DESIGN AND MATURATION OF A SEAWEED MATERIAL

A MATERIAL- AND PRODUCT-STRATEGY STUDY GUIDED BY SMALL-SCALE VALUES

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MASTER THESIS
“Within the limitations, the possibilities are limitless”

- Jules Deelder - (freely translated)
As an Industrial Design student, a consumer and an enthusiast on being around, in and on the sea, I can get quite down-hearted concerning plastic pollution. Luckily, initiatives are being taken and plenty of promising alternatives are being developed, among which materials that are based on seaweed. This natural source appears very promising for industrial applications and personally, I am very intrigued by the idea of seaweed products.

Despite these developments, actual maturation of materials can be a slow process with many technical and corporate challenges on its way. The difficulty here lies in the motivation of the entrepreneur: what compromises is this person willing, and able to take?

In my thesis, I explore the challenges and the possibilities within the development and scaling of seaweed-based material, while exploring the initial values of small-scale stakeholders.

In this project, it has become clear that the transition towards bio-based materials is quite complicated: both consumers and industries are used to the use of plastic in their everyday activities and its matching infrastructures. Awareness is growing that a change within this habit is necessary for our environment. But, if we change our materials we need to change our whole concept of producing, doing business and of customer education. Then, I think that we have a chance with seaweed.

Therefore, as a technical design student, I chose for a more strategic approach within the material design. Therefore, this project contains the design of a material and a product proposal, but also an inseparable proposal to a scaling- and storytelling strategy.

Special thanks to:

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FROM WASTE FROM OUR COAST
TO THE COASTER OF JOOST
This project explores the maturation of a seaweed material. Three research questions are set, that concern how to design industrially with a seaweed-based material, how the material can mature while guarding the initial values of small-scale stakeholders, and how involved stakeholders can be convinced to accept a seaweed material.

Multiple analyses are performed to answer different parts of the research questions. The results provide some answers to the questions, but they also evoked more questions. These were translated into challenges that come with scaling of the seaweed material. These concern ‘material controllability’, a ‘multi-context fit’, ‘space to guard values’ and ‘time and trust’. To approach these challenges, a seaweed-based material is designed, market opportunities that fit multiple contexts are identified, scaling principles that create space for values are explored and stories that need to be told are identified.

From these results, opportunities and challenges are identified and the relations between them are formed into a development roadmap of the designed material.

The development roadmap consists out of three main phases. To concretize the strategy, a design is proposed for the first phase, consisting of a product design, a value chain proposal and a storytelling overview to lead to the next steps within the roadmap.
1. INTRODUCTION

1.1 Motivation
1.2 Research questions
1.3 Project scope
1.4 Method & tools

Image 3: Seaweed samples at Neeltje Jans, Eastern Scheldt
1.1 Motivation

From an environmental perspective
The main motivation for this project is the visible need to decrease plastic pollution, together with the complexity of the implementation of alternatives. An important reason for these difficulties is the increasing complexity of infrastructures and stakeholders’ objectives that comes with the increasing amount of types of plastic and plastic alternatives (Spek, personal communication, 11 December 2017).

From a design perspective
One of the issues of the acceptance of material innovations within an industry, is the long gestation and substitution period. One of the reasons for this is that the market and the new material should match correctly. Often, there is a mismatch once the new material arrives at the consumer. To design an alternative material that is acceptable by industry and consumer, it is therefore important to search fit applications for a fit material (Maine, Probert, Ashby, 2005). An important factor in this, and therefore a suitable starting point, could be the material’s origin.

From a seaweed perspective
What makes seaweed-based materials interesting as an approach, is that the cultivation of seaweeds does not compete for land-use or fresh water (Boonstra, 2014). Cultivation of seaweed can even have a positive impact on its environment, by the ability of seaweed to uptake nitrogen, phosphors and carbon (Hasselstrom, 2018). Currently, there is a large amount of nitrogens and phosphors in the ocean. This pollution forms the largest cause of the rising amount of ‘dead zones’ (oxygen-poor areas of ocean, suffocating other marine life) in the oceans. Synthetic fertilizers from agriculture are expected to be an influencing source (Pearce, 2018).

From a business perspective
There is much activity in the development of the seaweed chain within Europe. ‘But, there needs to be a market’. This market must make it interesting for companies to invest in the plans for the seaweed chain. ‘An interesting new product can make this more appealing’ (WUR, 2015).

From a local perspective
In the Netherlands, seaweed farming, research on extracts and the seaweed-market is gaining interest, this is mainly for the seaweed’s high potential in the food sector, chemical industry (concerning bio-polymers and medical applications) and energy sector (WUR, 2015). But since currently there is an absence of a market as well as of a product, the developments depend largely on support from the government or investors.

There can be an opportunity for seaweed-materials to grow along with the development of seaweed farms. But following this path at this moment, it might take a while before seaweed could be a bio-material for a large consumer market. Firstly because food and energy applications probably have priority within the first produced seaweed batches, since the development of these applications are already on the governmental agenda (Stichting Noordzeeboerderij, kick-off meeting, 2018). Secondly, because it can be estimated that the consumer market is ready for a natural alternative for plastic, but is it doubtful whether the consumer is also willing to take compromises in the quality and price of the materials. Therefore within the Dutch context, seaweed-materials will require more time to develop and can be a future opportunity.

And a global perspective:
Globally, there are also many locations where seaweed could offer a range of possibilities. Probably the most relevant location concerns the Caribbean area, where there is a large seaweed plague that has been occurring yearly since 2011 and is still growing in size each year (Langin, 2018). On the island of Sint Maarten, there is an urgent demand to take action with the excess of seaweed, to recreate a livable environment and create new jobs in new industries, since many jobs within the tourism sector were lost due to hurricane Irma in 2017, and the growing seaweed plagues. “St. Maarten’s tourism industry—its economic engine—is now anemic.” (Maede, 2018). Here, there can currently be added value because of this current, urgent need.
Seaweed is a promising bio-friendly material but asks for a self-sustaining supply and demand, as well as for knowledge on how to design with it for a large scale.

Image 5: Sargassum plague in Caribbean area. Here, Mexico (Vietnamplus.vn, 2018)
1.2 Research questions

Maturity
The project concerns the maturity of a seaweed material in an industrial environment (with this is meant: an environment that is focused on large-scale production). The material can be considered mature when it is independent of funding, accessible to consumers or other businesses, and when the concerning business is viable, with respect to its environment.

Values
Within scaling-up processes, concessions have to be made to fit in the industrial environment. The choice on which type of concession to make is quite important here, to make sure that the small-scale entrepreneurs core values as well as environmental factors like seaweed exploitation are protected.

Acceptation
Next to this, change comes with acceptation of concerning stakeholders. Therefore stakeholders need to be convinced of the advantages of the use and development of a seaweed material.

Research questions

Within these discussed themes, the following research questions are proposed:

1. How to design (industrially) with seaweed as a material?
   a. What is a suitable seaweed-based material for industrial applications?
   b. What are the characteristics of this material?
   c. What are the possibilities concerning material composition, applications, form, and production?

2. How can the material mature while guarding small-scale values and avoid exploitation?
   a. What are the values of small-scale stakeholders and large scale-stakeholders that are involved in the seaweed industry?
   b. Where do values clash?
   c. What strategies can you apply for the scaling of a material?
   d. How can the environment be protected within the scaling process, considering resource exploitation?

3. How can acceptance of the material be stimulated?
   a. Who are the stakeholders that are needed to convince?
   b. How can these stakeholders be convinced?
1.3 Project scope

Material
Because a ‘seaweed-material’ is a very broad concept, as a specific matter the extract alginate is chosen, based on the analysis in chapter 2.2, to experiment with throughout the further project.

Values and strategies
To explore the values of involved stakeholders (see research question 2), qualitative insights are needed that will be best to retrieve by scoping on stakeholders of the seaweed industry within the Netherlands.

In some cases, this scope might not cover the possibilities, and a larger scope is needed that is more globally focused. This larger scope is taken in analysis 2.4 that concerns different strategies of scaling, and in challenge 3.3, where the context of Sint Maarten is introduced as an additional context. The roadmap in chapter 4, is also based on this larger scope.
1.4 Method & tools

In image 7, the overall methodology and applied tools within the process are visualized.

From the three main research questions (top of the chart), analyses are performed to answer the sub-questions. Some analyses are used to zoom in on specific questions, and others are used to create an overview of the possibilities by zooming out (see image 7).

For the first two analyses, the main tools that were used were ‘benchmarking’ and ‘material tinkering’ from the method ‘Material Driven Design, a method for material experiences’ (Karana, 2015). Within the third analysis, that concerned the values of involved stakeholders, value exploration cards were made as conversation starters (see appendix A: value exploration cards) with stakeholders. Here, the cards served as a support for the analysis (the cards are not part of a proven tool). For the fourth analysis, input from the conversations that were held with the stakeholders was compared with existing literature on scaling. In the fifth analysis, input from the conversations was placed in an overview and by the hand of this, a narrative format was defined, inspired by literature on narrative frames (Zurlo, 2014).

From the results of the analyses, four challenges are formulated (see image 7: mountain icons). Within these challenges, a Harris-profile (Roozenburg and Eekels, 1995) was used as a basis format to create an overview of the (dis)-advantages and several material scenario’s. Then, for the second challenge, the method Context Variation by Design (Kersten, 2015) provided guidelines to find opportunities and challenges within the design for multiple contexts. For the third challenge, inspiration was gathered from examples from other businesses, or from retrieved feedback from a business perspective, to implement the findings from the earlier analysis. In the fourth challenge, a narrative strategy is formed by placing the narrative format and stories on a time-scale.

To cluster the retrieved insights, a 2x2 matrix (IFM, 2018) mapped out whether insights concerned the present or the future, and could be linked to challenges or opportunities. To provide an overview of the relations between the insights, principles of Technology Roadmapping (Phaal, 2004) were used as a basic format.

The insights from the roadmap were used as input for the design that concerned the start of the development roadmap, together with retrieved insights concerning the first customers. Next to the product, the involved business activities are introduced as a value chain (here is meant: a set of activities with the goal to add value). Lastly, an overview is provided for the storytelling strategy, based on the format of an ‘Audience tool’ (Miltenburg, 2018).
How to design industrially with seaweed?

- BENCHMARK
- MATERIAL TINKERING
- PERSONAL COMMUNICATION & VALUE CARDS
- PERSONAL COMMUNICATION & LITERATURE
- PERSONAL COMMUNICATION & LITERATURE
- SEAWeed APPLICATIONS
- SEAWeed MATERIAL
- STAKEHOLDER VALUES
- SCALING STRATEGIES
- ACCEPTATION

How to mature seaweed material while guarding small-scale values?

- MATERIAL CONTROLLABILITY
- MULTICONTEXT FIT
- CREATING SPACE FOR VALUES
- TIME & TRUST

- MATERIAL TINKERING
- CONTEXT VARIATION BY DESIGN (CVD)
- IN-FIELD INSPIRATION
- NARRATIVE STRATEGY

How to convince, and who to convince?

