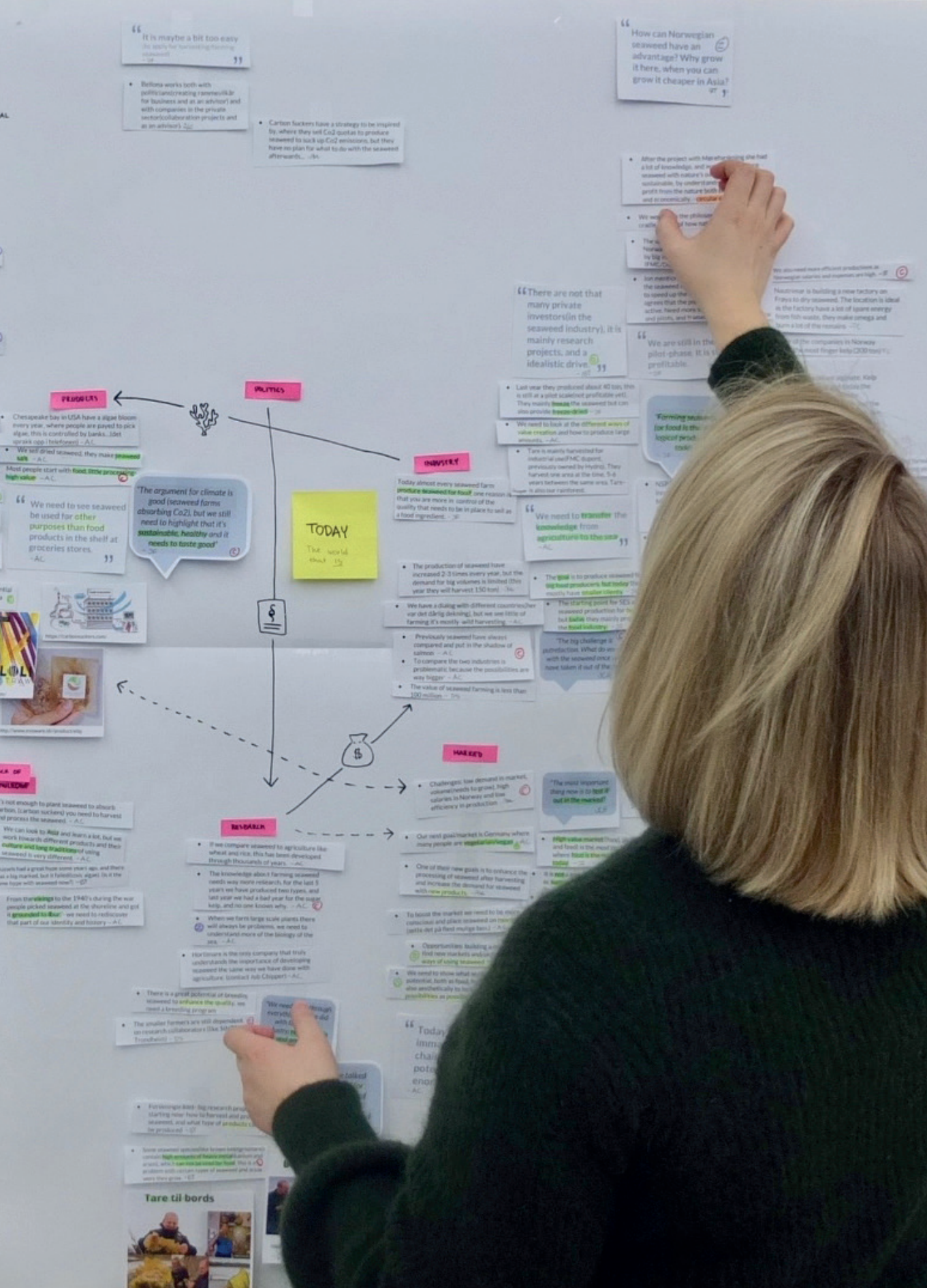
BIOMATERIALS: There are a few companies working on how alginate can be used in biomaterials such as bioplastic. However, most of these products are still on an experimental level and not yet commercialized. The material qualities of alginate are promising and can be biodegradable, although research is still required to understand what materials it can replace.

"We need to explore further how we can utilise seaweed as a raw material; there are fantastic possibilities, for example biopolymers (bio-plastics) from seaweeds"

Translated quote from interview with Annelise Chapman, Marine biologist and founder of Tango Seaweed

BIOFUEL: In Europe, seaweed biofuel is currently one of the main research areas; looking into how micro and macro algae can be used to produce bioethanol. Farming seaweed is the most sustainable way to produce and harvest biomass at scale in order to avoid unnecessary interference in nature with biodiversity. Today, farming seaweed is still very expensive due to an immature value chain and manual labour. The price per kilo of seaweed needs to be significantly reduced to make biofuel from seaweed feasible.




PRODUCERS
POLITICS
INDUSTRY
MARKED
TODAY
Tare til bords

MAIN FINDINGS

1 **MARKET GAP**: As there is little promotion and knowledge concerning seaweed in the general public today, there is a lack of demand for seaweed.

2 **LACK OF PRODUCT DEVELOPMENT:** There has been an increased interest for farming seaweed during the last 5-10 years, but too few work with product development.

3 **FUTURE POTENTIAL:** To upscale the industry a range of diversified products and services needs to be developed. The predicted usage areas in the future are food, animal feed, fertilizer, biomaterials and biofuel.

PERSONAL REFLECTIONS AFTER INITIAL RESEARCH:

We are at the beginning of a potentially large industry; seaweed farming. When upscaling seaweed farming, it is crucial to consider how the industry can be developed in a sustainable way, avoiding overexploitation and harmful interference with the marine ecosystem.

NEED FOR COMMON STRATEGY
MAPPING

3. STRATEGY

NEED FOR COMMON STRATEGY

ONE OF OUR MAIN FINDINGS IS THE NEED FOR A COMMON STRATEGY, ACROSS SECTORS ON HOW TO DEVELOP THE INDUSTRY IN A SUSTAINABLE WAY.

We met Julia Lohmann, during a trip to Helsinki. Julia Lohmann is a seaweed designer and professor of practice at the Aalto University. She provided us with an additional perspective; the importance of considering all the non-human stakeholders and the whole ecosystem when developing a new way of exploiting a natural resource. Meaning to not let the highest bidder win, but choose the ones that can contribute the most by considering the biodiversity.

To take the right precautions, the government needs to be more involved and update regulations to facilitate both for innovation and for sustainable development. The seaweed industry is still small compared to other ocean industries and needs more funding to collaborate across fields and leverage the benefit of existing competencies along the coast.

Lack of product development is one of the main challenges in the industry. Farmers have the capacity to produce at least 2000 tons of seaweed, but due to the lack of demand, the annual production is around 200 tons. Research and product development is key to boost the industry and open up new markets.

One of our conclusions from the research phase is that the efforts to promote the industry is fragmented and mainly targeted at niche markets. To achieve a more rapid growth within the seaweed industry, we believe that increased, strategic marketing along with political lobbying is needed to influence on a larger scale.

"I don't think the government is ready when this is speeding up"

Quote from interview with Jon Funderud, CEO, Seaweed Energy Solutions

Photographer: Petr Krejci

NOT LETTING THE HIGHEST BIDDER WIN, BUT THE ONES THAT CAN CONTRIBUTE THE MOST.

Quote from interview with Julia Lohmann, Seaweed designer and professor of practice at Aalto University


UPSCALE FARMING
Facilitation
-Create public awareness

MAPPING

Together with a broad selection of experts from different fields, we have continously iterated a map that tries to embody key measures to develop a sustainable seaweed industry in Norway. We have used it as a systemic tool to validate our understanding of today's situation. The map proved to be very useful during interviews to visualize our findings and analysis. This raised new questions and gave us a deeper understanding of the steps towards Norway's vision of 2050.

We wanted to explore different ways of structuring findings and develop the map through different methods. Models like future forecasting, back casting and three horizons was tested out. To get more input on the different models, we contacted Jomy Joseph and Josina Vink, PhD fellows at AHO. They were very helpful in explaining the different strengths of the methods and how to apply them to our purpose. In some way applying these methods turned out to be limiting. The map would include goals and challenges in many different levels, including a perspective of time. Therefore, we finally restructured the map to include main actors, goals and objectives, serving as a semi structured roadmap.

The map has also functioned as a tool for us to ideate and place our concepts within the timeline of Norway's vision for 2050. Having the map on the wall in our classroom, was a constant reminder of all the different perspectives and considerations we needed to take into account when designing. During the project the classroom turned into a rich design space. This was very convenient during discussions and for aligning our thoughts and ideas.

CO-CREATION
DESIGN PROPOSAL:
ROADMAP
POTENTIAL

4. ROADMAP

CO-CREATION

During our initial research we talked to researchers and experts within seaweed farming and production. In the interviews we noticed patterns and similarities in both objectives and challenges.

We contacted Bellona when discovering that one of their focus areas is seaweed farming. They are currently working on several projects to speed up the industrialization of kelp production. To establish industries that have negative emissions, like seaweed farming, they are calling for a national strategy and concrete actions for upscaling. The feedback we have received from Bellona while working on this project has been very important. Here in a meeting with Stefan Erbs.

SEAWEED ENERGY SOLUTIONS: We also brought the map to Jon Funderud, CEO in SES, for feedback and validation of important steps for the industry. He had valuable comments on how the government needs to be involved and what the main challenges are today.

SEAS OF NORWAY: When we discussed the map with Seas of Norway we tried to take into consideration how they could use the map. Recently, when applying for funding, Seas of Norway included the roadmap in their applications.

DESIGN PROPOSAL : ROADMAP

The map, shown on the next page, aims to create an overview of today's main goals and challenges and predicted steps in the future. The objective of the map is to serve as a semi structured roadmap. Today's situation is illustrated to the left and the vision of 2050 is illustrated to the right. The space in between illustrates steps of development, and does not indicate detailed time phases of action. Illustrating phases of actions would require a joint effort from multiple experts, while our goal was to create a predicted overview of the potential seaweed industry. The level of details is also set to describe the objectives, not specific actions. The main actors such as; government, industry and research are represented by different colors, as shown below. This is to identify areas of responsibility for the suggested objectives and focus areas. The bigger circles represent the main goals, while the smaller ones are objectives to reach those goals. The outlined circles represent the possible outcomes.

The steps of development are based on four key goals to reach the vision of 2050; **1)** new markets, **2)** upscale farming, **3)** optimize exploitation of seaweed and **4)** offshore farming. By highlighting the importance of multiple focus areas, collaborations across sectors and shared responsibilities, we hope to provide an applicable tool for discussion and reflection.

Government

Research

Industry

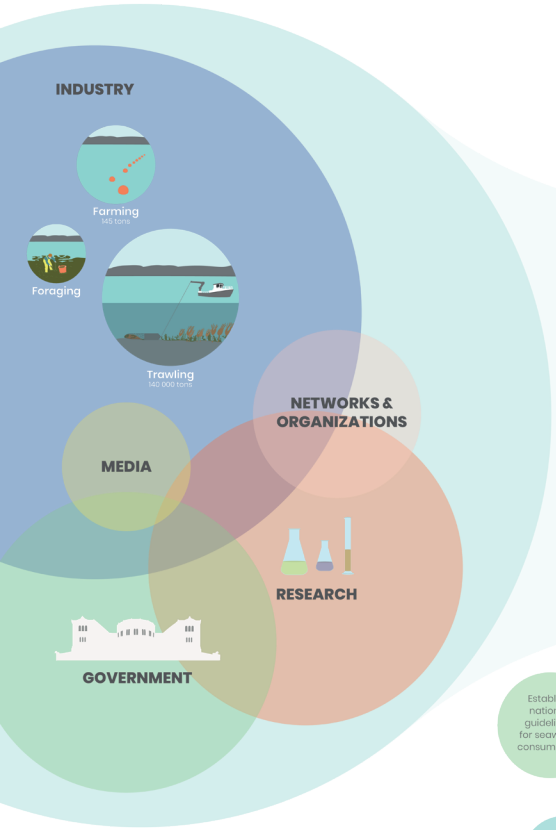
Media

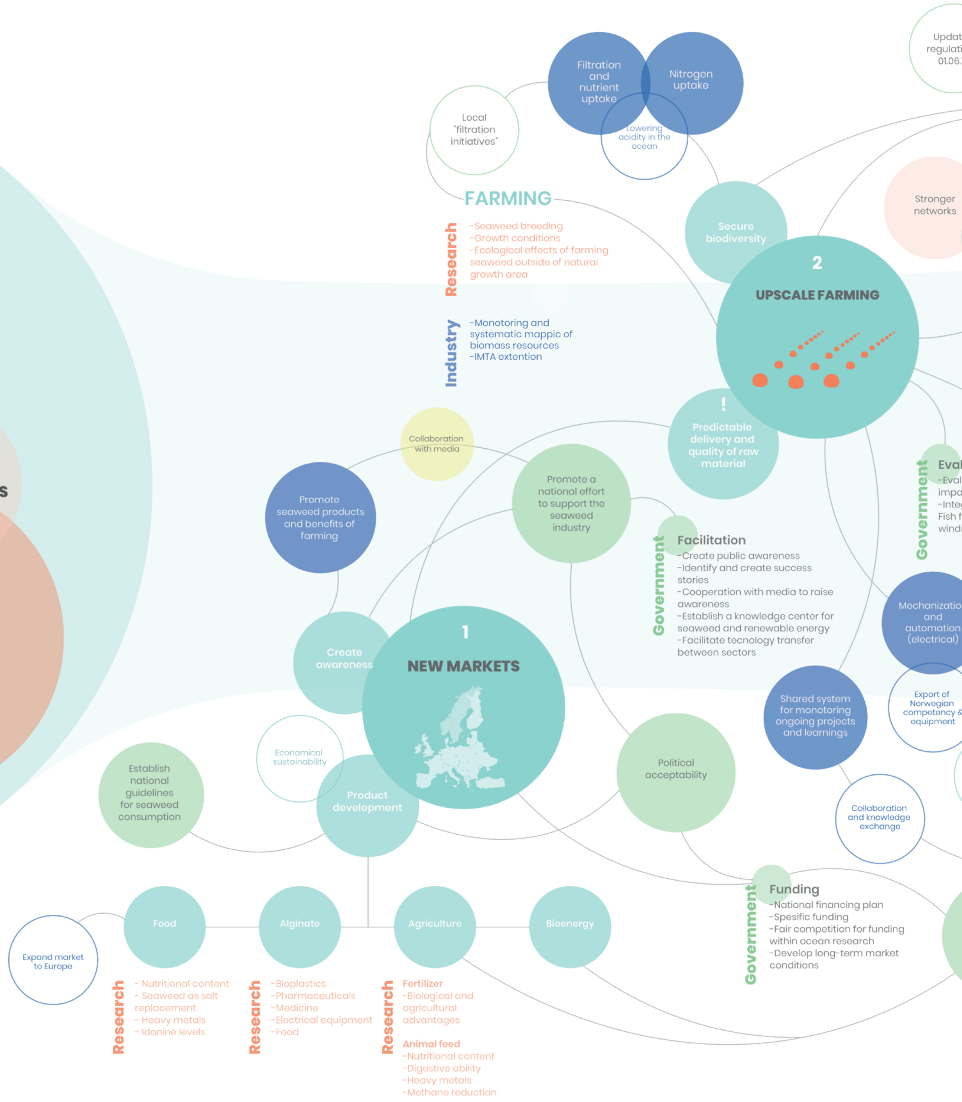
Networks

DEVELOPMENT: The roadmap has also functioned as a tool to ideate and place our concepts within the timeline of Norway's vision for 2050.