- TECHNOLOGY ROADMAPPING
- PRODUCT DESIGN
- VALUE CHAIN PROPOSAL

IN-FIELD INSPIRATION

NARRATIVE STRATEGY

HARRIS PROFILE

& MATERIAL TINKERING

CONTEXT VARIATION BY DESIGN (CVD)

IN-FIELD INSPIRATION

NARRATIVE STRATEGY

TECHNOLOGY ROADMAPPING

PRODUCT DESIGN

VALUE CHAIN PROPOSAL

NARRATIVE STRATEGY

Image 7: Process structure with used tools
2. ANALYSES

Within the analyses, questions are set up to explore and answer the essentials of the research questions.

The first analysis in 2.1 is a status overview of the seaweed industry concerning current seaweed applications. The analysis serves as a preparation to answer the question on how you can industrially design with seaweed (research question 1). Products and applications are explored through a benchmark analysis. Within this, used techniques as well as the maturity of the industries are analyzed. This results in insights concerning market gaps and industrial challenges.

In analysis 2.2, the scope is determined of the used seaweed matter, to be able to zoom in on the first research question (how to industrially design with seaweed). It is chosen to work with a seaweed component with expectedly the most industrial potential: alginate. In the further analysis is explored how this alginate behaves, how it can be used in the formation of a material and what its characteristics are. This results in opportunities and challenges to work with this material industrially.

Analysis 2.3 and 2.4 are set up to gain insight on how to be able to mature the material while exploring the values of small-scale stakeholders (research question 2).

In 2.3, the values of involved stakeholders are explored as well as the value clashes between small-scale and large-scale stakeholders. Conversations are held with small-scale entrepreneurs within the field to discuss their values within scaling. The discussed differences in values are confronted against each other, form which ‘value-clashes’ can be identified.

In 2.4, the approach zooms in to starting (small-scale) entrepreneurs within the seaweed industry. By more in-depth conversations, insights are retrieved on how small-scale entrepreneurs approach scaling-up processes and what challenges they face. These insights are compared with the accessible literature on scaling up, and different strategies are identified. This division and its characteristics can be used within deciding on a strategy used in the design.

In the final analysis (2.5), it is explored what the main interests for different stakeholders.

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2.1 Benchmarking seaweed applications

2.1.1 Goal

As a preparation for the first research question (how can you industrially design with seaweed), the benchmark analysis provides a status overview of current seaweed applications. The analysis is used to gain insight into the existing markets and the used techniques/seaweeds in order to find a fitting scope later in the project.

2.1.2 Approach

A benchmark is made of applications from different algae/extracts, in different markets. Existing applications are explored through searching for online news articles/blogs on new material developments and seaweed-based food applications, talking with stand-holders and exploring materials on the material event Materia (at Ahoy Rotterdam, March 13, 2018), following references in fishery papers on alginate (McHugh, 2013) and expert contact with the seaweed researcher Havard Sletta and seaweed designer Nienke Hoogvliet (Sletta, personal communication, February 16, 2018), (Hoogvliet, personal communication, March 20, 2018).

The amount of applications is very diverse. Therefore, only the applications were integrated in the benchmark that were considered to characterize a products group. From those, the expected material origin is described as well as the maturity of the product and the natural feel of the product (the last description is required to gain insight on consumer acceptance). The complete benchmark can be found in appendix B: benchmark analysis.

2.1.3 Benchmarking findings

Products from algae go way back in time, mainly within Asian cultures. This Asian market has developed itself over the centuries and established itself into a mature industry that focuses mainly on the food- and medical sector (Zwamborn, 2018). Lately, Western cultures started to see value in the seaweed as well and seeing opportunities within the food, agriculture, bio-plastic, fashion, and design industries. The following findings derive from the benchmark:

1. Maturity of the industry

Most industrial applications work with extracts of seaweed (mostly with the extracts alginate or agar agar). This industry is mature with production sizes over 30,000 tonnes per year (Bixler, 2011) and worldwide accessibility, but it has the least natural production process and experience. These applications have to meet high standards concerning hygiene and safety, taking for example the application of surimi food (Park, 2014) or the future application of biocompatible implants (image 8-a), (Pitt, 2014). Therefore the processes of extraction are very much controlled and organized.

The product design applications that focus on a basis natural material (no extract) embrace the irregularities and imperfections of the material and the product. The material is harder to control, but this is used as an aesthetic value, as seen in the furniture design “Terroir”, made from a seaweed and paper material (Fastcompany, 2015) (image 8-b).

2. Performance as packaging

Most packaging applications work with the extracts from green seaweeds (Image 8-c)(Newplasticseconomy.org, 2018), or red seaweeds. With many applications in their development/concept phase, it is difficult to define what is already possible and what is still a sketch of the possibilities. The Asian company Evoware has a very promising product on the market that is a bio-plastic film for packaging applications.

3. Future food

Competition with the food industry on access to seaweed resources is not desired, since healthy food is one of the world’s primal needs and seaweed could become a healthy part of our future diet. Therefore it is valuable to take into account what the needs and requirements of the food industry are (image 8-d) (see chapter 2.2 for the material decision).

Conclusion

The challenge for a material design will be to find a source that is able to form a performing material and which does not compete largely with the food industry. This choice for a material will be explained in the analysis 2.2: Seaweed material.

Also, it will be an opportunity to fill the gap between products from industrial extracts that are controllable but lack naturality and products that are very naturally but produced on small scale. The challenge here mainly lies within the controllability of natural ingredients, as well as the transparency within the industry of extracts.
<table>
<thead>
<tr>
<th>Name</th>
<th>Material</th>
<th>Source</th>
<th>Maturity</th>
<th>Natural experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocompatible implants</td>
<td>Extract from green seaweeds</td>
<td>cultivated green seaweed</td>
<td>Research</td>
<td>Low naturalness</td>
</tr>
<tr>
<td>Terroir</td>
<td>Pulp + Paper</td>
<td>Collected from shore</td>
<td>On exclusive market</td>
<td>High naturalness</td>
</tr>
<tr>
<td>Evoware</td>
<td>Agar Agar</td>
<td>Red seaweed extract</td>
<td>On Asian market</td>
<td>Apparent naturalness</td>
</tr>
<tr>
<td>Weed burger</td>
<td>Dried seaweed</td>
<td>Cultivated green seaweed</td>
<td>On Dutch market</td>
<td>Apparent naturalness</td>
</tr>
</tbody>
</table>
2.2 Alginate as a seaweed-based material

2.2.1 Goal

The goal of this analysis is to explore what approaches and opportunities are interesting for research question 1; ‘How to design with seaweed as a material’. Specifically, it concerns question 1a; ‘What is a suitable seaweed-based material for industrial applications’ and the parts of 1c, ‘What are the possibilities concerning material composition and production (forming of material)’.

2.2.2 Approach

First, the decision on the scope is explained, by introducing the distinction between different seaweed species and their polymer-forming matters (see image 11). Deciding to continue with a focus on alginate, first the chemical and biological structure and the material forming principle is explored. Within this, two approaches are explore. Firstly, a material is formed from an alginate extract. Secondly, because the extraction process of alginate appeared have some important downsides (see 2.2.6), material is attempted to form from raw material as well (with alginate inside the material). The insights that are retrieved from this exploration result in opportunities and challenges that this material provides.

2.2.3 Scope

Within seaweed (macro-algae), the three main groups can be distinguished of green (Chlorophyta), red (Rhodophyta) and brown (Phaeophyta) seaweeds (MESA, 2018). All contain different natural polymer-forming matters (Appendix C; table of carbohydrate content), (Boonstra, 2015).

Green seaweeds mainly store their nutrients in starch, which is a polysaccharide that is able to produce a biopolymer from, but is least promising for producing a strong one (PSLC, 2005). Most red seaweeds are rich of the polysaccharides ‘agar’ and/or ‘carrageenan’, and brown seaweeds contain the polysaccharide ‘alginate’ (McHugh, 2013). All these are polysaccharides are able to form biopolymers (MESA, 2018). Therefore, Agar, Carrageenan and Alginate are all possibilities to apply as a biobased-material, but they are not interreplaceable due to significant chemical differences and forming behavior (Barbaroux, 1990).

It is decided to choose the polysaccharide ‘alginate’ as the most potential matter for industrial applications. Firstly, because the large seaweed plague (see chapter 1.1: motivation) around the Caribbean, African and Indian coast consists of the brown seaweed Sargassum (see image 9) and this can therefore be an abundant resource for the near future.

Secondly, alginate from brown seaweeds can also be an accessible resource for the further future, because brown seaweeds grow well in temperate/artic waters on many global locations (Kennedy, 2018). For example, Ascophyllum nodosum is a species that grows well in Europe and can be found abundantly in the Eastern Scheldt as well (see image 10).

Thirdly, this type does not compete as much with the food industry as green/red seaweeds do, since Ascophyllum nodosum takes time to grow and is therefore expectedly not viable for food production and Sargassum, being a plague, is not appealing to cultivate.
Image 11: types of algae and their main polymerforming content
2.2.4 Alginate

Alginate is also known as Alginic acid, or Algin. It can be found in the cell-walls of the stem of brown seaweed (McHugh, 2013) and has the function to provide the plant resistance and strength to withstand tides and currents (Tomasso, 2011). In image 12 the content of a cellwall is illustrated.

Within the cell-walls of the stem, alginate is present in a salted form of algenic acid. Algenic acid is a polysaccharide, existing of multiple alternating acids (mannuronic acid and guluronic acid), with the structure illustrated in figure 13 (Pubchem, 2018).

At the COOH-groups, ions can bond. This can be a.o. calcium, magnesium or sodium. Through the bonding with calcium, the polysaccharide can form crosslinks between polysaccharides, forming a network (figure 14), as was visible in the representation of the cellwall in image 12. This can be used as the principle to form a bio-material.

Now, sodium salts of algenic acid (image 15) can dissolve in water and can therefore be extracted from the seaweed easily. The other salts (calcium-alginate and magnesium-alginate) can not dissolve in water. To extract all alginate, these salts have to be converted into sodium alginate. (McHugh, 2003). The process-tree of the extraction of alginate can be found in Appendix D: Extraction process of alginate. After extraction, the sodium-alginate is known as a hydrofile powder-form (see image 16).

Image 12: Cell wall model for brown algae from the order Fucales. (Deniaud-Bouet et al, 2014)
Part of the polymer chain of polysaccharide Algic Acid. (Adapted image from Pubchem, 2018)

A crosslink with Calcium ions

Part of the polymer chain of polysaccharide Sodium Alginate. Here, sodium ions formed into a dissolvable salt with the chain of Algic Acid. (Adapted image from Pubchem, 2018)

Sodium-alginate powder
2.2.5 Material forming from extracted alginate

**Forming principle**
The formation of crosslinks between the polysaccharides can be activated by adding the right proportion of calcium-rich water to the sodium-alginate powder. The sodium-ions dissolve and present calcium-ions can bond to the COOH-groups. This principle is called ion-exchange (Picken, personal communication, March 14, 2018).

When the crosslinks are formed, the water needs to evaporate slowly. The result is a rigid and brittle material. This method is the conventional way of producing material from alginate, which is also used for the production of alginate film material (Gao, 2016).

A more advanced method is the principle of thermo-mechanical mixing. Here, a destructuring agent is needed to disrupt the forming of intermolecular bonds under a thermo-mechanical input (Gao, 2016). This method is not widely explored yet for alginate, so information on the exact process will need more exploration. But this method can have advantages for industrial production since it facilitates the use of multi-phase production systems and is therefore suitable for a wider range of applications. (Gao, 2016).

Within this chapter, the question that is desired to be answered concerns the technical and experiential properties of gelled alginate as an extract. Next to this, it also explores more information on the end-life of alginate (recyclability and biodegradability).

**Method**
Answers are explored through material tinkering on the characteristics and recyclability. For this, the conventional method of forming a material from alginate is applied through evaporation (see Appendix E, test 1). Within this tinkering test, the extracted alginate powder (see appendix I for the safety sheet of the used material) is mixed with water with the proportion 1:10 (alginate:water). It is stirred & divided over different samples (image 17).

**Results: Process characteristics**

**Forming time**
The principle of ion-exchange happens quickly after addition of water, within two minutes the material is formed into a gel. The forming process of the material therefore needs to happen within this time. The quicker the material is formed, the smoother the surface.

**Temperature**
Because the addition of heat speeds up the gelling of alginate, it is considered as an endothermic reaction. Therefore, water temperature is an important parameter. If the short processing-time creates problems within the production process, a cool environment could slow down the reaction.

**Drying time**
After 8 minutes the material is gelled, but still very flexible. (image 18). The material then feels soft, smooth, cold and jelly. After a week, all water is evaporated and the material loses its flexibility and softness. The material feels warmer and more precious (as ceramic).

**Results: Material characteristics**

**Scent**
In a wetter state, the material has a medium sea scent, which dissappears when dried further.

**Flammability**
The material has a low flammability (the ability of the material to ignite) and is flame retardant (the material slows down the spreading of the flame). When exposed to flames, the material starts carbonizing (image 19) (Appendix E: test 10).

**Reaction to water**
The material considered as hydrophilic, since the contact angle of water on the surface is less than 90 degrees (Product Release, 2017) (image 20). But, the material absorbs water rather slowly. When put on water, it floats for a couple of minutes before it has absorbed enough water to sink. After water absorption (in 24 hours it had absorbed 100% of its own weight on water), it retrieves its flexible character again. When dried again, it retrieves its constructive character again (Appendix E: test 11).

**End-of-life**
The material is biodegradable, in combination with the enzym alginate. Also, recycling of alginate is theoretically possible (Picken, personal communication, March 14, 2018). In practice it appears to be an energy intensive and complicated process (Appendix E, test 2) (image 21).
Left:
Top: image 17: sodium-alginate + water
Bottom: image 18: gelled alginate

Right:
Top: image 19: flammability test
Middle: image 20: Contact angle test
Bottom: image 21: recycling test
Several tests are performed within tinkering part 1 (appendix E), to see what possibilities there are to work with alginate, without having to extract the alginate. This is desired because the extraction of alginate is an expensive process. Furthermore it involves the use of chemicals (Langlois, 2012) and is therefore known for having a polluting waste-stream that often is pumped into sea (McHugh, 2003). Furthermore the industry is not transparent in their resources and labour conditions (Picken, personal communication, March 14, 2018). Therefore among some designers, there is a slight aversion noticeable towards working with material from this industry (Dijkstra, personal communication, March 12, 2018).

Method
For these tests with raw seaweed, seaweed was gathered at the Eastern Scheldt and after it was dried and grinded. (Appendix F: Eastern Scheldt seaweeds) (Appendix E, test 3). The drying is done in an incubator, that dries slowly on a temperature of 40 degrees Celsius to not burn the material or change material characteristics (image 22).

Tests were done firstly on treating the seaweeds with alcohol, to attempt to break the lipids within cell-walls. This came from the assumption that the alginates are capsuled by lipids of the cell-wall (see image 12, p.23). Alcohols could break these lipid chains (PEER, 2003).

Secondly, tests are done with rennet, an enzyme preparation which is often used for milk-clotting (Farkye, 2003) (see appendix E, test 5, 6). This is done from the assumption that this could also provoke a change within the cell-structure, since enzym treatment is a common method in the production of bio-plastics. Since the results on the material’s workability were rather poor, test on further material characteristics are not performed.
It is decided to choose the polysaccharide ‘alginate’, which can be found in brown seaweeds, as the most potential matter for industrial applications. It has the potential to form strong polymers, is an abundant resource for the near future, an accessible resource for the further future and does not compete largely with the food industry.

Within the possibilities to form a material with alginate, there are two approaches: using alginate as an extract, and as a component within seaweed. Both approaches come with opportunities and challenges.

The approach of working with the industrial extract alginate is globally applied, accessible and provides a controllable material. The disadvantages of this approach are that the product comes from an intransparent industry which is known for its polluting activities.

The promising material characteristics of the alginate extract are flame retardentness, a chemical connection that is resistant to water and a ceramic-like, soft feel. The challenge here is how to cope with the intransparent and polluting extraction process, that is contradictionary to the values of small-scale stakeholders within the seaweed industry (see analysis 2.3)

To work with purely the raw seaweed as a material basis material is a very interesting approach considering the transparency of the process. The challenge here concerns that this approach is not explored widely yet (see analysis 2.1). Regarding this, while taking into account the small results from tinkering with the pure material, the chances of creating a workable material in the time scope of this project seem small. The main challenge here is how to be able to control the material and the process.
2.3 Stakeholder values

2.3.1 Goal

This analysis will look at which stakeholders are involved in a possible seaweed-chain that can eventually become an industry. The analysis concerns what stakeholders find most important (their values) and where these values can clash. This concerns the second research question, that questions how to mature seaweed-material while guarding small-scale values. This chapter concerns the sub-questions 2a and 2b, that question what these small-scale values are and were values can clash. With values, value-clashes and opportunities identified, a design challenge can be formulated which focuses on how to find opportunities of a material business, in a way that value is added, original values are guarded and value clashes are taken into account. Within the context of the value exploration, terminology can be interpreted in different manners and are part of a business jargon which is also discussable. But these are frequently discussed topics among the stakeholders, therefore it is interesting to map out what steps in the value chain are taken and where these values are essential in value exchange.

2.3.2 Scope

The results are based on a field analysis of the seaweed industry. The scope of small-scale stakeholders concerns the stakeholders that are involved in the development of the seaweed industry within the Netherlands. Through interviews with stakeholders, insights are retrieved and translated to a more generic overview.

2.3.3 Approach

- The interviews were supported by value-cards, a tool that was set-up for this particular analysis (see Appendix A: value exploration cards). On the value-cards, values that were expected to be important from an environmental perspective (low eco-impact, transparency), were listed together with those from a social perspective (transparency, social impact) and economic perspective (competitive advantage, risk reduction, newness, independence). People that were involved within the analysis were different small-scale stakeholders (with this is meant: enterprises/researchers/students/artists existing of one person or with less than 15 partners/employees), amongst which were visitors of a seaweed networking event (taking place in the Hague, 2018) organised by ‘Stichting Zeewierboerderij, material designer Nienke Hoogvliet and entrepreneur Nienke Dijkstra. These stakeholders were asked to choose their core values among the different options or to add their own. Chosen values were used as a conversation starter to talk about the differences between those values and the reason why these were considered as important.

- The most common subjects that were discussed were translated to core values with help of a ‘value-cheatsheet’ from the method ‘Brand the Change’ (Miltenburg, 2017). This cheat-sheet was used to create recognisable expressions of the identified values. These values are listed on the left of image 26.

- In order to identify value clashes within the stakeholder-network, other involved stakeholders were determined (large-scale stakeholders, with this is meant: established organisations or enterprises with over 15 employees) by exploring the established large-scale seaweed industry from alginate production reports (McHugh, 2013).

- The most important interactions among all stakeholders were explored and simplified visualized in image 26 with the black arrows. Specific interactions are visualized in Appendix G: stakeholder interactions.

- From the interaction-overview and the previous conversations with stakeholders, an estimation is done on the values of large-scale stakeholders (image 26 on the right) and the value clashes between small-scale and large-scale stakeholders (image 26, in the middle).

- These values and clashes are put to discussion with stakeholders in the field to check its correspondence.

In this chapter, the different roles of small-scale entrepreneurs that want to scale up are described and visualized (image 26, left). On the right side of image 26, other involved stakeholders are illustrated. These are stakeholders that are involved in the development of the seaweed industry but are more established institutes/businesses. Then, identified core values are described and small-scale values are compared to large-scale values. Expected value clashes that can derive from this are described.
2.3.4 Roles of the stakeholders

Roles of small-scale entrepreneurs in the Dutch seaweed industry concern firstly the development of local seaweed farms and pilots for production of seaweed in the Netherlands. Secondly, there is the role of ‘bio-hacking’, with this is meant: experimenting to control and manipulate bio-matters, with seaweed as a basis. The next role concerns the design of materials, products or food to generate applications and therefore add value to the seaweed. Lastly, a role is to put the products in the market, by starting up businesses as entrepreneur. Most stakeholders fulfill multiple roles. For example, designers, as well as seaweed farmers, are also entrepreneurs within other fields of the seaweed industry than their own core activity.

Roles of large-scale stakeholders concern firstly the development of policies in governmental organisations, these policies interact with stakeholders inside the field but also integrate with other industries. Secondly, research is done on bio-matters and impact, which influences policies and transitions within industries. Thirdly there exists the role on a large scale of sourcing (wild sourcing) and preparation of material by industrial refineries (this is done on European or global scale). Then there is the role of creating & maintaining business, often done by investors searching for new techniques and products. Lastly there is the role of producing (done by larger production facilities, which are often based abroad).
2.3.5 Small-scale values

The ideology that drives the stakeholders forms the basis of their core-values. Among the interviewed small-scale stakeholders there was the desire to realize a change within the current economic and environmental condition. Important values that can be linked to this desire are sustainability, transparency of resources and sharing of knowledge. Often is strived for a low eco-impact through generation of focused solutions concerning materials (safe, biodegradable, recyclable, renewable or circular), producer responsibility and education. An important business-related value here is growth through scaling up, because this way impact can be enlarged. What is valued within the method of realizing a change, is disruption and challenging of the current situation. Within the attitude towards change, independence is valued to make the decisions that are required for this disruption. Within these business decision-making, intuition is valued, in order to make decisions that feel as the right thing to do.

2.3.6 Large-scale values

For large-scale stakeholders, sustainability is a core value as well. The difference is that the desired impact is not driven by growth and disruption, but by the need for durable transition through regulation. Integrated solutions are valued over focused solutions, whereas the solution needs to fit multiple levels or agenda’s in the corporation. Whereas small-scale stakeholders have much freedom of movement, large-scale stakeholders are therefore more restricted through complex decision-making where rationality is valued over intuition. Business related values here are accountability and a reduction of risk. Whereas transparency and sharing are valued by small-scale stakeholders within business activities, large-scale stakeholders value the building and protection of expertise to maintain a competitive advantage (image 27, right).

Image 27: Small-scale values (left), large-scale values (right) and value clashes (triangles)
2.3.7 Value clashes

Focused solutions vs. Integrated solutions
Where focused solutions are likely to be very promising and effective for environmental impact, they might not be implemented because they can be difficult to integrate in fitting corporate agenda’s or infrastructures. The other way around, integrated solutions often miss strength of the initial idea because of the compromises that came with integration.