ROADMAP TOWARDS 2050

TODAY





EURO/KILO
Price for seaweed

Customize application forms and system

Collective strength to push for change

Government

Legislation
-Create incentives for combining existing industries
-Licencing for optimized area use
-Establish legislative framework for the industry
-Establish concessions

HARVESTING

Research
-Optimal harvesting times
-Effects on marine ecosystem
-Storage methods and preservation

Industry
-New techniques and logistics
-Efficient transport
-Storage solutions to reduce costs
-Develop logistics for short window of harvesting

Cross sectorial contact and collaboration

4
FARMING OFFSHORE

Offshore anchoring of farms

Integration of existing facilities offshore

uation
uate local environemtal
cts
gration of possible platforms;
arming, offshore,
mill farms

Create an economy for byproducts

3
OPTIMIZE EXPLOITATION OF SEAWEED

Deep sea sedimentation

Carbon capture and storage

CO2 management

Large scale biorefineries

PROCESSING

Research
- Pretreatment
- Preservation methods: drying, freezing, freeze-dry, fermentation,
-Optimized exploitation of seaweed
-Conversion pathways
-Research CO2 emissions through LCA

Industry
-Systematic quality control
-Handle large amounts of harvested seaweed

Establish shared system for continuous evaluation of carbon footprint

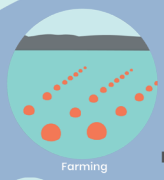
Develop sustainable processing of seaweed

Include seaweed farming in climate accounting

Seaweed foundation "Tareskogs-fondet"

Reaching Paris and Kyoto agreement goals

FUTURE



VISON FOR 2050
By 2050, Norway can produce **20 million** tonnes of seaweed and kelp at an annual value of **40 billion** NOK
From report: "Sjøkart mot 2050", SINTEF Almås & Rotvik, 2017

NETWORKS & ORGANIZATIONS

MEDIA

RESEARCH

GOVERNMENT

nal feed

Fertilizer

Biofuel

TONS
Biomass from seaweed

Sources:
The Submariner Research Institute, Stella Sea Region
Sjøkart mot 2050, SINTEF
Opportunities and risks of seaweed cultivation in Northern Europe

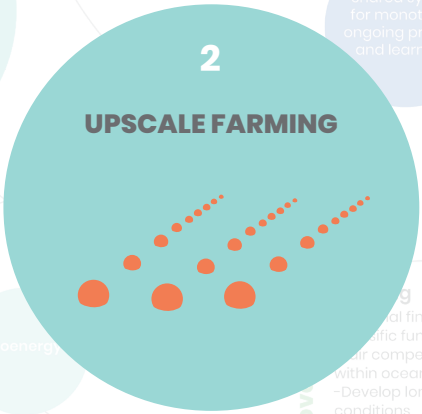
Dagbjørn Skipnes, Senior scientist, SINTEF
Jon Funderud, CEO, Seaweed Energy Solutions
Stefan Eros, Adviser, Seaweed Culture, Iceland
Anders Karlsson-Drangsholt, Entrepreneur, Seaweed Culture, Iceland
Lucas Gates, Founder, Seagriculture
Asbjørn Stavland, Secretary of Norwegian Seaweed Network

AHO
Made by Frøya Thue and Frida van der Drift Breivik

MAIN GOALS

NEW MARKETS: The main objective today is to create new markets through product development. The current focus areas are the fields of alginate, agriculture, biofuel and food. Among these, food is the biggest focus area. Parallel to this more efforts needs to be made to create more awareness about the inherent potential of seaweed. To achieve this the government needs to be more involved by promoting and funding projects.

UPSCALE FARMING: One of the key objectives when upscaling, is providing quality and predictability to the deliveries of raw materials. Upscaling seaweed farming requires a joint effort from all actors. Research needs to be conducted to understand more about the potential impact on ecosystems and what precautions to take into account. Technology and automatization is crucial to keep costs down and to enable harvesting of large amounts. Stronger networks can push for more collaboration across sectors and gain greater political influence.



OPTIMIZE UTILIZATION OF SEAWEED: Through development of advanced biorefineries new possibilities opens up. By developing new products, utilization of seaweed can be further optimized and ensure that all valuable substances are used. As seaweed absorbs large amounts of CO^2 this can to some degree be captured and included in the climate accounting in Norway. It is crucial to develop sustainable extraction methods to ensure minimal emissions. Minimal use of chemicals and optimal extraction methods may create new markets for by-products.

FARMING OFFSHORE: Establishing offshore seaweed farms is predicted to be the final goal of upscaling. This step will depend heavily on all previous milestones to make it feasible. Collaboration between offshore industries is key and new methods of transportation and preservation must be adapted to sustain longer transport. Development of anchoring and adjustments for durability is needed for the farms to endure the harsh environment offshore.

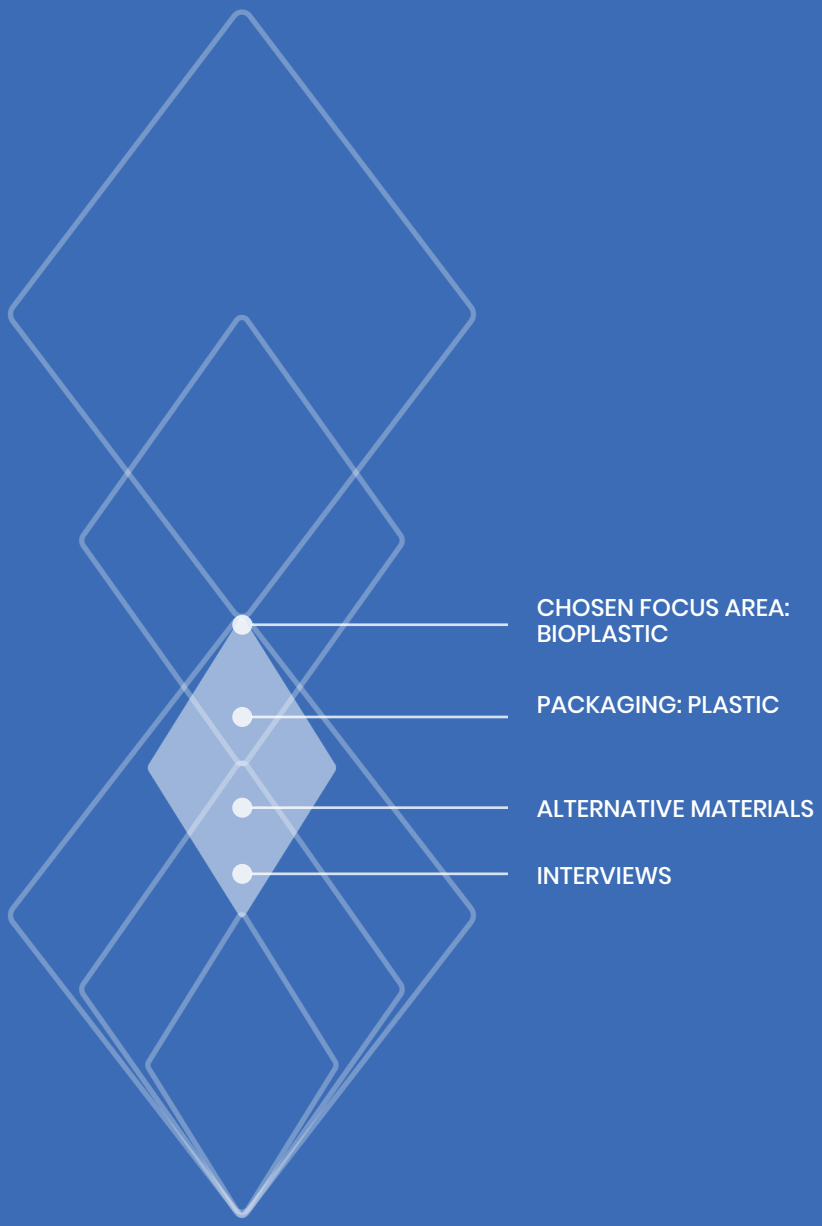
POTENTIAL

The overarching goal of the roadmap is to contribute to a national strategy for upscaling seaweed farming in Norway. We hope the map can function as a tool in discussions and create a shared understanding of a common strategy towards a sustainable seaweed industry. Together with actors from the industry, politics, research and management, Bellona is currently working to identify opportunities and challenges by upscaling. We hope that our way of visualizing and structuring the map could inspire the organization, trigger internal conversations and be a tool for the future projects and collaborations.

FEEDBACK: The final map was shared with Dagbjørn Skipnes, Senior researcher at Nofima, Stefan Erbs advisor in aquaculture at Bellona, Jon Funderud, CEO, Seaweed Energy Solution and Lucas Gates, Seas of Norway. The overall feedback we got was that the map provided a good overview with the main steps of a possible development. The map illustrates the complexity of the development, but the next step would be to go more into details and concrete actions, which several of the experts mentioned. Stefan also commented that it would be nice to see the bottlenecks in the development.

> I REMEMBER WHEN WE FIRST LOOKED AT IT WE WEREN'T REALLY SURE HOW TO DISPLAY THE PROCESSES RELATED TO SIZE OF MARKETS ETC. NOW EVERYTHING LOOKS LOGICAL. LOOKS LIKE YOU GOT ALL THE AREAS AND INDUSTRIES.
>
> Feedback from Lucas Gates, CEO, Seas of Norway


From farm
Drying / freezing
Food products
By hand
Alginate


CHOSEN FOCUS AREA:
BIOPLASTIC
PACKAGING: PLASTIC
ALTERNATIVE MATERIALS
INTERVIEWS

5. BIOPLASTIC

CHOSEN FOCUS : BIOPLASTIC

BASED ON OUR FINDINGS OF THE FOUR OPPORTUNITY AREAS WITHIN SEAWEED; FOOD, AGRICULTURE, ALGINATE AND BIOFUEL, WE HAVE CHOSEN TO EXPLORE HOW ALGINATE FROM FARMED SEAWEED IN NORWAY CAN BE USED AS BIOPLASTIC.

More specifically we want to explore how alginate bioplastic can be used as packaging for food, and how this can support upscaling the seaweed farming industry. As designers, we believe the area that we can contribute the most is packaging. As one of our main findings is the lack of product development, we see a demand for new ideas. By working with seaweed as a biomaterial we hope to inspire the industry and find areas to replace unnecessary use of plastic from fossil resources.

Today there are a few companies and startups working with seaweed as a biomaterial. The companies are situated all around the world, using local seaweed with different qualities and aesthetics. As mentioned, most of the products are still on the experimental level and not yet commercialized. Nevertheless, the products show great potential for thinking differently about what packaging can be, with new functionality and degradability.

During our diploma we have been introduced to two startups called B'zeos and Seas of Norway, working with how seaweed can be used as bioplastic. Both startups have offices in Oslo and we have been in continuous contact with them over the last months. It has been very valuable to share ideas and get feedback throughout the process.

Water capsules by Ooho!, Skipping rocks Lab

3D printed algea by Erik Klarenbeek & Maartje Dros

Packaging by Margarita Talep

PACKAGING : PLASTIC

TODAY, MOST PACKAGING IS CREATED FROM PLASTIC, ALSO CALLED POLYMERS. IN 2015 PACKAGING ACCOUNTED FOR 146 MILLION TONS OF THE PLASTIC PRODUCTION (GEYER ET AL., 2017).

During the last years there has been an increased focus on how plastic is a environmental problem, but we also want to emphasize what a fantastic material plastic is. Plastic is saving lives every day. It improves hygiene, provides food security and reduces food waste by preventing food from drying out. Polymers can be water and heat resistant, they can be flexible and shaped in multiple ways with different qualities and aesthetics. They are super light which reduces transportation and therefore CO^2 emissions. Over the last decade the price on plastic has continuously dropped, and is now one of the cheapest materials available.

These are some of the reasons why plastic has been the preferred material for packaging and why the consumption has increased drastically over the last decade. Even though plastic is a great material for many usages, the overconsumption we see today is causing problems. One of the largest problems is when plastic becomes waste, is dislocated and ends up in nature. As we only have documentation on how plastic turns into smaller pieces, there is still uncertainty concerning how long it actually takes before plastic breaks down.

Most plastic packaging can be recycled and turned into new products, but the waste handling systems today are not equipped to handle the amounts we produce. Which is why most countries in USA and Europe has found the easy way out, shipping most of their plastic waste to China.

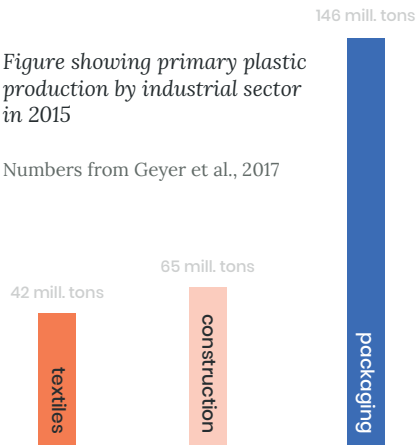
[...]China, which has imported a cumulative 45% of plastic waste since 1992, recently implemented a new policy banning the importation of most plastic waste, begging the question of where the plastic waste will go now.

Citation from article in ScienceAdvantages, Amy L. Brooks, Shunli Wang and Jenna R. Jambeck, 2018

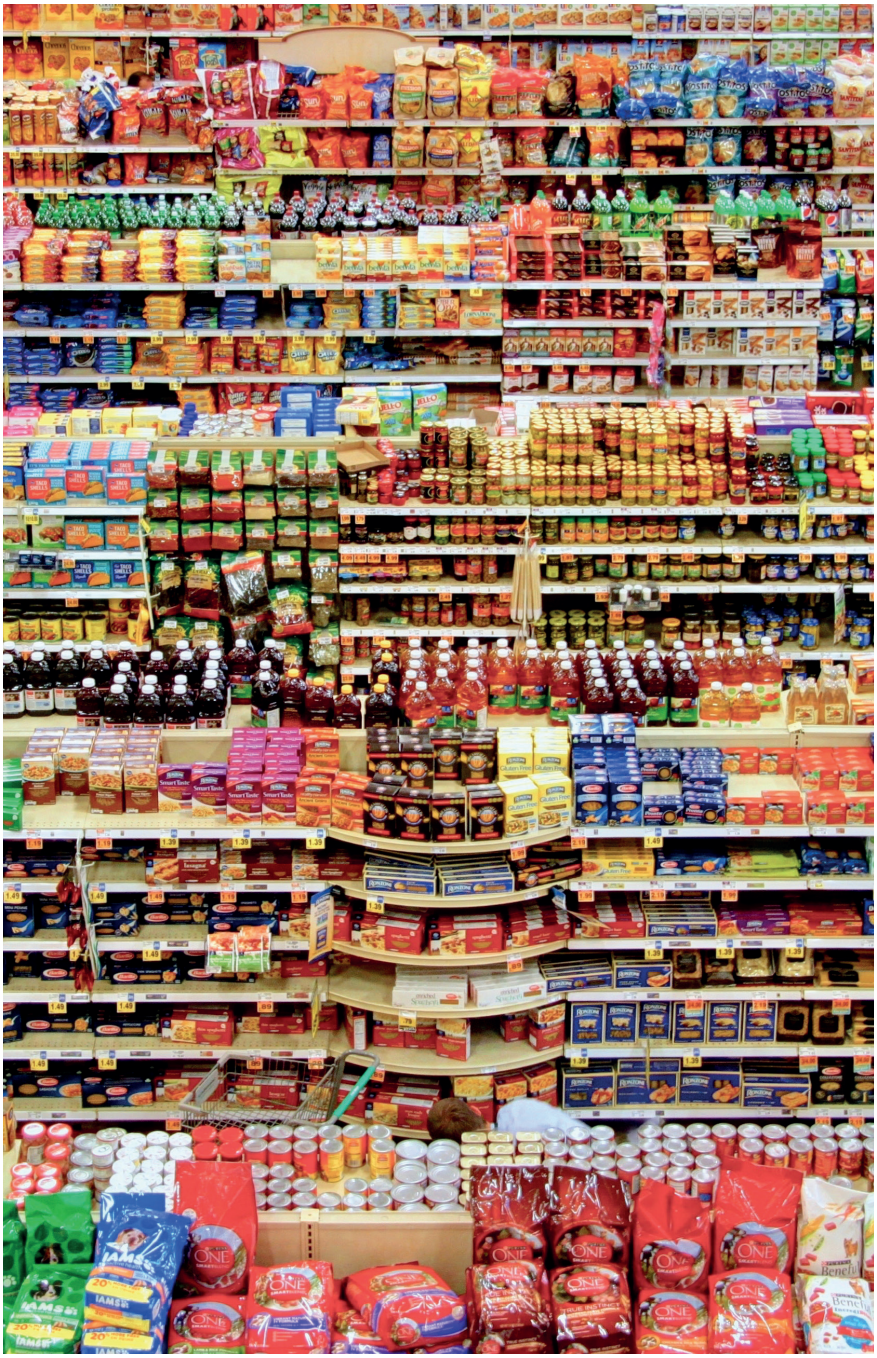
In 2018 China banned most types of plastic import, leaving Europe and US to deal with their own plastic waste. Consumers pushing to reduce plastic use and increased focus on how plastic affects wildlife, puts additional pressure on governments trying to solve the plastic problem. In March 2019, the EU Parliament sealed the ban on single use plastics. Several governments around the globe has banned plastic bags and other types of single use plastic.