Disrupt & challenge vs. Reduction of risk & accountability
The values that are conflicting as well concern the attitude of stakeholders, whereas among small-scale stakeholders disruption/challenging is valued and among large-scale stakeholders an attitude of accountability and risk reduction is valued.

Independent decision-making vs. Justified & accepted decision making
Empowerment of a project is considered as the start of the value chain, since the start of new industries and therefore new value chains requires support. Whether it concerns a research subsidy, starting capital, or network activities. The clash that can occur, concerns a difference in what drives the stakeholders to make decisions. Small-scale stakeholders are often driven by intuition (doing what works and feels right) and have much freedom of movement within their decisions, in which independent decision-making is valued. Large-scale stakeholders as supporting organs have way less freedom of movement and decisions need to be justified: impact needs to be proven. Through the absence of yet existing proof in this emerging field, receiving support is often een opportunistic process. Finding the balance within this contradiction requires much time and resources that are lost for the actual development.

Growth through scaling vs. Transition through regulation
A second clash can occur within ideas how changes should be made. Where small-scale stakeholders want to increase their impact through scaling up a focused idea/product, large-scale stakeholders often want to adapt their existing products stepwise towards an alternative.

Sharing of knowledge & transparency vs. Building & protection of expertise
Based on idealistic values, many small-scale entrepreneurs require transparency from industries they are working with. After all, one of the common core values is to have a low eco-impact, but this must be visible. A change within producing industries is desired here. This clashes with the established industries, because their competitive advantage is built on confidentiality. Because they work on a larger scale where competition forms a larger threat, protection of their expertise and resources are important. The established industries have to change radically to become transparent, which is a slow process with advantages that are difficult to see from an industries perspective. Therefore, the advantages of transparency need to be highlighted and alternative methods of competitive advantage need to be explored.

Conclusion
With values and value-clashes identified, a design challenge can be formulated on how to generate opportunities for a material business in a way that value is added, original values are guarded and value clashes are taken into account. The most important value clashes to take into account are between focused solutions and integrated solutions, between growth and transition, transparency and protection, disruption and risk reduction and independence and acceptance. In chapter 3.3, opportunities are proposed on how to to cope with these clashes.
2.4 Scaling strategies

2.4.1 Goal

Scaling up can be seen as a part of maturisation, because it makes the material accessible to a larger group of consumers. In this analysis strategies of scaling are explored. This concerns research question 2c; which scaling strategies are visible within the industry. Research question 2d (how to deal with material exploitation) is used as argumentation to choose for a suitable strategy.

2.4.2 Approach

To retrieve a viewpoint and insights on the strategies that are happening within the industry asks for multiple approaches to connect the dots between theory and practice. In-depth conversations were held with product designer Nienke Hoogvliet, the founder of Zeewierboerderij IJmond/product designer Nikki Spil and with a producer of seaweed fertiliser/developer of a biorefinery Dirk Jan Vos. In these conversations was talked about how the development of seaweed products is going and how scaling up will be possible.

Through stories within the field there were different strategies visible for scaling up which are defined within the report as ‘Step-by-step’, ‘Hitch-hiking the Industry’ and ‘Local Global’. These strategies are compared with theoretical scaling strategies used for agricultural innovations (which is best comparable with seaweed innovation), strategies from a Startup culture and from local production through AM.

Factors that are important when choosing a strategy are firstly the space for the small scale values of the entrepreneur, the speed of the scaling-up process and the risk of exploitation of seaweed as a natural source. The first two factors derive from the project objectives, the last one comes from an older prediction saying that all the efforts to stimulate the use of seaweed as a material through modern biotechnology are very promising, but it has been already long predicted that it will also be a serious threat to industrial exploitation of seaweeds (Jensen, 1993).

2.4.3 Strategies

1. Step-by step

What is broadly visible, is that designers/entrepreneurs develop their technique/material until it is workable and design a product that is feasible to realise on a small scale. This is used to gain interest, feedback and support to develop the material further. If the material is a succes, the next step is to make the material suitable for higher scale production. The step after, is making it suitable for mass production. This is for example visible at Ooho (see appendix B: Benchmark analysis) and Zeewierboerderij IJmond.

This approach shows overlap with the concept of ‘linear scaling’ within agricultural innovations (Wigboldus, 2016). Here, the ‘scaling phase’ is regarded as a phase that comes after ‘figuring out the technique’ (see image 28). After the scaling phase, comes the implementation of applying the technique elsewhere (see image 28). Every entry of a market or an enlarging a market requests for adaptations within the product and organisation to match.

Linear scaling approaches that can be seen in practice within the agricultural sector, are often struggling to grasp complexities that are involved in scaling processes. On a small-scale, technologies and practices can be perceived as sustainable and inclusive, but can have undesirable effects on a larger scale, or under different ecological, geographical or political conditions (Wigboldus, 2016).

Image 28: Step-by step scaling

2. Hitch-hiking the industry

Another strategy is to look for support from investors of larger industries. Certain companies can adopt the idea and help developing the material from the industrial perspective. To gain attention from these companies, the material has to be controllable enough and suitable for certification. This is a trend that comes together with the growing start-up culture. More and more companies invest in start-ups trough accelleration programmes, hackathons, start-up competitions, or EIR (Entrepreneur in Residence) or through direct collaboration (Rao, 2015). In the seaweed-world this is visible for example in the project of Tjeerd Veenhoven that is adopted by H&M (Tjeerdveenhoven.com, 2018) or a fabric spinning factory that intended to
By 'hitch-hiking the industry' (see image 29), the process can suddenly go really fast. The small scale entrepreneur does become dependent on the industry and values can conflict between the different stakeholders (see value analysis in chapter 2.3). These clashes occur mainly because the entrepreneur needs to adapt his values to an existing industry, which often is an industry that is required to change.

The local global strategy makes it more difficult to design one specific product for a specific user, because the context is changing, but it makes it possible to design a base-product for multiple locations. The large advantage of this strategy is that the risk is low concerning consumer adoption (if one location does not work, the venture does not have to fail). The scaling-up process is furthermore independent from large investments for industrial production facilities, transport and distribution and can therefore stay transparent and in control of the entrepreneur with a faster scaling-up process.

If production methods allow, a strategy can be to produce locally and expand production locations globally, called local global (image 30). Additive Manufacturing (AM) is a production method that can stimulate local production and which is easily translatable to other locations (Sauerwein, 2017). Luma, an algae lab in Arles, applies this strategy by 3D printing algae compounds (Atelier-Luma, 2018).

The quick development of AM technology enables a shift from globally spread production to more local production models and describes the consequences of this (Jiang, 2017). Interesting for this project is that the competitive advantage of these strategies will shift from manufacturing and supply chain capabilities to accessibility to customer and designer networks. Also, intellectual property will change through this and new forms of intellectual property will become more important. For example Open Source or Creative Commons (Jiang, 2017).

Conclusion

Applying a local-global strategy, the large advantage is that the scaling up process is more flexible, which results in less risk concerning consumer adoption. Furthermore, the entrepreneur is independent from large investments and has the control to maintain its small scale values. The difficulties here, and therefore can be regarded as a design challenge, are intellectual property, as well as that a product needs to fit multiple locations. Designing with seaweed, it should be regarded that resources are taken care of and only go for accessible resources.
2.5 Stakeholder acceptance

2.5.1 Goal
This analysis concerns the communication regarding the seaweed material, the material-strategy and products from seaweed. The goal is to be able to tell the right story to the right stakeholder, concerning research question 3: what and whom to convince.

2.5.2 Approach
The first step of this analysis is to explore the interests of the involved stakeholders. These interests are based on the stakeholder’s business activities that were discussed during the interviews in the analysis on stakeholder values (chapter 2.2). The second step is to create a format in which these interests can be addressed. Narratives can be a useful tool here, since they communicate and they can be a useful element with a maturation strategy.

2.5.3 Stakeholder interests

Consumer
The consumer is the main stakeholder to convince the benefits of seaweed products. The story that needs to be told to the consumer mainly concerns the product: its functional advantage (whether it contributes to the consumers well-being or ease) and economic advantage.

Seaweed farmer
Since seaweed farming in the Netherlands is still a starting business, the seaweed farmer will have most interest in approachable markets. Therefore an horizon of markets and product are interesting for this stakeholder. This covers market sizes, expectations on market growth and the viability to provide cultivated material for the concerning market (what is the added value).

Bio-refinery
Since the bio-refinery needs to create a viable process, the interest goes primarily to the possibilities to add value to the waste-material from its process. Also, the market horizon is interesting for this stakeholder, since it contributes to scaling up the bio-refinery industry.

Designer
Designers, artists, engineers want to know what the possibilities are of the material, what the characteristics are and how to apply them in their design.

Entrepreneur
Small scale entrepreneurs need to know the market horizon to be able to decide to enter the field. Because they are the risk-takers, there is interest in information on the risk, possibly in the form of a risk analysis.

2.5.4 Narrative format
Within this project, a new market is targeted together with a new technology. This means that there is the possibility to experiment with new technology and create new applications, while also creating new market categories (Zurlo, 2014). A narrative format that fits here could be an ‘explorative narrative’. The function here can be to create a platform that allows different narratees to actually participate in the story and prototype to represent different evolved interest (Zurlo, 2014).

Government
The government will have interest in the impact horizon, concerning the environmental, social and economic impact, currently and in the future.

Research
Research is interested in new research areas (knowledge gaps) and in data of the use and impact.

Wild sources
Wild sources as harvesters of seaweed plagues, are interested in the possibility to add value to the material. Also, they need to know what requirements are needed for the seaweed material in order to add this value.

Investors
Investors are interested in the horizon of seaweed products. What is seaweed in 20 years and how is this horizon worked towards to?

The industrial refinery
The desired message to deliver to the industrial refinery concerns the advantages of transparency and the future of bio-methods of refinery. What the industry is interested in is the horizon of seaweed (up-scale) markets.

Production facilities
Up-scale production facilities are interested in proven material characteristics and the material's behavior, in order to reduce the risk to experiment with production.

Retail
Retail is interested in consumer responses on earlier prototypes, to reduce risk. Also, the market horizon is important to assure that there is a market for the given retailer. Also, branding/storytelling is important for the retailer.
Conclusion

There are many sides of the story around seaweed products. A design challenge will be on how trust in the seaweed industry can be gained by telling the right story on the right time to the right stakeholder. The format of storytelling will be explorative, by creating a platform that allows different narratees to participate or be integrated in the story to represent different evolved interests.
3. CHALLENGES OF MATERIAL MATURATION

3.1 Introduction to challenges

3.2 Material controllability
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   3.2.2 Approach and tools
   3.2.3 Material composition selection
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3.3 Multiple context fit
   3.3.1 Goal
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   3.3.3 Context overlap
   3.3.4 Context differences

3.4 Create space to guard values
   3.4.1 Goal
   3.4.2 Approach
   3.4.3 Inspirational principles
   3.4.4 Opportunities per value clash

3.5 Timing of stories
   3.5.1 Goal
   3.5.2 Approach
   3.5.3 Stakeholder interests & readiness

Image 32: Material design tests
3.1 Introduction to challenges

Coming from the analyses, the main challenges are identified.