Figure showing primary plastic production by industrial sector in 2015

Numbers from Geyer et al., 2017



But, if we ban plastic, what alternatives do we have?



Photographer: Peter Bond, Unsplash

ALTERNATIVE MATERIALS

TODAY WE HAVE SEVERAL ALTERNATIVES TO PLASTIC, ESPECIALLY WITHIN SINGLE USE PRODUCTS. MANY OF THEM CAN SERVE AS ALTERNATIVES TO PLASTIC, BUT WE NEED TO MAKE SURE THAT THE ALTERNATIVES ARE NOT CAUSING MORE HARM THAN WHAT IT'S TRYING TO REPLACE.

It can be difficult to determine if something is a better alternative or a less harmful substitute. It's important to consider the whole lifecycle, from raw material to waste, to assess if a product or material is better than plastic. One of our findings is that it's also difficult to trace back the origin of materials and how it has been processed and refined. Although the packaging says "eco" or "bio", it doesn't necessarily mean that it's more sustainable than plastic. If the packaging is transported across the globe the emissions from transportation will increase the carbon footprint. And if the material is not handled correctly through waste management, it might cause more harm. To get a deeper understanding of the complexity we have looked at a few of the most commonly used alternatives today.

Most of the alternatives are produced in countries far away, resulting in long distances of transport, this needs to be included when evaluating materials. Misleading use of terms can cause problems when materials that claim to be compostable, are not. Producers are rarely taking the responsibility of instructing how the materials should be handled after use, making it difficult to adapt to existing waste systems. Another main finding is that the current waste handling systems are not advanced enough to separate bioplastic from plastic. PLA and other bioplastics goes to incineration, meaning it will be burned, instead of being composted or recycled. Alternative materials like PLA will contaminate plastic recycling if the amount accedes 5%, leading to a recycling problem. To make the alternative materials optimal, new ways and facilities to compost these materials needs to be established.

BIOPLASTIC can be either bio-based or biodegradable.

BIO-BASED PLASTIC refers to the renewable sources used to make the particular plastic.

BIODEGRADABLE means that a material can break down in nature.

COMPOSTABLE MATERIALS need to be in an industrial facility to decompose.

PLA is made from fermented plant starch such as corn, cassava, sugarcane or sugar beet pulp. It is often a residual from production of other products, often from USA or Asia. PLA is a compostable material.

CORNSTARCH also called CPLA, is crystallised PLA. It is crystallised to withstand higher temperatures. It can be biodegradable or compostable.

BAMBOO can be used as serving plates, chopsticks etc. It's mostly grow in Asia and South- and Central America.

WHEAT BRAN is a by-product from flour production. It's edible and is often used as serving plates and single use cutlery, it can also be thrown in food waste.

WOOD CUTLERY is made of different wood types and is compostable.

Images from various sources

INTERVIEWS

To learn more about today's situation we interviewed experts within different fields. We wanted to understand how companies and organisations working with food, handle packaging. We also wanted to learn more about the efforts being done in order to shift to alternative materials and what type of ripple effects this has. We talked to Ingrid Kleiva Møller- food and environmental manager at Øyafestivalen, Petter Wahl Sekne- product developer and chef in Fursetgruppen, Alvhild Hedstein-sustainability director in Bama and Aasa Andersen-CEO in A-packaging.

> **WE ARE WILLING TO PAY MORE FOR SUSTAINABLE ALTERNATIVES. THE WHEAT BRAN WE USE TODAY IS ALMOST TWICE AS EXPENSIVE AS PLASTIC.**
>
> Quote from interview with Ingrid Kleiva Møller, Food and environmental manager, ØYA

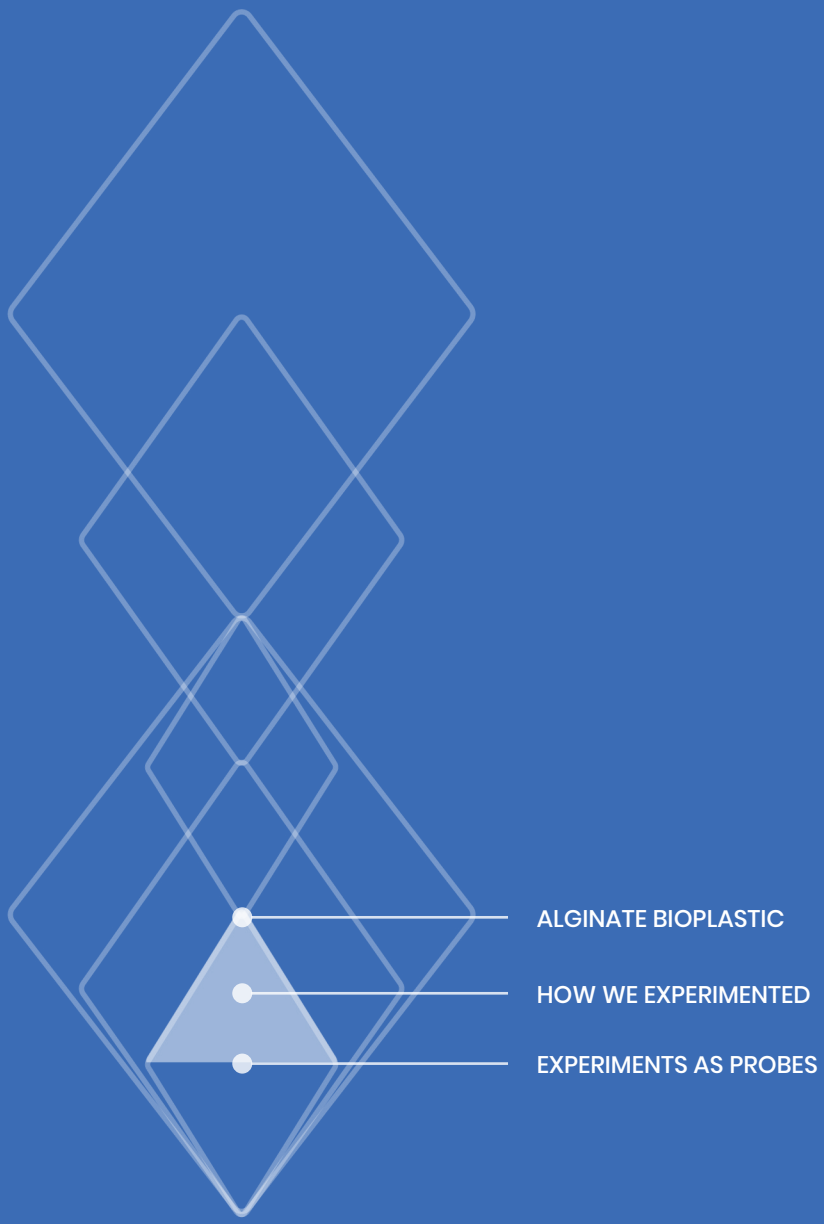
> **WE HAVE CHOSEN COMPOSTABLE PACKAGING FOR FOOD AND BEVERAGE, IT IS RARELY CLEAN ENOUGH TO RECYCLE.**
>
> Quote from interview with Ingrid Kleiva Møller, Food and environmental manager, ØYA

> **WE WILL ALWAYS CHOOSE SIRCULAR OVER BIO.**
>
> Quote from interview with Alvhild Hedstein, Sustainability director at BAMA

IF IT'S NOT RECYCLED IN THE RIGHT WAY, IT'S NO BETTER THAN PLASTIC.

Quote from interview with Ingrid Kleiva Møller, Food and environmental manager, ØYA

Photo by Pål Bellis


ALGINATE BIOPLASTIC
HOW WE EXPERIMENTED
EXPERIMENTS AS PROBES

6. MATERIAL EXPLORATION

ALGINATE BIOPLASTIC

In March, we were invited by Julia Lohmann to help facilitate a workshop at Kristineberg Marine Research and Innovation Centre in Sweden, with master students from design and architecture from Alto University. Here we met postdoc Martin Sterner, researching how to make alginate bioplastic from farmed seaweed. His focus has been on how to utilizie the whole raw material, make the process more energy efficient and to use less chemicals when extracting alginate. Through Martin's expertise we were lucky enough to learn the basics of how to actually make alginate bioplastic, enabling us to start our own material experiments back at AHO.

The method is quite simple; alginate is carefully mixed with water. Our alginate gave us a good viscosity at 2-3% of the solution. Then water and calcium chloride is mixed. These two solutions will react instantly when in contact, providing both limitations and exciting possibilities. By first dipping forms in alginate and then in calcium, you get one thin layer. Depending on the purpose of use, this can be repeated several times to create thicker and more rigid shapes.

VISIT TO SEAWEED FARM: During the workshop we visited Tjärnö Marine Laboratory. On a planned excursion we traveled by boat to see the seaweed farm setup to conduct research at the laboratory.

WET LAB: At Kristineberg Marine Research and Innovation Centre we learned how to extract alginate from the newly picked Saccharina latissima (sugar kelp).

ALGINATE BIOPLASTIC: Here we are learning how to make bioplastic from alginate and carefully measuring the different substances.

HOW WE EXPERIMENTED

To make bioplastic from alginate we needed sodium alginate and calcium chloride. These ingredients are not sold in normal grocery stores making it quite hard to find. We contacted Olav Gåserød, Lead Scientist at DuPont Nutrition & Health, he was kind enough to give us two samples of sodium alginate and more tips on how to conduct our experiments. Even though we knew it was the same substance Martin had used: sodium alginate, we were not sure is was the same type of alginate.

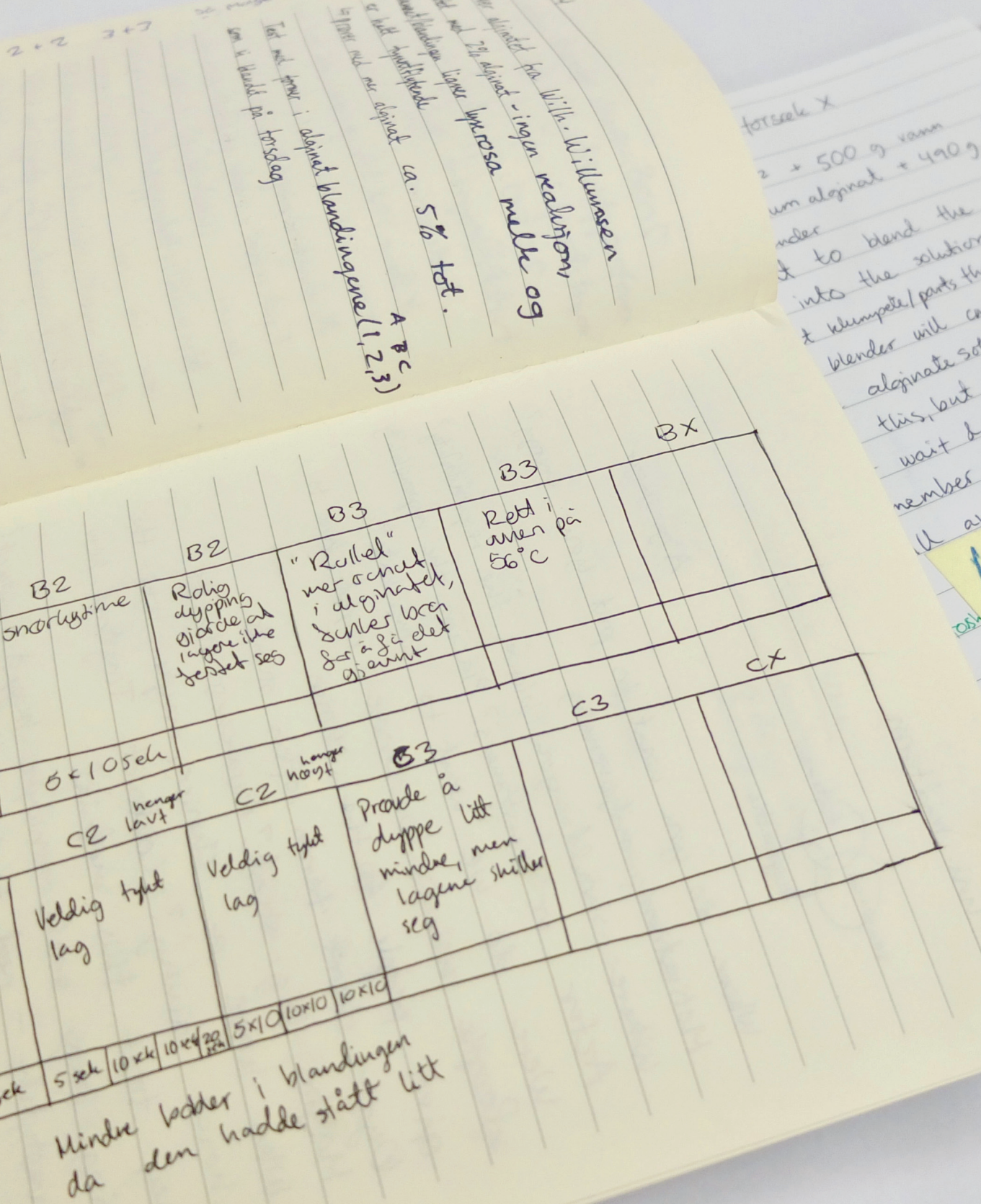
Usually calcium chloride is sold in 100 kg packages for industrial use, but we only needed a small amount. We were excited to find out that a brewery shop at St. Hanshaugen sold smaller quantities.