The first challenge, deriving from the material-analysis, is to improve the controllability of the material. In the material-analysis was concluded that there is a split in approaches visible: working with the raw material and working with the industrial material. This split was also visible in the benchmark analysis. Each approach has its own advantages and constraints (see the conclusion of analysis 2.2). Within this challenge, it is regarded on which approach the focus will lie on, by comparing the impact of the different approaches. Based on this impact, a new material is composed. Then, controllability of this material is improved through material tinkering iterations. This exploration results in opportunities and challenges in the present and in the future.

The second challenge, deriving from the strategy analysis, is to fit a product concept in multiple contexts. In the strategy-analysis was concluded that a local-global strategy seems to be a fit approach for material development since it facilitates a transparent scaling-up process, where values stay in more control of the designer. The difficulty concerning this strategy is the change of contexts, that requires different design features and implementation strategies. Within this challenge, it is explored how the complexity of this changing context can be integrated with the design/strategy. This is done by the guidance of the Context Variation by Design method (Kersten, 2015). The results point out possibilities and challenges in the present and in the future, mainly concerning interesting markets and accessible resources.

The third challenge, deriving from the stakeholder value analysis, concerns coping with value clashes between stakeholders. Within the value analysis, small-scale values were explored and constraints within value exchange between stakeholders were pointed out. Within this challenge, it is explored how the right circumstances can be created to guard values. This results in a list of principles that are applied in the further roadmap.

The last challenge concerns the timing of stories, to be able to tell the right story to the right stakeholder, to build acceptance. In analysis 2.5, which concerned the stakeholder acceptance, the main important interests of the stakeholders are explored. Within this challenge, it is defined which stories can be told right away, and what researches need to be done to convince other stakeholders in the future. This results in elements of a storytelling strategy.
Figure 33: Four identified challenges
3.2 Challenge 1: A controllable material with a positive impact

3.2.1 Goal
The goal of the challenge is to cope with material controllability, in order to fill the gap between uncontrollable raw material and intransparent industrial material. This controllability is of importance within the development of a material that can be reproduced on a larger scale while guarding the small-scale advantages of a low eco-impact (See analyses 2.1 and 2.2).

3.2.2 Approach and tools
- First, a new material composition is developed that is estimated to have the highest possible viability together with the lowest possible impact. This is done by firstly looking at the overall impact of different approaches. Because a complete impact analysis will not fit the time scope of this project, a Harris Profile (Roozenburg en Eekels, 1998) is used to gain insights on the strengths and weaknesses of different scenario’s. This tool is adapted by instead of using criteria to evaluate different concepts, argumentations are used in order to evaluate material scenarios. This way the tool can function as an argumentation framework and provide decision guidelines.

The scenarios are based on three materials: industrially extracted alginate, a seaweed waste-pulp from the bio-refinery (with alginate content) and a mix of the two materials. The first material (extracted alginate) is experimented with in analysis 2.2. The principle of the second material (seaweed waste-pulp from the bio-refinery) is experimented with too, only now it is chosen to use raw material that is a waste stream from a bio-refinery instead of a raw material. This has less impact on the environment and is economically more attractive (D.J. Vos, personal communication, April 4, 2018). The third material is added to the assessment later, because the first two materials showed quite opposite results.

Because alginate as an extract, the first material, is the only currently mature one, an LCA-review of this material is used (Langlois et al., 2012) and compared with other literature, to be able to form a scenario. The two other scenarios are based on assumptions regarding the differences (Appendix I: impact arguments).

The scenarios are difficult to compare because their advantages and constraints are spread over different fields. Therefore the different arguments that are considered as most important (these arguments derive from most impactful factors from the alginate LCA of Langlois et al. (2012), the project objectives and stakeholder interests) are divided into impact categories concerning eco-impact, upscale feasibility, impact on acceptation and small-scale feasibility.

The scenarios are scored on their expected impact on the different categories (see image 35, page 45).

In 3.2.4 and 3.2.5, the set-up for material tinkering tests to explore the controllability of the material is introduced. and the parameters are explored that influence the controllability of the chosen material. Within the tinkering tests, the main steps were set up the same: multiple samples were made with varying parameters, from which the best options were chosen to continue on. Along these steps, other insights were retrieved as well, like the influence of water temperature, how to minimize scent and improving the pressing techniques. An overview of these tinkering steps can be found in appendix J: tinkering part 2.

- In 3.2.6, the found material characteristics are described of the base material.

- In 3.2.7, present and future challenges and opportunities concerning this material and its process are identified.
Image 34: Pure alginate extract (left) and a mix of alginate extract with refined seaweed pulp (waste from bio-refinery)
The image shows that concerning the environment and material acceptation, scenario B has the most positive impact. The bio-refinery process that creates this material makes no use of chemicals and the process functions at room temperature, which lowers the energy use for heating and cooling, there is no waste-water and the process generates clean water (D.J. Vos, personal communication, April 4, 2018). In contrary to this process, the industrial extraction process of alginate (scenario A) will relatively have most impact concerning the use of chemicals and the use of electricity, next to heating & cooling, wastewater, water treatment and use of fresh water (Langlois et al., 2012) (Appendix H). Because of the use of chemicals for the extraction, used water gets contaminated.

The downside of scenario B is that currently, the feasibility is very low: there are not many small-scale resources available as knowledge, tooling and controllable processes. Another important argument is that there is no raw material accessible for large scale. It will either be harvested (which is undesired for large scale) or cultivated (currently not viable yet).

For up-scale feasibility as well as small-scale feasibility scenario A would have the most positive impact. This is mainly for the accessibility of resources and a mature industry (see appendix H), as well as a more constant, controllable material (see analysis 2.2). Because of its up-scale feasibility, it could have an overall larger environmental impact compared to the plastic industry than scenario B. The disadvantage is that the processes will stay intransparent (see analysis 2.5). Being a value clash with other stakeholders (chapter 2.3.7), this scenario scores low on ‘acceptation’.

Scenario C has less extreme values but shows an overall positive impact. The material mediates between opposites concerning technical and value solutions, which makes it communicative. It uses the global resources of scenario A, that creates more up-scale possibilities. By being transparent about the mix of the material and the differences in impact, it can contribute to acceptance (See analysis 2.5) The only large constraint (for each of the scenarios) is the low-scale feasibility. This is a temporary constraint because it concerns resources, that are arrangable. Therefore, it is chosen to design with a mix of alginate extract and the waste-pulp of the bio-refinery.

Theoretically, the waste stream is more controllable when alginate is added as a binder (scenario C). But being a new material with a specific process and development, this controllability needs to be explored within its own process.
Table 1: Arguments for impact: scores by evaluation of different material scenario's

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scoring scale</th>
<th>A: Alginate</th>
<th>B: Bio-refinery waste</th>
<th>C: Mix (A+B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-2</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>1. Eco impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Upscale feasibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Acceptation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Small-scale Feasibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Image 35: Assessment of material-scenario's on estimated impact

- 2 red blocks: large disadvantage for positive impact
- 1 red block: disadvantage for positive impact
- 1 green block: contribution to a positive impact
- 2 green blocks: large contribution to a positive impact
3.2.4 Tinkering set-up: sheet pressing

For the material consisting out of a mix of the alginate extract and the waste pulp, the parameters that influence the controllability of the material are explored through material tinkering (see Appendix E, test 7,8,9). Within this tinkering, experiments were set up to find the differences between proportions of the ingredients, pressing temperatures, thickness variations and the influence of pulp preparation.

For tinkering, the same process is explored, which existed out the following base steps; mixing the ingredients, pressing the material into sheets, and drying the material.

The used ingredients are refined pulp from Irish Ascophyllum nodosum, sodium-alginate (see Appendix I and J for material information sheets of the pulp and sodium-alginate) and tap-water from Delft/Rotterdam. Later in the process, glycerol was added since it is a common ingredient to use as a plasticizer for starch-based bio-polymers (Ortega, 2016) and could be of value as well for alginate-based bio-polymers. In practice, it appeared to reduce brittleness of the material and was therefore integrated in the composition of the material. For pressing, a kitchen-grill was used, while when more controlled parameters as pressing thickness and temperature were to be tested, a transfer-press was used (image 36).

3.2.5 Controllability parameters

Along the tinkering process, more parameters came to the surface as the order of adding ingredients, the time of pressing, the influence of water temperature, the effects of shape, preparation of the ingredients and the effects of glycerol. All found parameters derived from tinkering are described, and can be used as guidelines within design and production of the material for more specific applications later in the project.
Pulp preparation
In preparing the pulp, the wetness and the courseness of the pulp are of influence. Pulp that is too dry, is not suitable to use, since it seems to absorb all water that the alginate needs for its reaction, disturbing the process. When using pulp that is too wet (oversaturated) the material does not form as a whole, but forms local material connections. Course pulp creates a non-uniform material with a rough surface, which profits from stronger alginate bindings and suffers from weak areas of concentrated pulp. Fine pulp creates a more uniform material with a smoother surface, with slightly weaker, but more uniform alginate bindings. Thirdly, the smell and color of the samples can be neutralized by washing and sieving the pulp before pressing (image 37).

Order of material ingredients
The order of mixing the ingredients is essential, whereas the start of the reaction should be delayed to the end, in order to create a uniform mixture.

Proportions
A range of proportions of the ingredients is possible. This range is mainly influenced by pulp preparation and product size and it influences the material costs and technical characteristics (see chapter 3.2.6: material characteristics). Basically, a larger proportion of pulp creates a cheaper material, which is more brittle, with a shorter processing time and less water resistance. A larger proportion of glycerol creates a more flexible material, with a longer processing time and more water resistance. The proportion of alginate is desired to keep as low as possible, to have the lowest eco-impact and lowest material costs.

Water temperature
Since the gelling of alginate is an endothermic reaction, using colder water slows down the reaction and using warmer water accelerates the reaction.

Water hardness
The hardness of the water defines how much calcium and magnesium is in the water. Water that is too poor of calcium, inhibits to create the potential amount of material connections. Water that is too rich of calcium, should theoretically not be such a problem, but it does make the mixing-step more difficult, since the reaction seems to be started more quickly and there is less time available to work with the material.

Pressing temperature
Within the material tests, experiments are done of pressing the sheets in a heated press with a range of 15 degrees C - 170 degrees C (image 36). Pressing under higher temperatures, has the advantage that the reaction is accelerated, once the material is in its desired shape. Therefore, pressing on high temperature demands a short pressing time. Also, the material showed less deformation in the drying process. Lower temperatures demand more reaction time (therefore more time in the press) and more support of the shape throughout the pressing and the drying process.
From the influencing parameters that are explored, a base material can be composed. This material can be adapted according to the parameters again, when using within the design for more specific applications.

The designed material serves a renewable, bio-based and bio-degradable basis for a range of materials. It consists of refined seaweed pulp from brown macro-algae, with a binder from sodium-alginate and glycerol. Image 38 shows the material, this sample is a sheet of 4 mm thickness.

The following specific characteristics are defined:

Feel
The material has a rough texture with a soft and warm feel.

Scent
It has an apparent odor which is a mixture of sea and soil.

Impact resistance
As a sheet material, it has a poor resistance to bending impact (Appendix J).