Back at school, we set up a small “lab” in the workshop and started measuring water, calcium chloride and sodium alginate. We quickly realized that we needed to contact Martin again to get the mixing ratio. At this point we moved into a completely new field of chemical reactions, weird textures and smells.

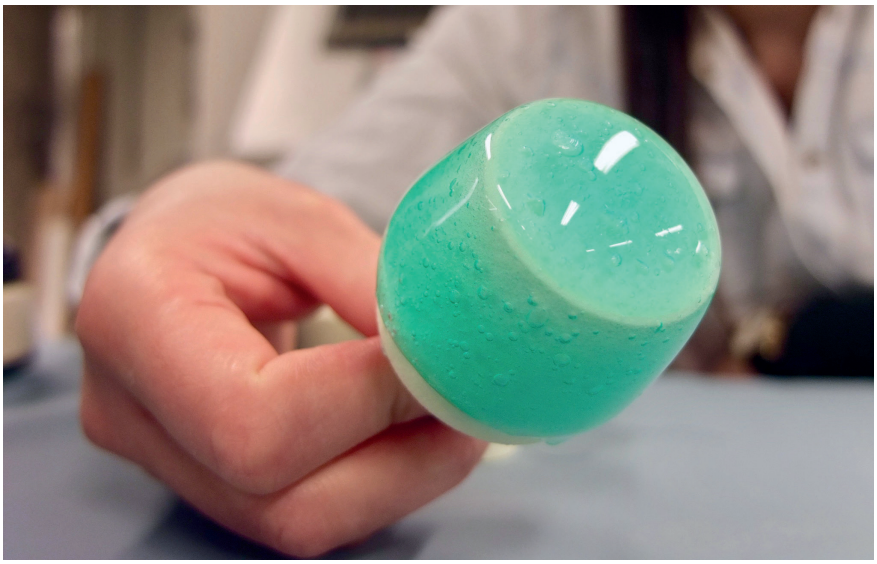
In Sweden Martin showed us the shapes and forms he had made out of styrofoam, that adhered the alginate solution and made the first layer stick to the surface.

We have had a lot of fun when trying out different methods to create different forms and odd shapes. The material experiments have been essential in our ideation process and helped us to imagine even more radical ideas. Some of the experiments was very successful and some failed completely, creating frustrations as we often did not understand why. Our understanding of the material was limited and many unknown factors like; pH value in the water, humidity and temperatures were factors beyond our control. Luckily Martin has been our champion when we got stuck and helped us to move on and keep experimenting.

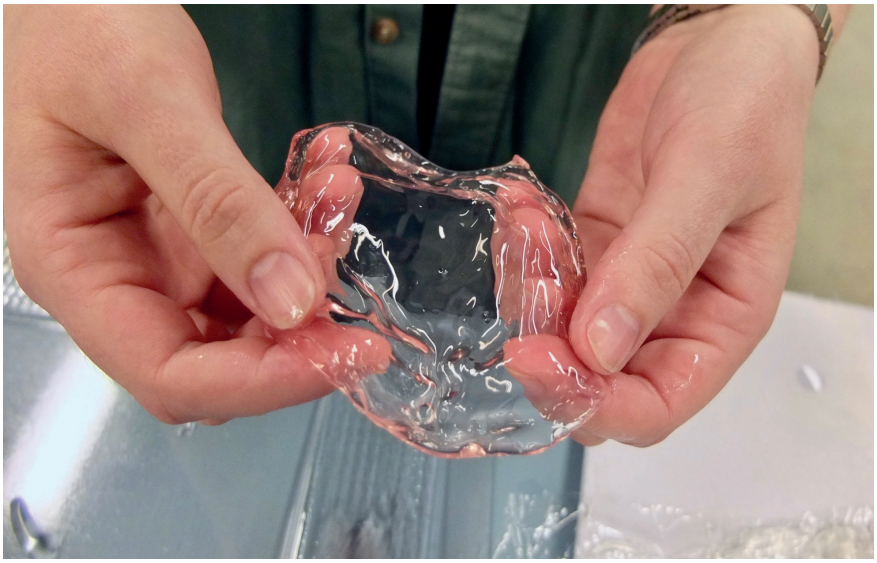
SETTING UP THE "LAB": We wanted to make similar small cups to experiment with viscosity and thickness. We needed multiple identical shapes to learn more about the material behaviour and strength. Therefore we turned 16 cups in green styrofoam to be able to compare the different solutions with different percentages and test out few layers versus multiple layers of alginate.



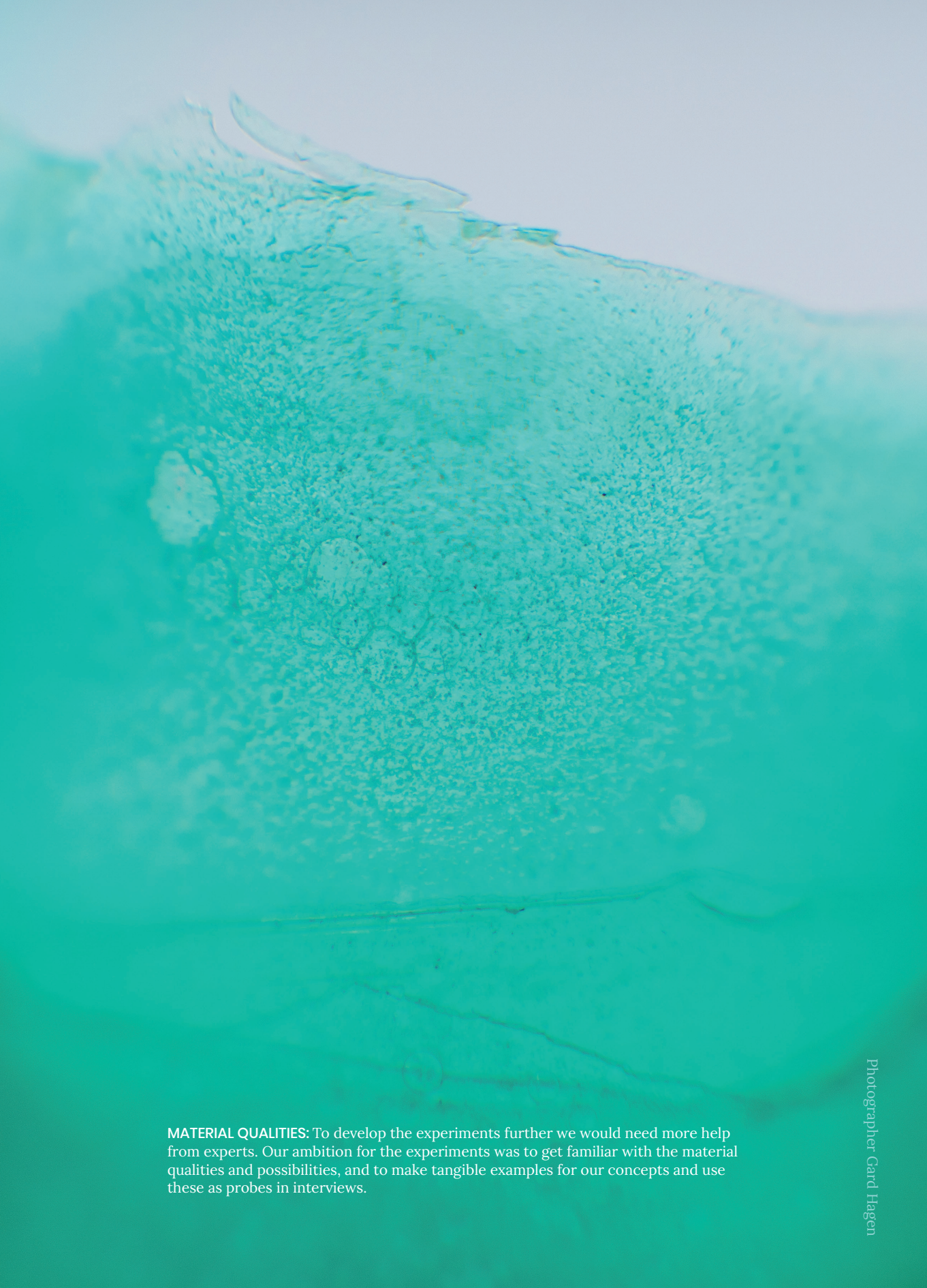
DOCUMENTING: During the first round of experimentation, we did not keep track on how many times we had dipped the different shapes and had a more playful session. During the second round we tried to do the experiments a bit more structured, were we documented everything and tested solutions of 1%, 2% and 3% of alginate, and wrote down the results.



CREATING LAYERS: After many attempts, we found out that a solution of 2% percent of alginate was the most suited for our experiments, mixing 10 grams of sodium alginate with 490 grams of water.

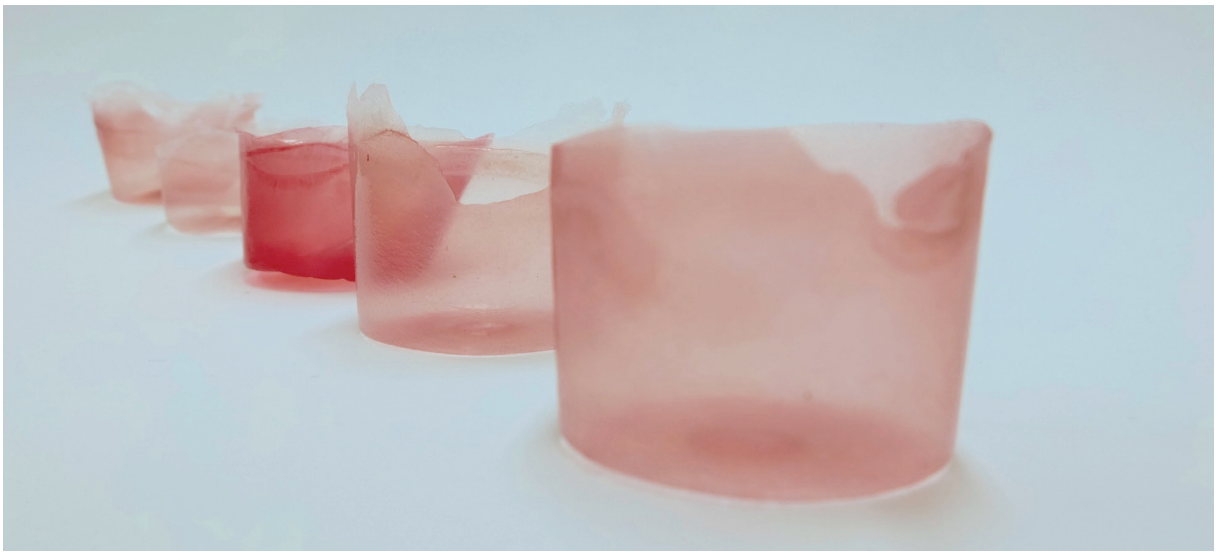


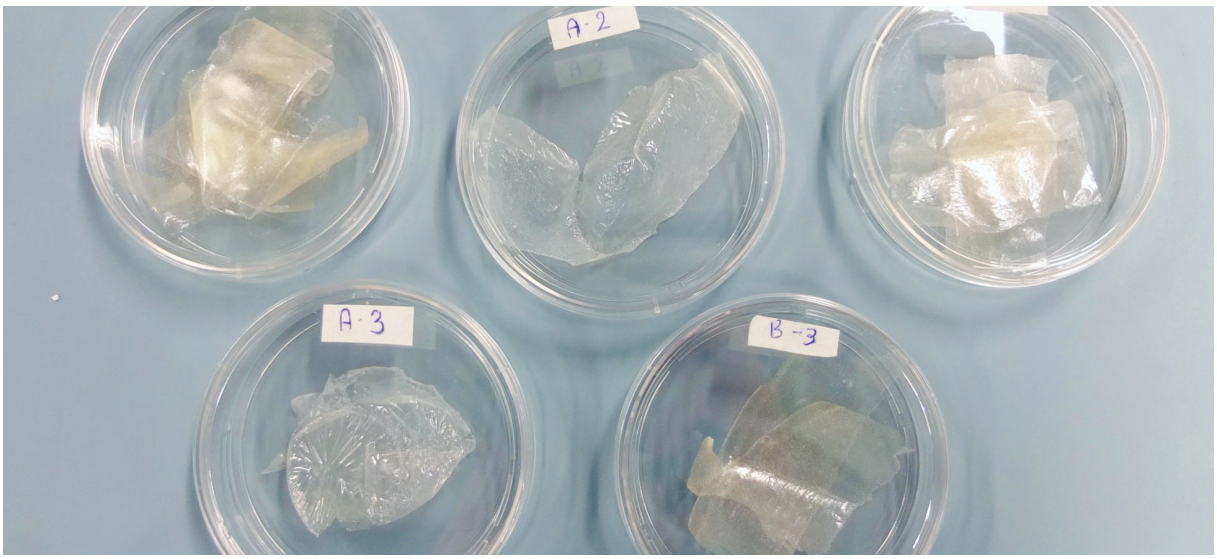
ALGINATE "SHEETS": We discovered that the alginate solution would only stick to particular surfaces. When we tried dipping aluminium and plastic the alginate layer would "slip" right off. These "failed" attempts made us realise that we could use this "technique" to make thin sheets of alginate.



MATERIAL QUALITIES: To develop the experiments further we would need more help from experts. Our ambition for the experiments was to get familiar with the material qualities and possibilities, and to make tangible examples for our concepts and use these as probes in interviews.

Photographer Gard Hagen




A-2
A-3
B-3

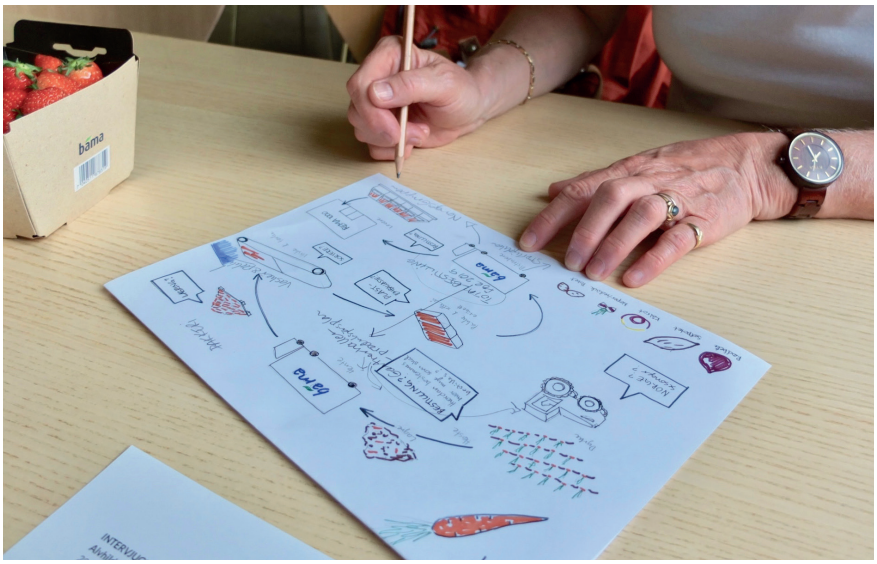
EXPERIMENTS AS PROBES

In the interviews with Øya, Fursetgruppen, Bama and A-Packaging we also brought the material samples as probes to see their reaction to the new material. The probes were very valuable as they opened discussions and reflections we could not foresee. Questions like how the material would handle transportation, heat, storage and water resistance gave us an additional perspective of how complex packaging is. These questions were important during our ongoing ideation. Questions and discussions about future potential and edibility validated our ideas about creating new food experiences and functions.