Water resistance
The material has slow water absorption and is lightweight. This makes it float for a couple of minutes on water before sinking. The materials’ chemical structure connections are water resistant, meaning that after absorption and drying, the material has the same strength (Appendix E, test 11).

Flame resistance
The material has a low flammability and a flame retardant character (Appendix E, test 10).

### 3.2.5 Base material characteristics

**Pressing time**
Pressing too long in a heated press, makes that the moisture inside the material evaporates too quickly, creating cracks in the material. When pressing too short, the material has not formed all its connections yet and will be separated when opening the press. This relates closely to the pressing temperature.

**Material thickness**
The thicknesses of the sheets that were experimented with had a range from 2 mm to 10 mm. The thinnest sheets resulted in very fragile samples. The thicker sheets were stronger samples, but were more difficult to press (this required a mixing-material with a higher viscosity to support the shape). Also, the thicker sheets require a longer drying process, that can form more risk of occurring cracks.

**Material shape**
Round shapes result in less waste (since the press creates round shapes) and due to the brittle character, this shape damages less quickly. Also, three-dimensional forms seem to be less prone to damage.

**Drying environment**
The material dries in about 4-5 days. Within this time, it shrinks around 15-20% (this depends on the proportions). Slow drying of the material (on room temperature) creates results in less cracks and deformation in the material. Also, air flow on both sides of the material is important, to avoid shrinkage stresses.
3.2.6 Opportunities and challenges

Present challenges and opportunities

An opportunity for plant growth
The used seaweed *Ascophyllum nodosum* contains nutritious values of potash, calcium, magnesium, zinc, copper, iron and cobalt (appendix K: material sheets). Also, the seaweed extract alginate is characterized by slow absorption and release of water (see 3.2.5) while maintaining its internal connections. Because of this, alginate functions as a stabilizing colloid and can regulate water within the soil (Stephenson, 1963). These characteristics make the material suitable for applications for plant growth, covering a large part of the needs concerning nutrient and water regulation. Therefore a market opportunity lies in the agricultural sector whereas the product’s characteristics contribute to plant growth (nutrients and water regulation) and natural scents are more easily accepted in this sector.

Coping with odor, fragility and reproducibility
The present challenge is to cope with the odor and the fragility of the material and to reproduce the same product on a large scale.

Future challenges and opportunities

An opportunity as a packaging material
A more future opportunity is that the material is resistant to pressure impact, it is completely bio-based and has the potential to be food-safe. Therefore it could be a suitable material in the future for (food)-packaging.

Coping with stronger regulations and more complex production methods
Having an apparent odor and a poor bending resistance, the material needs much more development, which can be a time-consuming process. Also, the requirements for packaging (especially food-packing) are even more strict and will require many tests, money and time.

An opportunity to become independent from industrial alginate
The future material is desired to be made with all ingredients from a bio-industry. If the alginate that is in the seaweed could perform the reaction as the extracted alginate does, the material has the least impact. This will be a promising opportunity, but requires a research investment as well.

Further future challenges and opportunities

An opportunity as a safety material in architecture
The material is flame retardant (see 3.2.5), and has the potential for good acoustic and thermal qualities (D.J.Vos, personal communication, April 25, 2018). This means that it could add value within architecture.

Coping with regulations and complex production methods for safety material
The challenge here is that the product sizes are larger, which results in a more complicated production process. Furthermore, the building-industry has strict regulations, which require very specific knowledge of the material’s content and its behavior in possibly dangerous situations. This information is not available yet, so time is needed for concerning research.
As a material composition it is chosen to work with a mix of a waste-stream pulp from the bio-refinery and an industrial alginate extract. This composition is chosen because this scenario showed an overall positive impact. It has a positive environmental impact, while having access to up-scale opportunities.

Through material tinkering, a base material is composed that consists of a waste pulp and a binder of alginate and glycerol. For this material, the characteristics are described concerning the feel, scent, impact resistance, water resistance and flame resistance.

The parameters that influence the material characteristics and the process are described as well, which concern the preparation of pulp, the order of ingredients, proportions of the ingredients, water temperature, water hardness, pressing temperature, pressing time, material thickness, material shape and the drying environment.

Conclusion

From the material characteristics, present and future opportunities and challenges are defined. These are listed below as [M] (from Material):

[M1] A present opportunity is that the material can be valuable for plant growth, because it covers a large part of plant's nutrients needs and alginate has the ability to function as a water-holding agent.

[M2] Present challenges are to deal with the material's odor, fragility and reproducibility on a large scale.

[M3] A present market fit can be within the agricultural sector.

[M4] A future market fit can be within the building industry, because the material is flame retardant and has promising acoustic qualities.

[M4] A future challenge is to know the specific content and the materials behavior in dangerous situations.

[M5] A further future market fit can be (food)-packaging, because the material is resistant to pressure impact and has the potential to be a food-safe material.

[M6] A further future challenge will concern strict packaging requirements and the material's low bending resistance.

[M7] A further future (environmental) challenge will be to improve the material's process of alginate extraction towards a more bio-friendly one.
3.3 Challenge 2: 
Multiple context fit

3.3.1 Goal
The goal of the second challenge is to integrate the complexity of a changing context into the design/strategy by gaining insights into the differences or overlap of different contexts. This will be of importance when applying a local-global strategy (see analysis 2.3). The content of seaweed differs per location, so does the context. If the product is meant to be scalable, it is necessary that the product is easily adaptable and fits multiple contexts.

3.3.2 Approach and tools
Most design approaches are based on one specific context. In later stages, when scaling up, the solution has to be translated to a new context which comes with a larger or different consumer market and with new stakeholders. This is a time-consuming and complex process. Applying the philosophy and some tools from the method Context Variation by Design (CVD) (see Method, chapter 1.4), more insights are created in an earlier stage in the design process. These insights concern the suitability of translating a base solution between different contexts. One of the goals of this method is to shorten the TTM (Time To Market) and have a more cost-efficient scaling-up process (Kersten, 2015). This contributes to the main objective of this project that concerns the maturation of the material.

Through taking several steps of the Context Variation by Design method (Kersten, 2015), possible differences and similarities between the two contexts are explored. These are translated into the present and future opportunities and challenges. Having these insights, it is possible to specify the strategy towards a future goal and choose an opportunity to design for.

The first context is in the Netherlands (in and around the North Sea), the second context at St-Maarten (Caribbean). These contexts are chosen because they show accessible resources concerning seaweed and knowledge, and therefore are logical as a starting point. They show large differences at first sight and are therefore an interesting couple for applying a CVD-approach.

For each context, insights are retrieved within fields of the context's environmental situation, seaweed situation, community culture, business culture and available resources.

These insights are combined to identify overlap and differences and retrieve opportunities from.
Image 42: Map: Atlantic Ocean (wikimedia.org, 2018) with the context locations Sint Maarten and The Netherlands.
3.3.3 Context overlap

After insights were retrieved from both contexts, the contexts were compared. This resulted in the following context factors that both contexts seemed to have in common:

1. Plastic Problem
Both contexts have a plastic problem and an immature recycling system. At Sint-Maarten, there is no recycling system, which is a large problem for public health (Van den Dool, 2018). In the Netherlands, there is a recycling system but it is yet too complicated (H. Spek, personal communication, December 11, 2017). There is awareness of the need for change, but the transition towards a system that is designed on recycling, will be a slow process.

2. Desired independency in consumerism
Within the market segment that is targeted in the Netherlands, people are looking for a more communal and independent way of consuming. This is strongly visible in the growth of a tiny-house movement within the Netherlands. A larger demand for natural building materials is expected, since larger building companies are also responding to this trend (Voor de wereld van morgen, 2018). At Sint-Maarten, it is not a trend but there is a strong need to empower citizens to build their own houses with accessible and safe materials (P. van der Veen, personal communication, May 23, 2018).

3. Start-Up culture
Both contexts have a need to empower start-ups (in businesses that do not concern tourism). The government wants to stimulate this.

4. Agriculture
Seaweed is very well applicable as a fertilizer in the bio-agriculture industry. In the Netherlands there is the need within agriculture for environmentally friendly products. At St-Maarten, there is the need to develop an agricultural sector, since currently almost all fruit and vegetables are being imported, making these of low quality and accessibility. The difference is the market size, whereas the market size at Sint-Maarten will be a small, while in the Netherlands it can be a larger market which is more easy to extend to a European market.

5. A need for independence
For the Dutch context as well as on Sint-Maarten, independence of external resources is convenient or even necessary. In the Netherlands, this independence means that it is easier to build Intellectual Property and therefore maintain a competitive advantage. It also means that an entrepreneur can be less dependent on funding. At Sint-Maarten, this independence is also very important whereas all resources need to be imported which makes them expensive.

3.3.4 Context differences

1. Connection with environment
Sint-Maarten is sparsely populated, surrounded by ocean and beaches. Habitants live relatively close to nature. At Sint-Maarten the environmental problems (like plastic pollution and seaweed plagues) are clearly visible. People might be willing to do something about it, but generally have other concerns that have priority, like safety, housing, and healthy food.

The Netherlands are more densely populated, which can result in more distance to nature. There is a motivation among people to do something good for the environment, but the environmental problems and the impact are hard to see, which demotivates to take action.

2. Import/export
As an island, Sint-Maarten has less access to resources. Also, imported ingredients are more expensive. In the Netherlands, there is more access to resources as has a more favorable trading position.

3. Seaweed availability
At Sint-Maarten, the accessible seaweed is a plague which makes it an abundant source. In the Netherlands, seaweed is imported from other European countries or even from Asian countries or it is cultivated in small numbers.
**Image 43:** Context overlap (top) en differences (down). Left photo: cultivation experiment in NL by Stichting Noordzeeboerderij (Noordzeeboerderij, 2018). Right photo: Washed ashore Seaweed from the Sargassum plague at Sint Maarten (Photo by P. van der Veen).
same techniques could be used for extracting fertilizers from the seaweed, which creates a closed circle of nutrients at St-Maarten and improves the situation of overnutrition of the ocean. (based on overlap 4).

A current and future challenge is to deal with the differences in access to resources of the different contexts. Because there is a need for independence of external resources in both contexts in the start-up phase (overlap 5 and difference 2 and 3), a start with accessible resources is desired. In the Netherlands there is better access to production resources, while at Sint-Maarten there is better access to seaweed. A current opportunity is to combine both resources and a future challenge is to prepare both locations for local accessible resources.

A present challenge is to deal with the differences of consumer drivers to buy sustainable products and the differences between the visibility of the impact of their actions (difference 1). An opportunity here can be to let the contexts influence each other positively, through making impact visible one way and making alternatives to plastic economically accessible the other way.

A future opportunity will be to close the loops of seaweed products in industrial circular processes for plastic. These are not mature/ do not exist yet in both contexts, but are in development (overlap nr 1). Therefore it will not add direct value now, but future seaweed loops can be adapted to them beforehand.

A nearby future opportunity is to share techniques of communal house building between the two contexts. There is a need for accessible natural building material in the Netherlands and a need for local and therefore affordable material at St-Maarten. Seaweed could fulfill both needs. This is based on the common context factor that there is a desire for independency in consumerism for building of houses (overlap 2).

A current opportunity is that the start-up culture and start-up programmes that connect entrepreneurs at St-Maarten and the Netherlands can connect the contexts in a seaweed project. This is based on overlap 3, that points out the the desire to empower start-ups in both contexts.

A present opportunity is that seaweed extracts can be used as a fertilizer in the bio-agriculture industry, since there is a market for this in the Netherlands as well as on St-Maarten. The

Conclusion

[C1] A future opportunity will be to close the loops of seaweed products in industrial circular processes for plastic. These are not mature/ do not exist yet in both contexts, but are in development (overlap nr 1). Therefore it will not add direct value now, but future seaweed loops can be adapted to them beforehand.

[C2] A nearby future opportunity is to share techniques of communal house building between the two contexts. There is a need for accessible natural building material in the Netherlands and a need for local and therefore affordable material at St-Maarten. Seaweed could fulfill both needs. This is based on the common context factor that there is a desire for independency in consumerism for building of houses (overlap 2).

[C3] A current opportunity is that the start-up culture and start-up programmes that connect entrepreneurs at St-Maarten and the Netherlands can connect the contexts in a seaweed project. This is based on overlap 3, that points out the the desire to empower start-ups in both contexts.

[C4] A present opportunity is that seaweed extracts can be used as a fertilizer in the bio-agriculture industry, since there is a market for this in the Netherlands as well as on St-Maarten. The

[C5] A current and future challenge is to deal with the differences in access to resources of the different contexts. Because there is a need for independence of external resources in both contexts in the start-up phase (overlap 5 and difference 2 and 3), a start with accessible resources is desired. In the Netherlands there is better access to production resources, while at Sint-Maarten there is better access to seaweed. A current opportunity is to combine both resources and a future challenge is to prepare both locations for local accessible resources.

[C6] A present challenge, is to deal with the differences of consumer drivers to buy sustainable products and the differences between the visibility of the impact of their actions (difference 1). An opportunity here can be to let the contexts influence each other positively, through making impact visible one way and making alternatives to plastic economically accessible the other way.
3.4 Challenge 3: Create space to guard values

3.4.1 Goal

In analysis 2.4 is identified what value-clashes can occur between stakeholders. In this chapter, several opportunities are explored on how to cope with these clashes.

To generate a general solution to the identified value clashes can turn into a blunt result when applied to specific cases. Therefore, the value clashes are most valuable to use as general insights. Despite this, it will be interesting to look if it is possible to integrate the values in an overall strategy to facilitate the right circumstances to consider and cope with value clashes.

3.4.2 Approach

- For each value clash (see image 27 in analysis 2.3), ideas are generated on how this clash can be turned into an opportunity. These ideas come forth from strategies/approaches from existing companies/organizations/speakers that inspired me during conversations, analyses, and events within this project.

- The opportunities that are identified are described for each clash and can be applied as general elements in a material strategy (see chapter 4: roadmap).

3.4.3 Inspirational principles

a) Embracing complexity

Inspiring approaches/principles were firstly the method Context Variation by Design that was applied in chapter 3.3. In this method, complexity is embraced within design and development (Kersten, 2015).

b) Connecting networks

Secondly, during the time I spend doing tests at the workshop of BlueCity in Rotterdam, I learned more on the principle and advantages of a Blue Economy in which circles are closed and networks are combined.

c) Flexibility as a competitive advantage

Then, during an event at the TU Delft of the Bio-Engineering institute (27-3-2018), the use of flexibility as a competitive advantage was discussed by the CTO of the company Nanopore Technologies. Flexibility is also an factor that is visible within the CVD approach, where it is preferred to create the right circumstances for scaling, instead of scaling one product (See analysis 2.4, scaling strategies).

d) Controlled sharing knowledge

The principle of controlled shared knowledge is seen often within starting industries. One example is Stichting Noordzeeboerderij, where members have access to certain knowledge (Stichting Noordzeeboerderij, 2018).

e) Broadening impact

Lastly, by joining Dopper’s Changemaker Challenge and talking with coaches from Climate Kic, feedback that was given from a business perspective, showed a focus on broadening impact. The importance of a broad impact is also visible in successful material projects as from the Asian company Evoware. (Mulyono, 2017).

3.4.4 Opportunities per value clash

Per value clash (triangles) that was identified in 2.3, opportunities (circles) are explored and described, based on the principles a-e.

Focused solutions vs. Integrated solutions

Whereas complexity is needed to integrate solutions (principle a), focused solutions are needed to communicate and concretize concepts. When a material/solution has different levels of complexity, it is as well applicable as a focused solution on the short term, as for an integrated solution in the long term. An opportunity here will be to work on different levels of complexity of the material. This complexity mainly concerns the adaptation to industrial production processes, the development of material content and market expansion to multiple locations.

Another opportunity is to design for impact on social and economic aspects as well next to eco-impact, to
show the possibilities for integration in more complex systems. Within this, the focus can be on multiple fields concerning functional, environmental, social, economic and emotional value (principle e).

**Growth through scaling vs. Transition through regulation**

By creating flexibility in applying the material to different applications, the impact is enlarged as well. The material will be less specified and optimized to one application, which has the advantage that more established industries can find common ground with the material to start a transition. The importance of facilitating this transition is discussed in chapter xx: Discussion. An opportunity here will be to design the material for multiple fitting applications. This is based on principle a.

**Sharing knowledge, transparency vs. Building & protection of expertise**

Because expertise and intellectual property are threatened by transparency and sharing of knowledge, it is important to generate other methods of competitive advantage. One opportunity can be to use the flexibility and freedom of movement as an expertise. By sharing low-value applications but protecting high-value applications, the concept of a material can spread and grow while a competitive advantage is protected (based on principle c).

Another opportunity can be to control the sharing of knowledge through platform-based sharing. Examples of such platforms can be seen in Stichting Zeewierboerderij or BlueCity, or in ideas for a Seaweed Company (Wouters, personal communication). Through such a platform, ideas can be shared and protected, but the development of knowledge is not restricted. (Principle d)

Also, it can be a strategy to research and highlight the advantages of transparency of impact & processes to reduce resistance (inspired by principle b).

**Disrupt & challenge vs. Reduction of risk & accountability**

It will be an opportunity to disrupt thoughtfully, with less risk. This overall risk could be lowered by a smart timing of resources, to reduce investments (principle b: using waste-streams and connecting networks).

**Independent decision-making vs. Justified & accepted decision making**

Low investments through a smart timing of resources can result in more independence and more freedom of movement. An opportunity here can be a quick start to generate practical insights that can be used to justify decisions on a larger scale (this is based on a personal value, of practical actions within design).

### Conclusion

The opportunities to be integrated in a strategy are:

1. **[G1]** Work on different levels of complexity
2. **[G2]** Design for impact on social, economic and economic levels.
3. **[G3]** Design material for multiple fitting applications.
4. **[G4]** Use flexibility and freedom of movement as an expertise
5. **[G5]** Control the sharing of knowledge through platform-based sharing
6. **[G6]** Research and highlight the advantages of transparency of impact & processes
7. **[G7]** Smart timing of resources and locations
8. **[G8]** Generate quick starts & practical insights
3.5 Challenge 4: Time & trust

3.5.1 Goal

In analysis 2.5, the main important interests of different stakeholders are explored. The goal of this challenge is to generate a storytelling strategy in order to tell the right story on the right time to the right stakeholder. Since for some stories, other actions need more elaboration before the story will be suitable to tell. Therefore a desire is that the stories support each other by contributing to the next story.

3.5.2 Approach

The interests of the stakeholders are evaluated on their readiness for being told. If researches need to be done in order to convince stakeholders or concepts need time to generate trust, the storytelling is planned for the future.

3.5.3 Stakeholder interests & readiness

In image 50, the readiness of the stakeholders is evaluated, and required actions are matched.

<table>
<thead>
<tr>
<th>STAKEHOLDERS</th>
<th>INTERESTS</th>
<th>READINESS</th>
<th>REQUIRED ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
<td>Product advantages, Product meaning/connection</td>
<td>Near future</td>
<td>Product design &amp; validation</td>
</tr>
<tr>
<td>Seaweed farmer</td>
<td>Market horizon</td>
<td>Future</td>
<td>Market analysis</td>
</tr>
<tr>
<td>Bio-hacker</td>
<td>Value possibilities of waste, Market horizon &amp; technical horizon</td>
<td>Future</td>
<td>Market analysis</td>
</tr>
<tr>
<td>Designer</td>
<td>Material meaning, guidelines, characteristics and accessibility</td>
<td>Future</td>
<td>Material &amp; process guidelines</td>
</tr>
<tr>
<td>Entrepreneur</td>
<td>Market horizon, and risk analysis</td>
<td>Future</td>
<td>Market validation, Risk analysis</td>
</tr>
<tr>
<td>Government</td>
<td>Impact horizon</td>
<td>Future</td>
<td>Market validation, Risk analysis, Impact analysis</td>
</tr>
<tr>
<td>Research institutes</td>
<td>Knowledge gaps, and practical data</td>
<td>Future</td>
<td>Product feedback (data collection)</td>
</tr>
<tr>
<td>Wild sourcers</td>
<td>Value-possibilities of waste, Raw-material requirements</td>
<td>Near future</td>
<td>Process / production design</td>
</tr>
<tr>
<td>Investors</td>
<td>Market horizon</td>
<td>Future</td>
<td>Market analysis, Consumer feedback</td>
</tr>
<tr>
<td>Industrial refinery</td>
<td>Market-horizon</td>
<td>Future</td>
<td>Market analysis</td>
</tr>
<tr>
<td>Production facilities</td>
<td>Proven material characteristics, Risk analysis</td>
<td>Further future</td>
<td>Material validation, Risk analysis</td>
</tr>
<tr>
<td>Retail</td>
<td>Consumer response, Market horizon, Story match</td>
<td>Future</td>
<td>Market analysis, Marketing strategy</td>
</tr>
</tbody>
</table>

Image 50: From left to right: stakeholders, interests, readiness and required actions.
A desire for the narrative (part of list of requirements xx) is that the stories within the narrative contribute to their following narratives.

The stories that are interesting to tell are numbered as N. The researches/actions that need to be done in order to tell a strong story is numbered as A.

[N1] The first story in each phase concerns the product advantages and product meaning for the targeted market. Here, the audiences are the consuming stakeholders (see chapter 5 for consumer descriptions).

[A1] To tell this story, the product design needs to be completed and validated.

[N2] When consumer reactions are known, the next step is to convince larger-scale stakeholders. This story concerns the value possibilities of seaweed waste and the requirements that the raw material needs to meet. Here, wild sourcers and the bio-hackers are the most important audiences.

[A2] To tell this story, the production methods need to be designed, prototyped and validated and the expected impact of the products needs to be explored.

[N3] The next large-scale stakeholders to convince will be retailers, in order to reach more customers and scale up the processes. For this, the consumer response to the material, as a result from N1 as well as the storyline of the material and the market horizon need to be told, with retail as the audience.

[A3] For this, a marketing strategy needs to be explored.

[N4] The next story that needs to be told is the market horizon, of the first targeted market but also of future targeted markets. The audience here are entrepreneurs, seaweed farmers, bio-hackers, investors, industrial refineries and retail.

[A4] To be able to tell a complete story, a thorough market analysis needs to be performed of all the three phases.