When showing people the materials, an interesting observation was the urge to test the strength, almost to the breaking point, and sometimes actually breaking the probes. The probes triggered a lot of curiosity and our interviewees provided us with good feedback on how the material could be valuable for them. One of our goals for the interviews, was to investigate the interest for the new material, and what challenges it would bring if implemented. We shared our findings from these interviews with the startup B'zeos and it proved to be very valuable for them. B'zeos also requested the contact details for the people we meet with, and we hope this can lead to possible collaborations.

FURSET GRUPPEN: Petter is a product developer and chef at Fursetgruppen. He gave us valuable insights on the challenges from a chef's point of view; the importance of presenting the food in an appealing way and what limitations alternative materials has compared to plastic.

ØYA FESTIVALEN: Ingrid described the festival as a small community, and a good arena to try out new materials and products that can influence the audience beyond the festival.



BAMA: Alvhild, the director of sustainability at Bama, provided us with a broad understanding of how the biggest fruit- and vegetable distributor in Norway work with sustainability and packaging. The most important aspect of packaging for Bama is food safety and minimizing food waste.

A-PACKAGING: Meeting with Aasa from A-Packaging, one of the few importers of alternative packaging, explained how all of their products are certified and they work to ensure the whole production line is ethically produced. She was very curious to learn more about bioplastic from alginate and how this could be produced in Norway.


FUTURE SCENARIOS
ZOOMING IN
OVERVIEW OF SCENARIOS
APPROACH: TRENDS

7. FUTURE SCENARIOS

FUTURE SCENARIOS

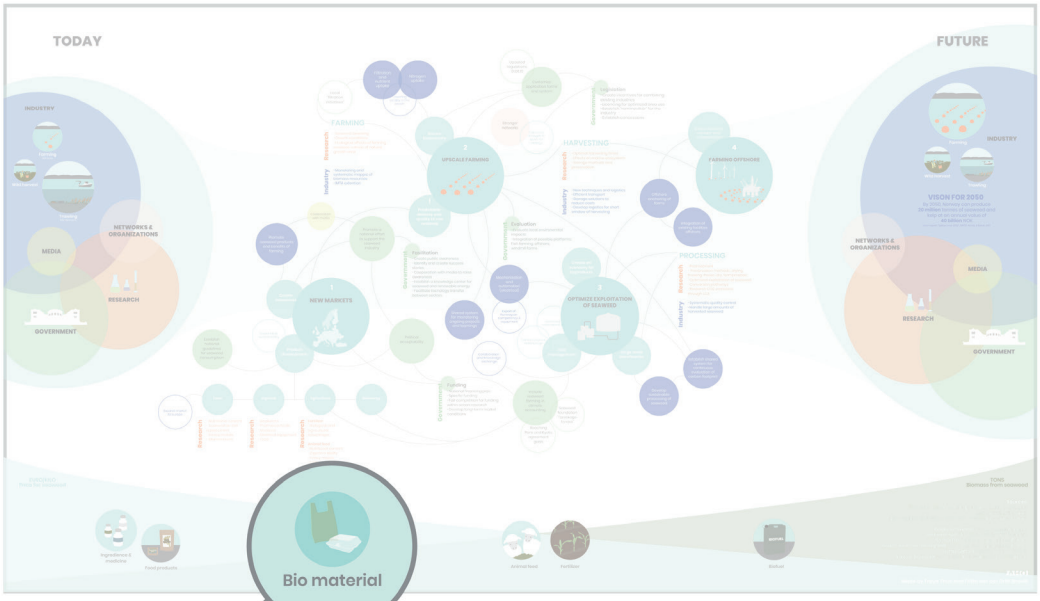
THE OVERARCHING GOAL OF OUR DESIGN PROPOSAL IS TO MAKE A CONTRIBUTION TO UPSCALE THE SEAWEED INDUSTRY IN NORWAY, TO REACH THE CLIMATE GOALS AND USE THE POTENTIAL OF SEAWEED TO MOVE TOWARDS A GREEN SHIFT.

Our design proposals consist of four scenarios illustrating a potential development of using alginate as bioplastic, which are based on our own explorations, interviews and feedback.

The main goal of the four scenarios is to inspire the emerging seaweed industry. Especially the companies currently developing the material for packaging. We envision the scenarios as possible steps going from introduction of the material to potentially challenging what packaging might be in 2030. We have chosen to base our scenarios within the next ten years, as we believe this timeline is enough to invision radical changes, but still be relevant for the stages of development needed today.

Through these scenarios we hope to inspire companies to think beyond replacement of plastic and aim for radical changes and experiences within food packaging. The scenarios highlight our idea that local food could be packaged in locally produced packaging. We imagine that increased investment in local competence and resources can enable this development.

Another important part of all our scenarios is transparency, as we believe that products should be traceable. We highlight this in our scenarios by explaining the benefits of using seaweed for packaging and where and how it's produced to the customers.



4 x FUTURE SCENARIOS

to exemplify a potential development

2020

Introduce material

2022

Challenge unneccessary use of plastic

2025

Challenge imbalance

2030

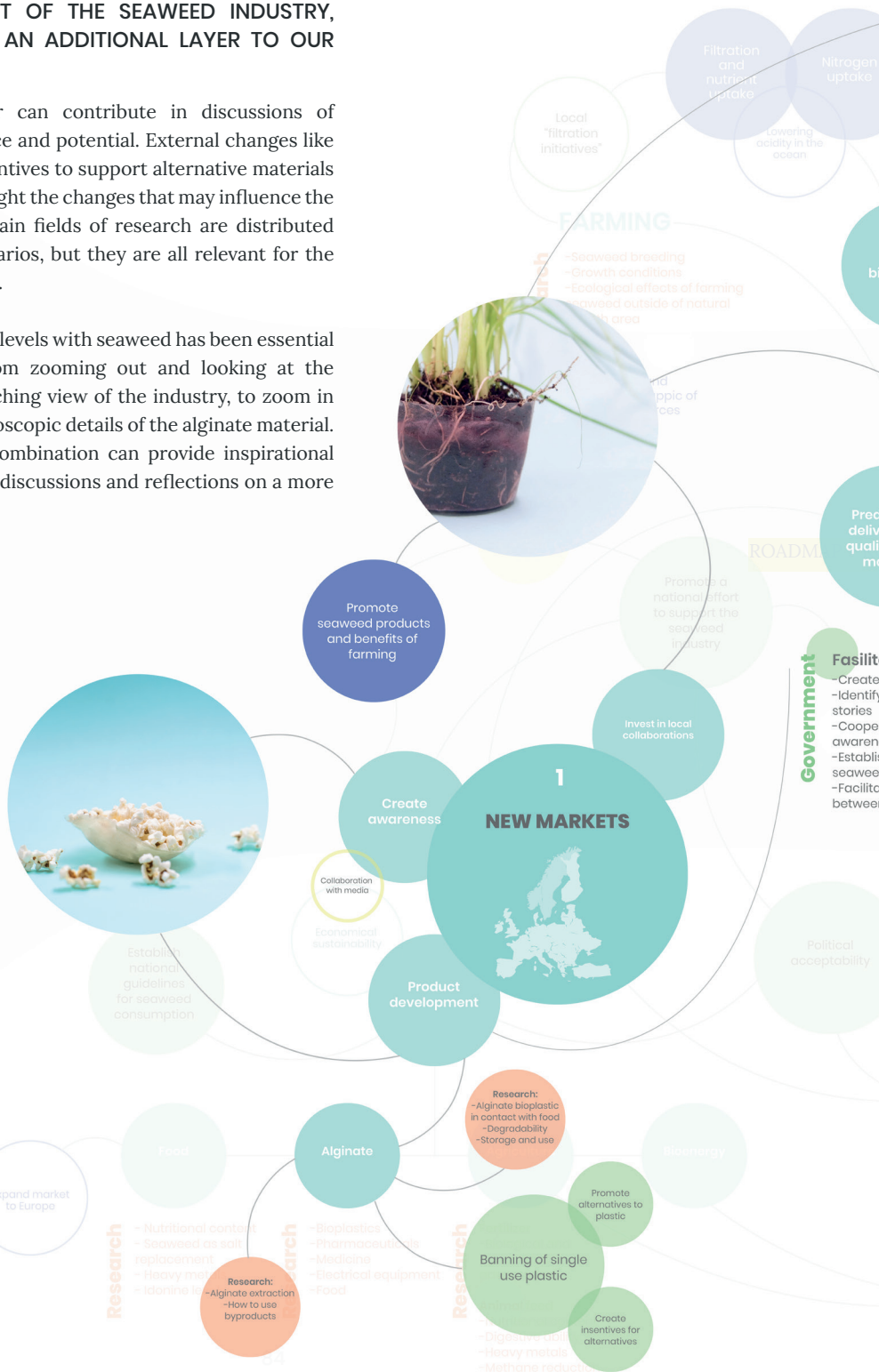
Challenge packaging

ZOOMING IN

AS A WAY OF ILLUSTRATING BIOPLASTICS' ROLE IN THE DEVELOPMENT OF THE SEAWEED INDUSTRY, WE HAVE ADDED AN ADDITIONAL LAYER TO OUR ROADMAP.

We hope this layer can contribute in discussions of biomaterials relevance and potential. External changes like plastic bans and incentives to support alternative materials are included to highlight the changes that may influence the development. The main fields of research are distributed in the different scenarios, but they are all relevant for the general development.

Working on different levels with seaweed has been essential in this project. From zooming out and looking at the systemic and overarching view of the industry, to zoom in and explore the microscopic details of the alginate material. We hope that this combination can provide inspirational examples and create discussions and reflections on a more concrete level.



Government

Legislation
-Create incentives for combining existing industries
-Licencing for optimized area use
-Establish "rammevilkår" for the industry
-Establish concessions

Cross sectorial contact and collaboration

Stronger networks

Collecitve strength to push for change

HARVESTING

Research
-Optimal harvesting times
-Effects on marine ecosystem
-Storage methods and preservation

Industry
-New techniques and logistics
-Efficient transport
-Storage solutions to reduce costs
-Develop logistics for short window of harvesting

2
UPSCALE FARMING

4
FARMING OFFSHORE

Offshore anchoring of farms

Research:
-Documented reduction of food waste
-Customization to each vegetable

Create an economy for byproducts

3
OPTIMIZE EXPLOITATION OF SEAWEED

Research:
-Alginate bioplastic quality vs. durability

Shared system for monetoring ongoing projects and learnings

Collaboration and knowledge exchange

Large scale biorefineries

Develop sustainable processing of seaweed

Establish shared system for continuous evaluation of carbon footprint

Industry
-Systematic quality control
-Handle large amounts of harvested seaweed

Government
Funding
-National financing plan
-Spesific funding
-Fair competition for funding within ocean research
-Develop long-term market conditions

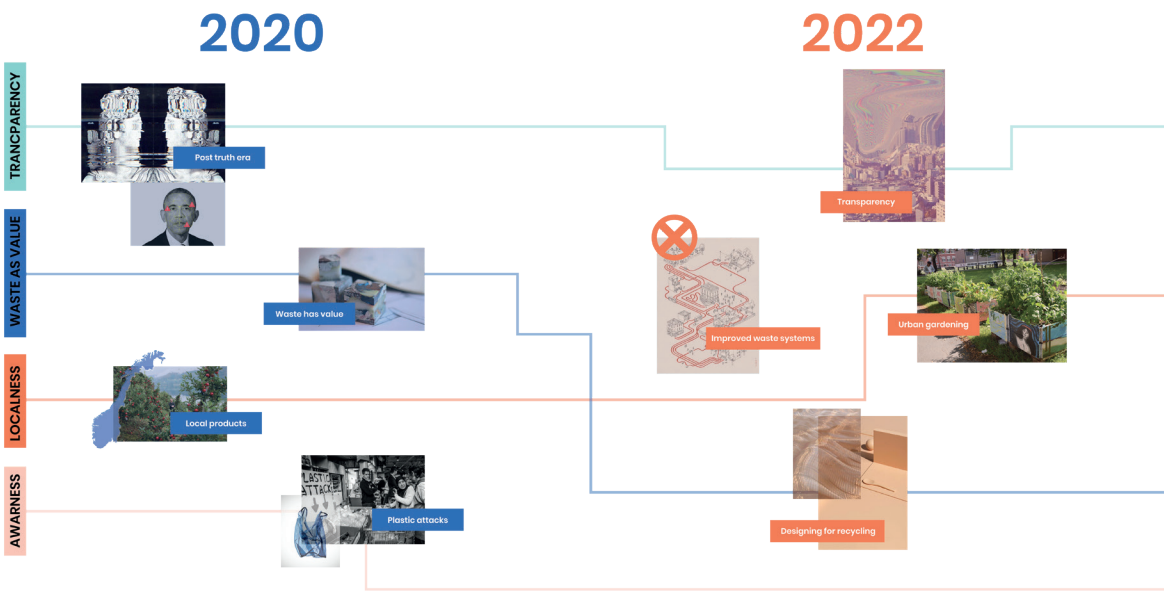
Include seaweed farming in climate accounting

Seaweed foundation "Tareskogs-fondet"

Reaching Paris and Kyoto agreement goals

OVERVIEW OF FUTURE SCENARIOS

TRENDS

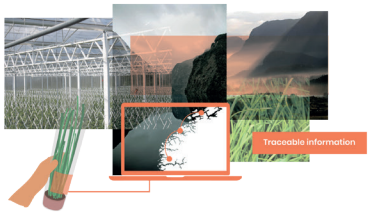


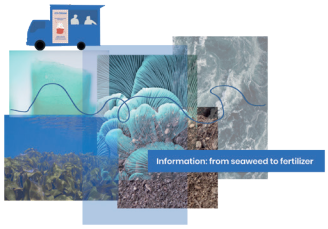
SCENARIOS

Introduce material

Challenge unneccessary use of plastic

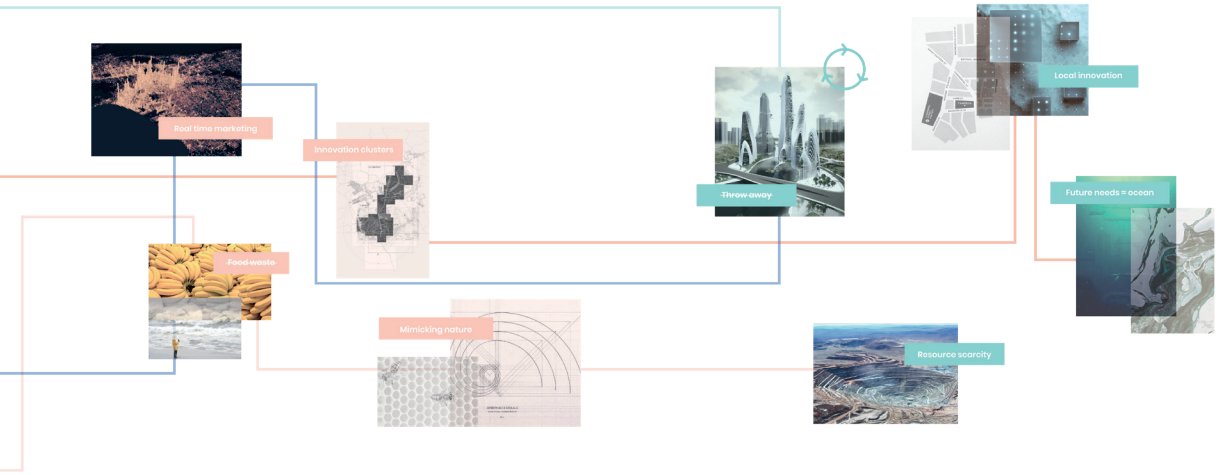
EXPERIENCE



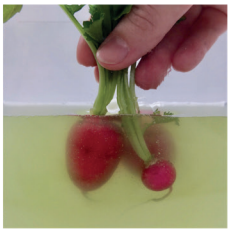


2025

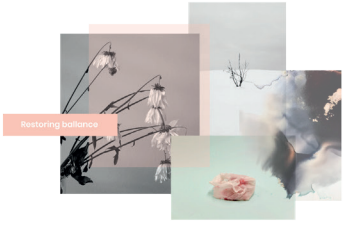
2025

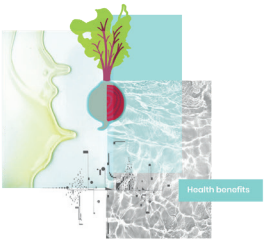


Challenge imbalance



Challenge packaging





APPROACH : TRENDS

TO HELP IMAGINE THE POSSIBLE FUTURE SCENARIOS, WE HAVE USED TRENDS AS INSPIRATION. THE TRENDS HAS HELPED US BUILD THE CONTEXTS FOR THE SCENARIOS FROM 2020 TO 2030 AND HAS INSPIRED THE TOUCHPOINTS WITHIN OUR SCENARIOS.

We talked to Claire Dennington, PhD fellow at AHO, for inspiration and guidance on how to apply trends. We have read trend reports such as WGSN (World's Global Style Network) and reflected on tendencies we see today in social media, news and the world around us. We have picked trends based on relevance and explored how these might influence the future.

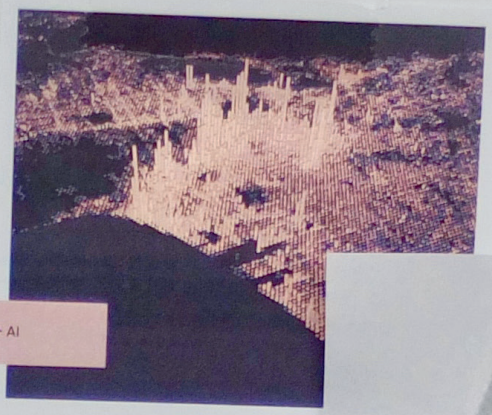
We have mainly focused on four trends and imagined how they might evolve into the future of 2030. The main trends we have focused on are: **1)** Customers seeking transparency in a post-truth era, **2)** a changed perception of waste as value, **3)** looking to nature for inspiration and **4)** an increased investment in local innovation.

Moodboards have been a valuable tool through the whole process and helped us visualize and conceptualize our ideas. As this diploma is a collaboration between two people, using printed visual inspiration has helped us align our thoughts and build on each other's ideas.

for the good

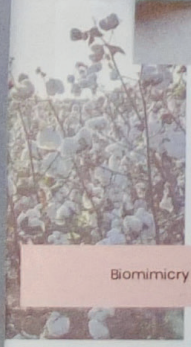
less food waste

ning patterns &
cting consumption



Big data + AI

Innovation clusters



Biomimicry

New use of raw materials

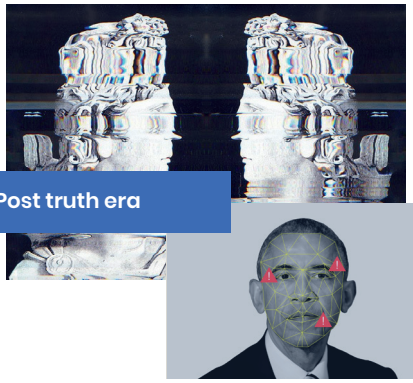
nature as
inspiration

SCENARIO 2020

We live in a post truth era where more and more things are being questioned. Within a politically turbulent landscape of fake news and revealed business scandals, consumers are seeking companies that share their values and encompass transparency.

Global movements are pushing for change through social media, demonstrations and symbolic acts. The concept of sustainability is changing from product to life cycle together with a new understanding of waste as value. Customers expect materials to be reusable and recyclable.

Consumers value local food because of it's high quality. They feel closer to the source by knowing how and where it is produced. This resonates with values concerning sustainability and aspiration to support local farmers and ethical ways of farming.



Post truth era

Plastic attacks

Waste has value

Local products

Images from various sources

2020: INTRODUCING THE MATERIAL

WE PROPOSE INTRODUCING THE SEAWEED BIOPLASTIC FOR PORTION SERVINGS AT FESTIVALS AND EVENTS TO CREATE AWARENESS AND INTEREST. THE MATERIAL IS EDIBLE AND CAN BE THROWN IN FOOD WASTE, TO ILLUSTRATE THE FOOD EXPERIENCE WE HAVE CHOSEN ICE CREAM AND POPCORN AS EXAMPLES.

We imagine festivals and events to be a good place to start before introducing the material to the market. The last years there has been an increased focus on food at festivals and events, making these good arenas to introduce new products. Making it valuable for restaurants and food producers to be present. This creates an increased need of single use cutlery and serving plates. Festivals and events need to respond to this consumption in a time of sustainable focus and banning of single use plastic. As festivals and events have regulations and restrictions regarding plastic use, change is forced which pushes for use of new materials.

In these contexts, the visitors can learn about the new material, the production, usage and how it becomes waste in more engaging ways. Festivals and events are usually within regulated areas making it easier to ensure that the material is handled the right way, also after use.

For single use serving solutions, the usage time is short and does not require the same water and heat resistance as packaging for longer use. This is positive when introducing a new material, as the quality does not need to be as high, and material properties can be tested.

Picture by Micheile Hendersen, on Unsplash

FOODSTAND: We suggest collaborations with local producers like Rørosis(ice cream) and Sørlandschips(nuts & chips). The portion servings are biodegradable and can be eaten or thrown in food waste.

POPCORN: To start introducing the new material we suggest serving portions for snacks like nuts, chips and popcorn. The content does not require a long lasting material as it will be eaten right away and since the content is dry it does not need to be water resistant. After use it can be thrown in food waste and will degrade naturally. The serving portion above and to the left, are our actual prototypes, made of alginate.

ICECREAM: We propose that the edible serving cups have different flavours like raspberry and vanilla to enrich the experience of eating ice cream. As shown on the picture, the cup will change shape in contact with the ice cream, working as a membrane but not letting the content out of the cup.


BAR
BAR
BAR
Shareable on SoMe


ICE CREAM
Information: from seaweed to fertilizer

POTENTIAL: With further development the material can be customized for different events and festivals depending on what type of experience they want the visitors to have, by playing with colors, branding, texture and flavor. We also believe that the material can be tested at other arenas like food courts, amusement parks and universities.

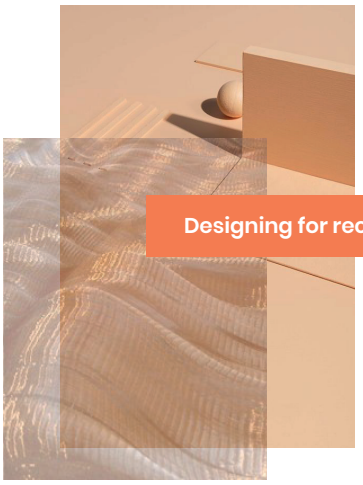
SCENARIO 2022

With the changed perception of waste as a value, we see new and improved waste handling systems creating more workplaces and better utilizations of all materials. Chemical recycling is piloted and can maintain the molecular structure and preserve the material qualities. Product afterlife is reconsidered, where companies are designing for recycling. Using fewer materials when creating a product, makes it easier to recycle and reduce wastage that goes to incineration(burning).

Simultaneously, new regulations and banning of more plastic products will drastically change the system and push for new alternatives. We learn from our mistakes and look to nature for answers as the main source of inspiration when developing new materials and systems. When designing new products nature's life cycle is the core of innovation, and transparency is the new normal. Information about material origin, production and carbon footprint is accessible for all.

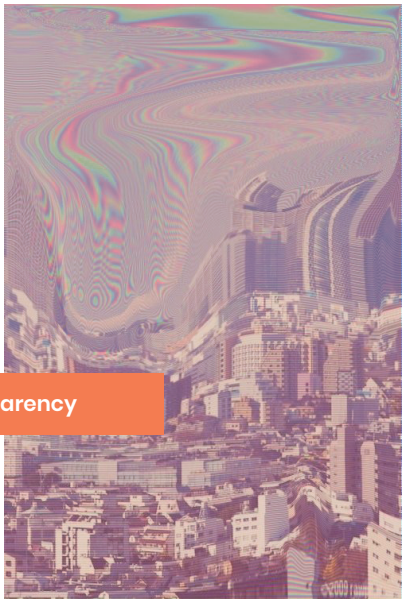
In crowded cities people strive to get closer to nature. Urban gardening on rooftops, balconies and abandoned parking lots build communities and gives a sense of achievement and serenity.

Improved waste systems



Designing for recycling

Urban gardening



Transparency

Images from various sources

2022: CHALLENGE UNNECESSARY USE OF PLASTIC

IN 2022 WE PROPOSE CHALLENGING UNNECESSARY USE OF PLASTIC BY REPLACING SOME PLASTIC PACKAGING WITH ALGINATE BIOPLASTIC. IT SERVES AS AN ALTERNATIVE WITH AN ADDED FUNCTION AND VALUE. TO ILLUSTRATE THE POTENTIAL OF ALGINATE BIOPLASTIC WE HAVE USED PACKAGING FOR HERBS, MORE SPECIFICALLY CHIVES.

Traditional packaging for herbs functions mainly as a container, while the new alginate packaging can nurture the plant and prolong it's life. The packaging functions as a membrane for the soil not letting water out, while nurturing the roots of the herb. The packaging releases phosphorus, nitrogen and minerals into the soil and keeps the soil moist, thereby prolonging the lifespan of the chives.

Furthermore, the packaging protecting the chives, can be thrown in food waste together with the remains of the plant.

During spring and summer the chives can be planted in the garden or on the balcony. The pot contributes to improving the soil with it's natural components.

We propose that Norwegian food should have Norwegian packaging. The origin of the packaging and content is communicated on the packaging to make the consumer aware that everything is produced in Norway. In this example, the chives are farmed at Naustdal Gård and the packaging is made in Ulsteinvik using seaweed farmed at Hitra.


CHIVES
Organic chives from
Naustdal Gård, Sogn & Fjordane


PACKAGING
This packaging is made of seaweed farmed at Hitra Read the (actually!) exiting story of seaweed packaging at hitraseaweed.no
Seaweed
Chives
This packaging is biodegradable please throw in food waste or plant it in your garden

REAL PROTOTYPE:
The chives “pot” is actually made of alginate.


Traceable information


Expanding lifecycle

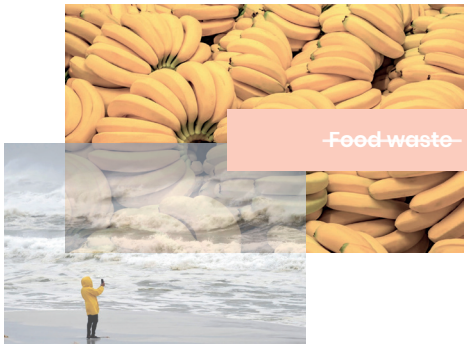
POTENTIAL: With further development the material can replace more unnecessary plastic use. We imagine that the potential seaweed has to improve soil can expand into new products like using it for flower pots and within agriculture. We believe that Norwegian packaging for Norwegian products can cut CO^2 emissions through less energy used for storage and shorter transportation distances.

SCENARIO 2025

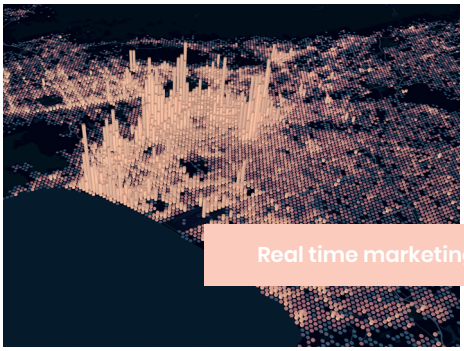
Purchasing food online is the new normal and AI has become a crucial part of predicting future needs by analysing big data. Throwing away edible food has become unacceptable, however, climate changes are disrupting seasons, making it difficult for farmers and food distributors to calculate the crops. This has led to the importance of real time marketing, pushing consumers to choose seasonal fruits and vegetables when they are ripe.

Increased investment in Norwegian innovation clusters (klyngedesign) creates new collaborations across different sectors. Local resources and knowledge creates stronger communities that benefits economy and new thinking.

To challenge the imbalance between food and packaging, material behaviour is designed to mimic nature. We are trying to restore balance between consumption and decomposition.

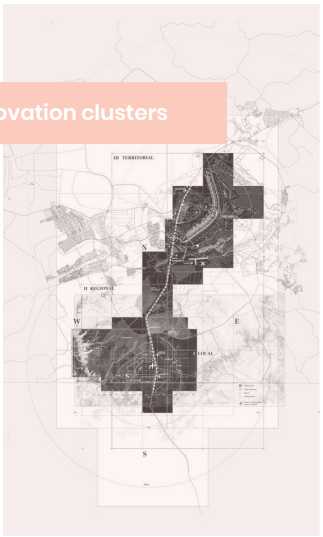


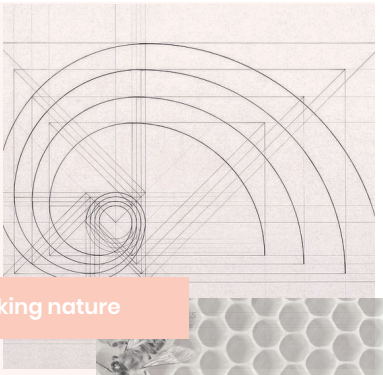
~~Food waste~~



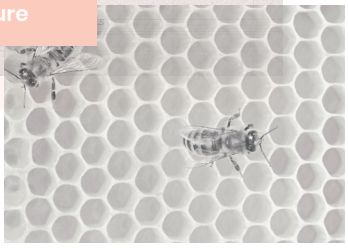
Real time marketing

Innovation clusters





Mimicking nature



Images from various sources

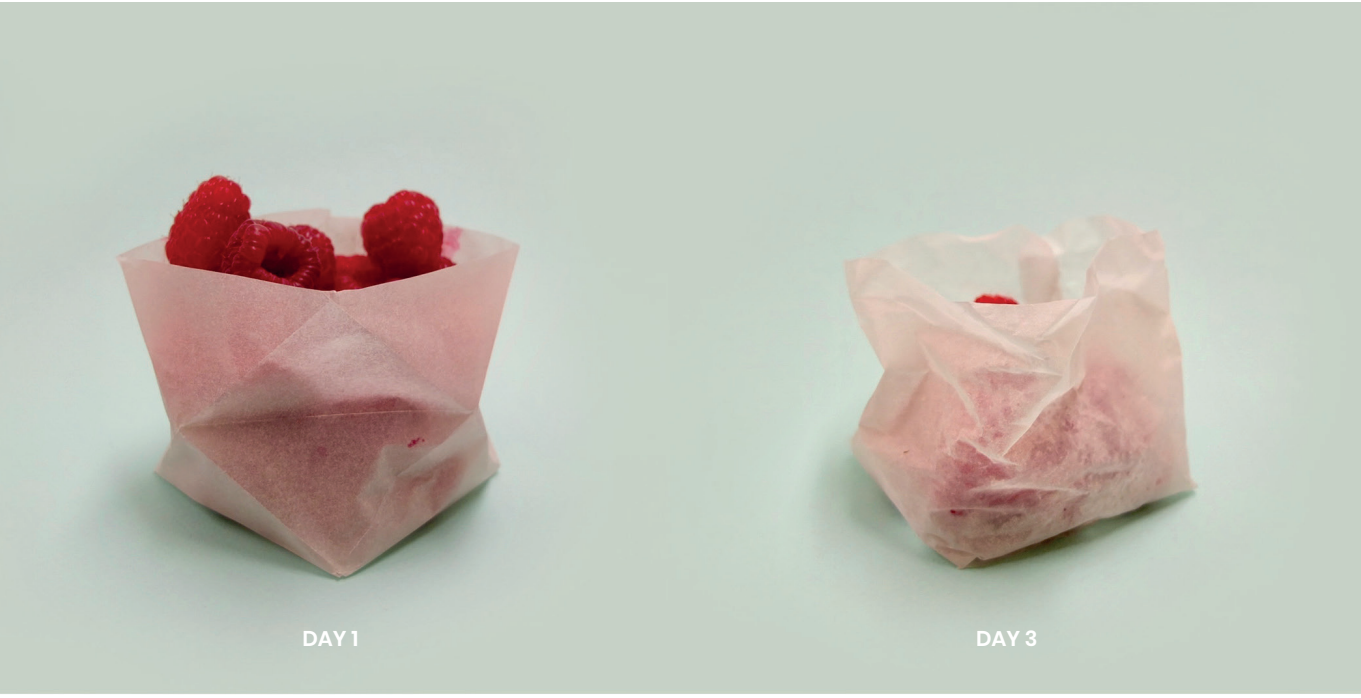
2025 : CHALLENGE IMBALANCE

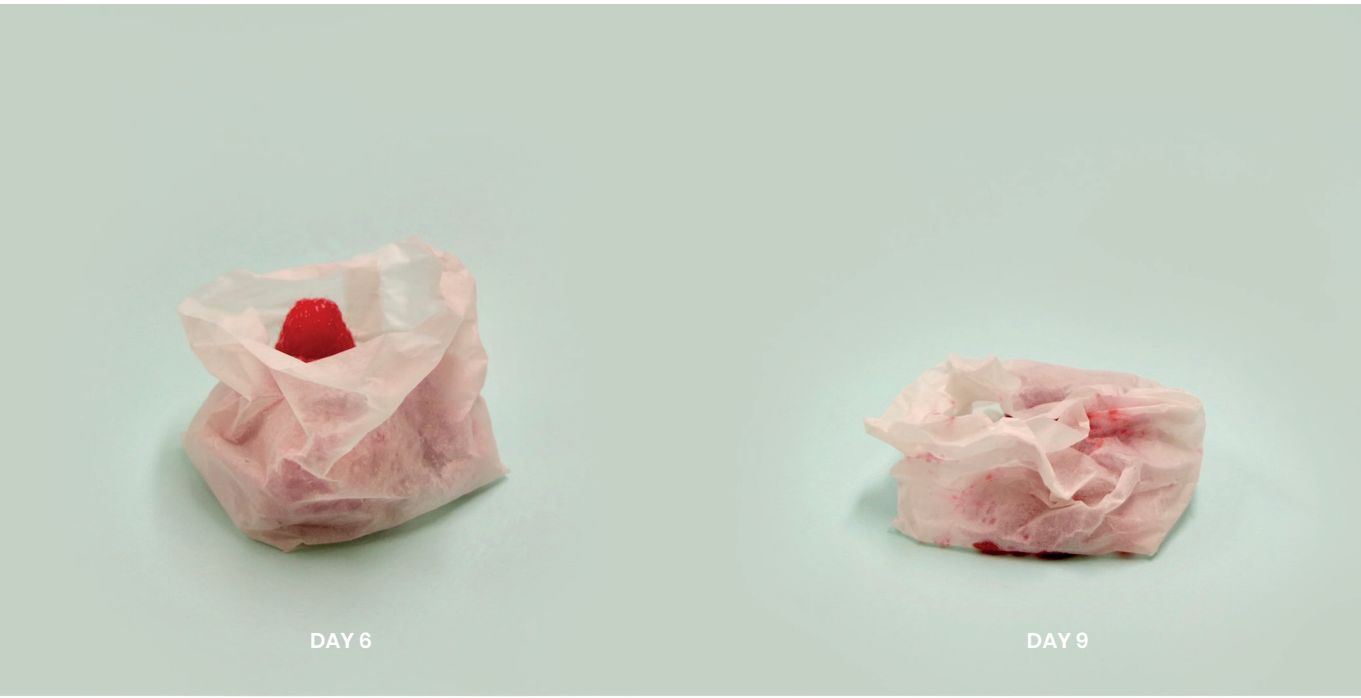
IN THE SCENARIO OF 2025 WE WANT TO CHALLENGE THE IMBALANCE BETWEEN CONTENT AND PACKAGING. TODAY FOOD EXPIRES IN DAYS COMPARED TO THE PACKAGING THAT LASTS FOR DECADES, ONLY TO BREAK DOWN INTO SMALLER PIECES.

We imagine packaging being perishable and degrading together with the content, to illustrate this we have chosen raspberries. We propose that with the new material we can challenge the perception of packaging, by giving the consumer a visual clue when the berries need to be eaten. The packaging is biodegradable and can be thrown in food waste together with the berries, if not eaten in time.

We believe the best solution for waste handling is a combination of recyclable materials and biodegradable waste. Using plastic only when necessary and provide natural materials for food packaging when possible.


RASPBERRIES
Organic berries from
Steinstø fruktgard,
Hardanger


DAY 1
DAY 3


DAY 6
DAY 9

PICNIC: Perfect for bringing to the park on a warm summer day. The packaging is biodegradable, and will degrade naturally if it's forgotten in the park.

Local food in local packaging

Restoring balance

POTENTIAL: The new function of packaging degrading with the content could also be used for other types of food like tomatoes, plums and grapes. We hope this concept can create awareness about the imbalance we see today and inspire more actors to think differently around what packaging might be. We also imagine that the packaging could change color or texture over time as the expiry date approaches.

SCENARIO 2030

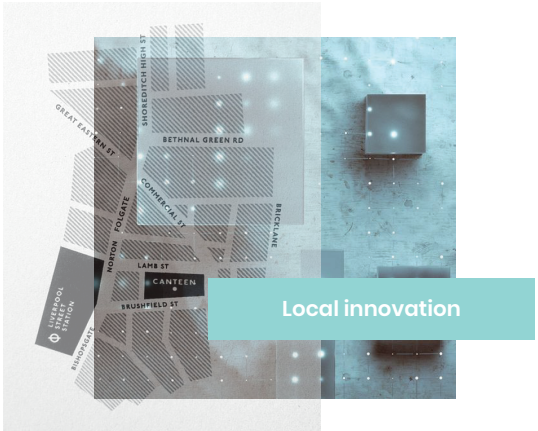
In 2030 we imagine increased resource scarcity because of climate change and population growth. As a response to this we have developed more advanced waste systems turning all waste into value. The term “throw away” belongs to the past, as we have learned that there is no “away”, and everything is considered a resource. Customers take it for granted that companies make the best choice in terms of sustainability and consider the whole ecosystem.

To meet the needs of the growing population, we look to the ocean for new materials, food and energy. Value is created along the whole Norwegian coast, with local communities pushing innovation further through cross disciplinary symbiosis. Automatization is key in this development and makes it possible for Norway to compete on the global market.

Resource scarcity

~~Throw away~~

Future needs = ocean



Local innovation

Images from various sources

2030: CHALLENGE PACKAGING

IN 2030 WE PROPOSE TO MOVE AWAY FROM PACKING TO OTHER METHODS OF PROTECTING, LIKE DIPPING. WHEN DIPPING THE VEGETABLES IN ALGINATE IT CREATES A NUTRICIONAL LAYER PROTECTING AND PRESERVING THE VEGETABLES.

To make local food with local packaging possible, we imagine stronger collaborations on a local level, where seaweed farmers, agricultural farmers, biorefineries and packaging houses work together. This could lead to stronger economy and more workplaces in communities along the whole coast.

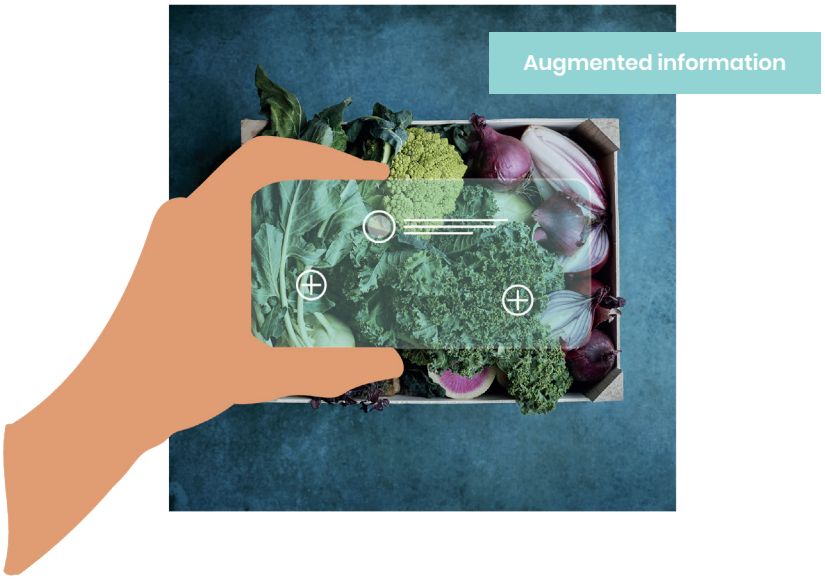
We imagine new possibilities of challenging packaging by using the natural substances in seaweed that actually enhances the products. Seaweed is full of minerals, vitamins, proteins and iodine. These valuable nutrients are part of the alginate layer creating an added health benefit for the consumer. The alginate layer will harden when dried and protect each vegetable in transportation and prevent them from drying out. The outer layer of alginate can be washed away, ensuring food safety and hygiene, while the nutrients on the inner layer will remain.

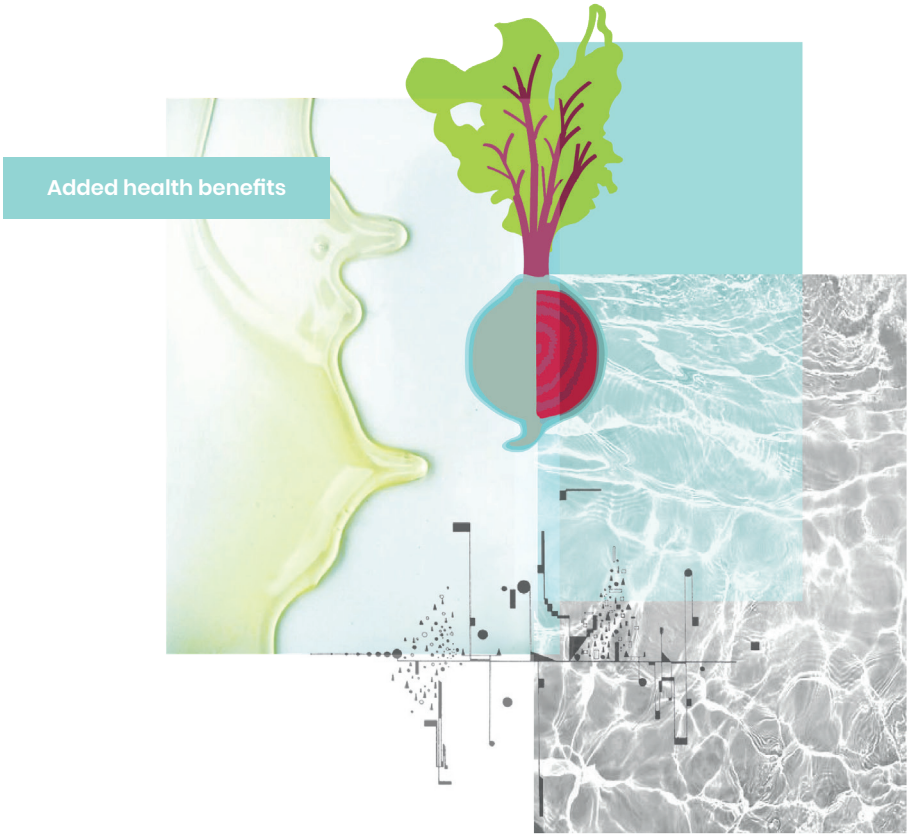
The packaging is customized to each vegetable for optimized protection and durability. Creating a stronger incentive for investing in alternative and natural materials that breaks the traditional perception of packaging.

We imagine that in 2030 ordering food online is the new normal, and that home delivery will reduce the need for packaging. Each vegetable has it's own membrane, making it possible to order only the amount you need. This can reduce food waste, because consumers don't have to buy large quantities.

ROOT VEGETABLES: Root vegetables are well suited for this type of packaging. The textured surface reacts well to the alginate and creates an even and strong layer. Root vegetables have good growth conditions in the Norwegian climate and supports the concept of local packaging for locally grown food. The glossy layer on the vegetables is actually alginate.


OUTER LAYER = PROTECTION
Is washed off before eaten
INNER LAYER = NUTRITION
Gives nutrients when eaten


Augmented information


Added health benefits

POTENTIAL: Today there is an iodine deficiency in the Norwegian population, we imagine that ionide can be added to the vegetables as a health benefit, since seaweed contain large amounts of ionide. This requires more research and involvement of actors like nutritional experts, chemists and biologists. We propose that this added nutricion can be funded by the government, like milk with added D-vitamin is today.

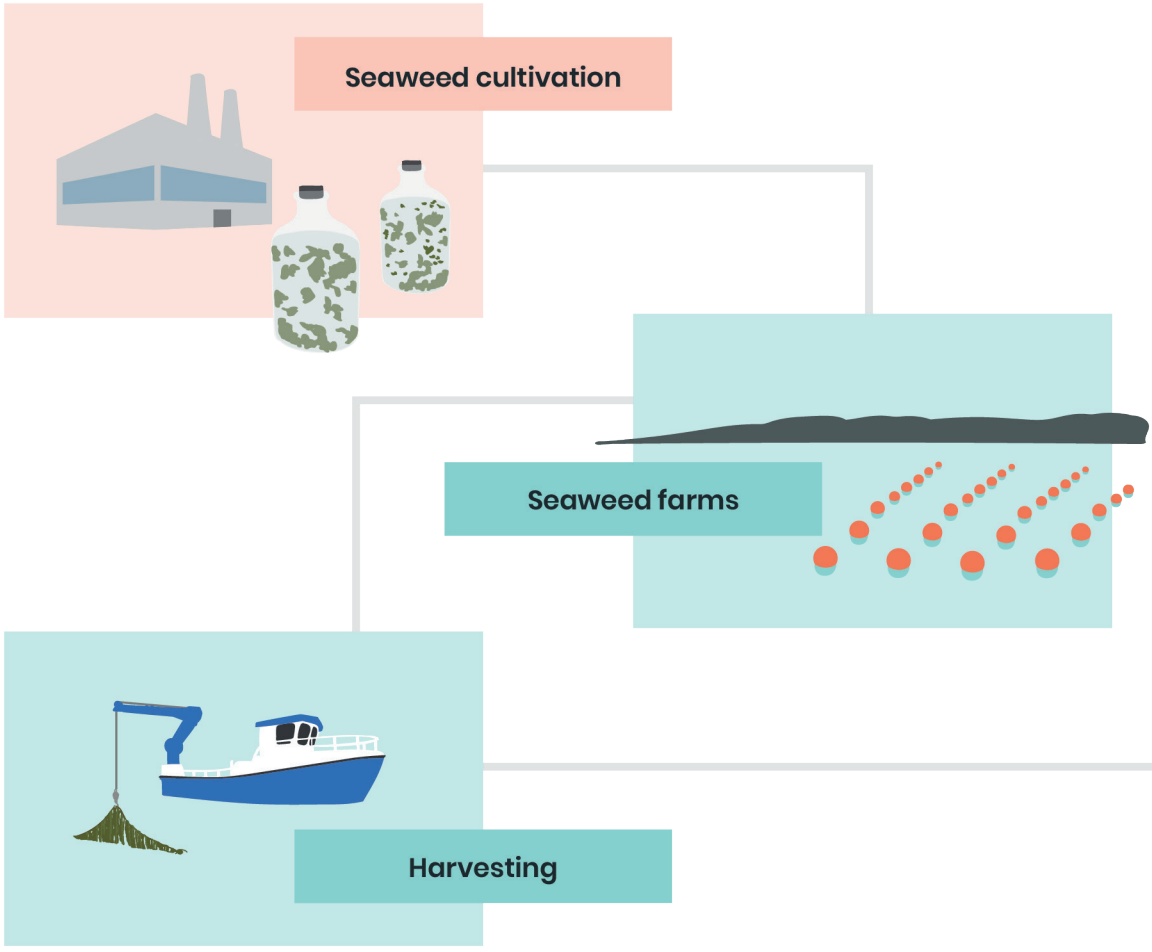
By more customization and individual “packaging” like dipping and spraying we believe this could contribute to less food waste, as you order what you need and all vegetables are protected individually. Fruits and vegetables naturally have a limited lifespan, but with improved protection this could potentially lead to Norwegian vegetables being available for a longer time on the market. What if dipping or spraying your home grown vegetables was possible?

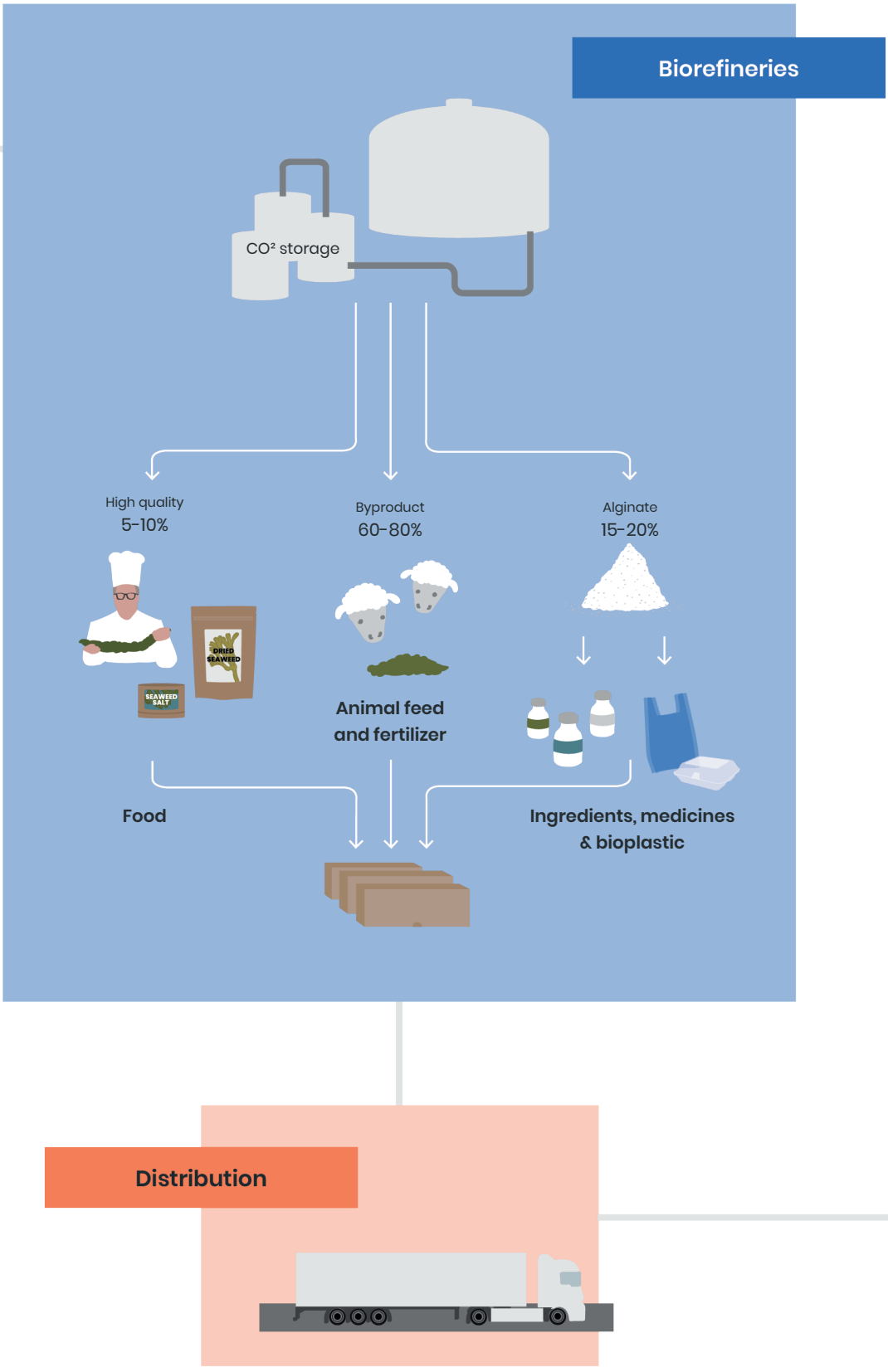
FUTURE PROCESSING OF SEAWEED

Being fully aware that we are not engineers nor manufacturing experts, we would like to present a broad overview of the steps backstage of our scenarios. From cultivation to processing and refining seaweed. The illustrated steps are based on our research and interviews with experts.

Farmed seaweed starts in cultivation hatcheries. These are mainly on land, where the seaweed spores are breeded on ropes. When ready, the ropes will be placed in anchored facilities at sea. Harvesting is mostly done manually, however, in the future this needs to be further automated, maybe even with autonomous harvesting vessels.

We imagine that the seaweed will be transported to biorefineries and separated into different production lines. The finest seaweed might go straight to restaurants and food producers, and the rest will be used to extract alginate. As mentioned seaweed only contains 15-20% alginate, where the remaining 80-85% could be used for animal feed and fertilizer, and in the future maybe even biofuel. This is how Martin Sterner, post-doc at KTH imagines the future of alginate extraction. Alginate will continue to be used as food ingredient and for medicines, but with new technology and innovation, additional purposes and possibilities might emerge, like our proposal of bioplastic.




Biorefineries
CO² storage
High quality
5–10%
Byproduct
60–80%
Alginate
15–20%
DRIED SEAWEED
SEAWEED SALT
Animal feed
and fertilizer
Food
Ingredients, medicines
& bioplastic
Distribution

CHALLENGES

PRICE: Price is one of the main challenges with bioplastic made of alginate. Today the alginate is too expensive to use for packaging and will depend on a large scale production of seaweed for multiple purposes. The price of seaweed may decrease by large-scale production and advanced processing to optimize the usage of the raw material. Automatization is crucial to ensure economic sustainability, because of high salaries in Norway, where manual labour is too expensive.

MATERIAL PROPERTIES: More research needs to be conducted to find out how alginate packaging will react in contact with different food, and how temperature changes will influence the properties. To ensure biodegradability and an optimal way of discarding the material, multiple tests and material developments are needed.

Food safety is the most important aspect of packaging. The bio packaging must not be in any risk of affecting the content. Ensuring that the material does not cause more food waste by shortening the durability, will be essential for further development.

Durability through the whole chain needs to be taken into consideration. Everything from production methods, storage and transportation, to durability and function during packing. A basket for strawberries needs to be functional in rainy weather as well as on sunny days.

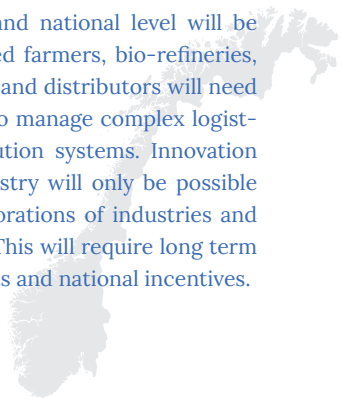
Communicating the difference of bio-plastic and regular plastic is important to not disrupt the recycling systems. Also, informing about the different material properties, highlighting that the bio packaging may change structure and tactility. However, the material qualities and function retains.

PRODUCTION AND PROCESSING: Using seaweed as packaging will depend on predictable delivery of raw material. As the packaging will be in contact with food, certifications of quality and content will be important to secure food safety.

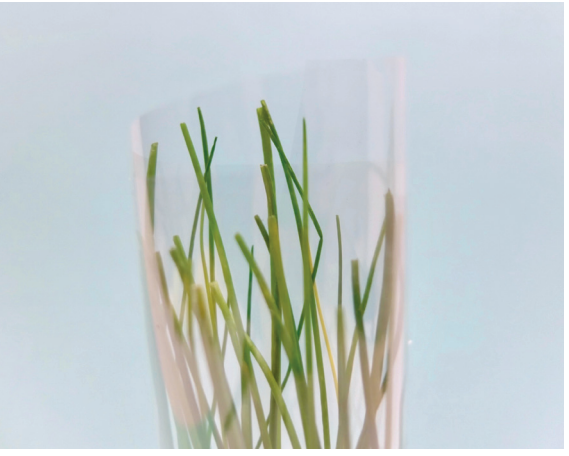
Looking at the bigger picture, predictability can be difficult as seaweed is affected by weather, temperature, pollution and ocean currents. All of these variables are determined by external factors and will be hard to control. Targeted and increased data collection could make it easier to understand the sources of the problems and work on solutions.

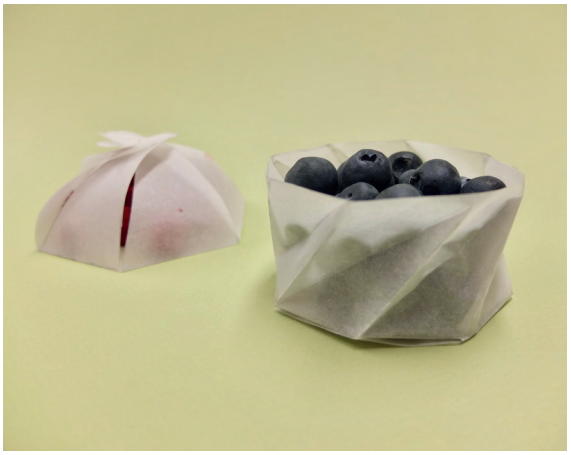
Calculations of carbon footprint is required to determine if alginate bioplastic actually is a better alternative to plastic. It will be important to continuously monitor the effects of seaweed farming and processing to ensure that bioplastic from seaweed is a more sustainable alternative.

Collaborations between different actors on both local and national level will be needed. Seaweed farmers, bio-refineries, packing houses and distributors will need to collaborate to manage complex logistics and distribution systems. Innovation within the industry will only be possible by cross collaborations of industries and competencies. This will require long term dedicated efforts and national incentives.



8. REFLECTIONS





REFLECTIONS

In the beginning of this project we had no idea of how vast the future opportunities of seaweed was. We feel very lucky that our chosen theme allowed us to have an **explorative approach** in an emerging industry. We've had a lot of fun during these months of exploring and designing.

Engaged experts, eager to share their knowledge and enthusiasm, made this project possible and really exiting. Without them, it would not be possible to dive so quickly into such a comprehensive topic. This also allowed us to continuously zoom in and out at multiple levels within the industry.

By **questioning** what a **service design project** is, interesting discussions and reflections occurred. As the project developed it became harder to define what our actual delivery would be. Is it a service design project if we don't have a service or journey? Can we call it system oriented design without having a gigamap? Is it product design, even though we don't have technical drawings? Because the project is a combination of different design disciplines, we decided to call it a design diploma. **A design diploma with a strategic approach, using service design tools and product design elements.**

By not collaborating with a specific company, we were **free to explore** the potential of seaweed on our own terms. Having continuous contact with different actors has been a good way for us to work towards the goal of inspiring the industry. We hope that our way of doing research through design have somehow inspired the ones we have been in contact with.

COLLABORATION: We have previously worked on several projects together. Our values and areas of interest is very much aligned, creating a good baseline for our collaboration. With different designerly skills, we complement each other. We also feel that we have **built on each other's strengths**. Taking ideation as an example: We both love ideation, Frøya pushes the ideas further in exiting directions, while Frida finds the essence and makes a realistic plan. By challenging each other we feel that we have evolved as designers and learned a lot on the way. These synergies makes it really fun to work together and we are proud to call this our diploma.

DETAILING: Working on several levels, seeing the bigger picture and zooming in to design tangible elements, has been very rewarding. One can always wish for more detailing, but this has not been our priority. We believe too detailed elements could draw the attention away from the larger picture and our end goal. We felt that further detailing of the scenarios would not necessarily strengthen them, but rather risk losing some of the inspirational excitement and curiosity intended.

STRATEGY: At times it felt **overwhelming to work on** a **strategy** aiming to influence a future industry. Several iterations and continuous validation of our understanding has been key to even claim that we can make a contribution. In a joint effort it would be interesting to develop a more specific timeline and detailed areas of responsibilities. Looking into local levels and efforts as part of the national strategy, could make the map more actionable. It has been challenging to get in contact with relevant governmental departments, therefore the governmental steps have not been validated. To further develop the roadmap we would push even more to involve policy makers and to understand their point of view and their planned investments in the industry. We hope elements of the roadmap can be used when further developing a national strategy for the seaweed industry. We also hope it can be helpful as a conversation tool and trigger further discussions.

CO^2 STORAGE: It's predicted that farmed seaweed can be used as a climate action to absorb CO^2 and therefore be a part of a national climate strategy. We would have liked to investigate this further. To get a deeper understanding on how CO^2 capture and storage actually works and if it's really sustainable in the long run.

MATERIAL EXPERIMENTATION: Our experimentation was mostly based on our learnings from the postdoc Martin Sterner. As designers with no prior knowledge of alginate, we managed to make material samples and simple shapes. We have only used the alginate in our experiments, but it would have been interesting to include more of the seaweed's components. We are wondering how this would affect the aesthetics and functions.

Looking back, we would have liked to **push our experimentation further**. We could have added other components to the solution, like glycerol. This could potentially make the material more flexible and thereby suited for more areas of use. The material samples we brought to interviews were quite fragile. With a more flexible material it would be possible to user test the material without it breaking. We also imagine that it would be easier to envision the applications we proposed in our scenarios.

Overall, more research needs to be conducted to commercialize seaweed bioplastic. **We understand our limitations and that chemists and professionals needs to take the development further.**

Memo to self; don't store seaweed experiments in the studio and leave for Helsinki.. Smells will develop, never to be forgotten.

We would like to thank the great people who made this project possible. Their help, support and guidance has been essential, thank you!

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“We just have to start!”

Quote from interview with Job Schipper, business development advisor, Hortimare