[N5] Then, the impact horizon needs to be told, that explains the exact impact of the to be introduced products and the scaling project on the environment local economy. The main audience here are governments.

[A5] For this, an exact impact analysis needs to be performed

[N6] When the impact of a large scale application of the material is known, it is interesting to communicate material characteristics, material guidelines and how to access the material to designers.

[A6] For this, material validation tests need to be elaborated on and production methods and characteristics need to be controllable.

[N7] Important stories to tell at the end of a phase contain the collected data of product impact to the environment or consumer, with research institutes as the audience as well as audiences in the next phase.

[A7] For this, product feedback over a longer period is needed

[N8] The material characteristics and production risks become clearer at the end of a phase, these stories can be told to existing production facilities as the audience, to facilitate transition in material use of these facilities.

[A8] For this, the material needs thorough characteristic tests and reflection on the production processes.

[N9] All different narratives of different applications of the seaweed in a future stage, can be collected to facilitate an overview of the possibilities of a seaweed industry (conclusion from chapter 2.5).

[A9] For this, a narrative platform needs to be created.
To provide an overview on how the designed seaweed material could develop towards a mature material, a technology roadmap is made which is based on the identified opportunities within this project.

The roadmap includes the developments within the availability of resources, required technologies, design themes and fit markets.

The attached ‘list of insights’ can be used as support within this chapter to look back at the insights that are retrieved in chapter 3: challenges, that are integrated in the roadmap.

4.1 Introduction to the roadmap
   4.1.1 Goal
   4.1.2 Approach
   4.1.3 Identification of markets and phases

4.2 Roadmap
   4.2.1 Content & principles
   4.2.2 How to read the roadmap
   4.2.3 Roadmap layers
   4.2.4 Roadmap chart (overview)
4.1 Introduction to the roadmap

4.1.1 Goal

Through the construction of a roadmap, a strategy is illustrated on how to maturate the seaweed material from its current condition, towards a material that is independent from funding, accessible for consumption by a broader public and provides business opportunities that are viable, with respect to the environment (See chapter 1.2). An additional goal of the strategy is to create a material that is accessible for adaptation by other industries [G1] (see the attached insight sheet).

4.1.2 Approach

The findings from the challenges in chapter 3 form the basis of the strategy.

- First, contextual insights [C1 t/m C6] and material insights [M1 t/m M6] are combined on a 2x2 matrix which is visible in image 5. The horizontal axis of the matrix concerns time (present or future) and the vertical axis concerns points of interest (challenges or opportunities). By combining these insights, three main phases of development and market approaches can be distinguished. These phases are described on page 58/59, as well as their overlap, which concerns how to get from the one phase to the next.

- Then, the three phases are integrated into a technology roadmap. Basically, a technology roadmap is a time-based chart existing out of multiple layers that visualize commercial and technical perspectives. It is used to enable exploration of evolution of the separate layers, as well as the linkages between the layers. Technology roadmaps are often used in the industry to support strategic planning, for example by companies as Philips and Motorola (Phaal, 2014).

The advantage of using this tool in this project is that it creates the opportunity to visualize the complexity of dynamics of linkages within changing factors. Technology roadmaps know various forms. Here, the generic form by EIRMA is used (see image 53)(Phaal, 2004), which addresses the different perspectives of technology, product developments and market opportunities.
- The generic form is adapted (see image 54) to the project by firstly adding a layer that concerns the availability and development of ‘resources’. This layer is divided into the categories of ‘accessible material’ and ‘knowledge’). This is done to facilitate a viable start of the value chain.

Then, the ‘technology’ layer is divided into the categories ‘material-developments’ and ‘production-developments’, because these are the main influencing technologies.

The ‘product layer’ is divided into the sub-layers ‘design areas’ to concretize developments and ‘storytelling’ to convince stakeholders.

Lastly, the ‘market’ layer is divided into the sub-layers ‘added value’ (in order to have a broad impact [G2]), and possible ‘market segments’ (to create a flexible strategy [G4]) and the expansion of ‘locations’ (to reduce risk and enlarge impact before transitions within industries has taken place (phase 3) [G1]).

- Within these different layers, the insights from the challenges (see insight sheet) are integrated.
4.1.3 Identification of markets an phases

In image 55, the context insights that are retrieved in challenge 3.2 and 3.3 are placed in the 2x2 matrix. In order to navigate from present challenges (lower left corner) to future opportunities (upper right corner), three phases are identified in which insight factors can be combined. These phases show overlap, where shared insights can be used to enter a new phase.

Phase 1. From seaweed-waste to agriculture

Present challenges of the material maturation are the heavy odor, fragility of the material and the difficulty to exactly reproduce a product [M2]. Furthermore, a challenge lies in the consumer’s motivation: environmental problems and direct impact are not clearly visible for Dutch urban citizens, and citizens in St-Maarten have more primal concerns than changing their environmental behavior [C6]. Then, another challenge is that there are little resources available in this stage of development [C5].

The available material resource is the Sargassum seaweed plague at Sint-Maarten [C5]. Start-ups within the Netherlands can be connected with start-ups at Sint-Maarten, creating a strong connection and being able to grow enterprises on seaweed on both locations more easily [C3]. At the start-up phase, there can be an opportunity for consumers from the different contexts to share information on agricultural techniques and their customer experiences. This can enlarge the visibility of the impact that consumers have: one way, the problem of seaweed waste and plastic waste becomes visible, the other way around, an alternative product becomes accessible [C6].

Overlap of Phase 1 and Phase 2:

From the agricultural sector that will be approached in phase 1, there are two ways forward (see arrows in image 55). Either, bio-extraction processes can be researched to improve [M8] to have access to independent bio-alginate. If this succeeds, loops can be closed within agriculture, having no more imported ingredients [C1]. The concept will become more independent and more suitable for local-global expansion towards all thinkable locations with a seaweed source. Or, research can be done to the specific content of the Caribbean and Dutch seaweeds that are used and the material’s behavior in dangerous conditions, for example fire [M5]. Legislation can become easier after these researches and together with consumer reactions from the first phase, new markets can be approached.

Phase 2. Empowered building

A new market that can be approached lies within the building industry, due the materials flame retardant character and its promises to be of good acoustic quality [M4]. The two contexts can support each other again by sharing the techniques for communal housebuilding, since in Sint-Maarten their is a strong need for independency within rebuilding their houses on small resources and whereas in the Netherlands there also is the trend that people do more and more construction activities in their houses themselves, or build houses themselves [C2]. This is preferably done based on closed loops of resources [C1], but if this is not succeeded yet, this market can also be approached with industrial alginate or other developed, more cheaper techniques. Since a threat in the future will be that if seaweed becomes too popular and the industries too large, depletion of seaweed can occur due to wild-harvest, on places where no seaweed plague is. Therefore it is necessary to focus the applications in the future on waste streams from cultivated seaweed [C5]. Since seaweed cultivation is still in development, this is a future phase.

Overlap of phase 2 and 3:

With many insights from the first two phases and multiple independent enterprises on multiple locations, it is possible to look at the most impactful plastic market: (food) packaging and disposables. The largest overlap is that there are seaweed waste-streams from cultivation as a steady resource [C5], but there still is the threat of depletion in a local global industry where it is hard to control whether all enterprises actually use this cultivated resource.

Phase 3. Industrial packaging

The material offers opportunities in packaging since it is resistance to pressure impact, it is lightweight and promising to be food-safe [M6]. The challenges that need to be solved before this phase is its low bending resistance. Also, strict packaging requirements need to be met [M7]. By this time, since many local global enterprises in previous phases have gotten used to the concept, it should be interesting to create a local global platform that controls the use of resources for all applications with the seaweed material, maintaining overview and avoid wild-harvest.
Image 55: Identified opportunity phases within 2x2 matrix (based on context and material insights)
4.2 Roadmap

4.2.1 Content and principles

The identified phases of 4.3 are integrated together with insights [N1 t/m N9] from challenge 3.5 (that implies a storytelling strategy) and with opportunities [G1 t/m G8] (how circumstances can be created to guard values). These are integrated into the form of a roadmap (more on the form of technology roadmaps is explained in 4.2).

This results in the following principle of the roadmap:

The goal of the roadmap is to work on different levels of complexity concerning material development [G1], through which quick-starts can be made, practical insights can be generated on the short term [G8] while having an adaptive development process that can facilitate a future transition of industries [G1].

Flexibility and freedom of movement between markets and applications [G3] can serve as an expertise on the short term (which creates competitive advantage) [G4], while on the long term knowledge and specific expertise concerning high value applications can be shared via controlled platforms [G5] to protect intellectual property.

More specific principles concern that needed resources and a working location are chosen and timed on their accessibility [G7] and that value needs to be added on multiple levels [G2].

The connecting layer within the roadmap is storytelling. A narrative plan [N1 t/m N9] is integrated to convince stakeholders and connect the different phases and markets. Through narratives from the previous phase, the new market can be motivated and convinced.

4.2.2 How to read the roadmap

Image 56 on p.72, 73 shows the roadmap. The horizontal axis represents time. This roadmap mainly concerns the relations between the elements in the roadmap. An indication of time will be discussed in chapter 6: discussion.

The different vertical layers show their expected developments. The black arrows show the relations between elements of the vertical layers.

Basically, the bottom left of the roadmap concerns what is currently available to use to start a new value chain. The top right of the roadmap, concerns the intended market to reach. All the elements in between concern the situations around the development.

4.2.3 Roadmap layers

Resources

Opportunity G7 (discussed in 3.4.3) points out to time the use of resources according to their accessibility. This means that seaweed will need to be available, but also the time to obtain knowledge needs to be planned.

Material

Currently, it is most viable to work with the waste streams of material at St-Maarten. Since the seaweed plague will (hopefully) not be a permanent problem, the strategy will work towards using cultivated seaweed waste as a material source [C5].

Knowledge

Since currently, knowledge on using seaweed material on industrial scale is scarce, it will be best to start working with low resources (as affordable molds and workable concepts) and through these concepts prepare for new techniques.

The first steps of acquiring knowledge within the first phase are most intensive: Firstly, it concerns the consumer reaction and evaluation of first prototypes and insights, which will be the input for a marketing strategy [A3]. This first evaluation will be the start of a long-term feedback plan [A7]. Furthermore, tests are set up at as soon as possible, to improve the extraction process of alginate [M8] in order to develop a future improved material.

Then, in order to convince stakeholders, a thorough market analysis is performed to validate future markets [A4], an impact analysis is done to validate a seaweed value chain [A5] and material validation tests are set-up to control the material in the production process [A6].

To prepare for the next phases, material characteristic tests will be set-up for flame retardence [M5] and tests are set up to improve odor and fragility [M2].

In the second phase, consumer reactions from the previous phase are evaluated and a new marketing strategy is proposed for the current phase [A3]. To prepare for the phase 3, the advantages of process transparency are explored to communicate to industrial stakeholders [G6], research is done on the recycling possibilities of alginate products [M8] (to adapt to future industrial systems) and material characteristic tests are set up for food safety and technical specifications [M7].

All along the roadmap, feedback is retrieved to create a long-term feedback overview [A7].
Technologies

The production techniques and the material content depend on the acquired resources in the previous layer.

Material (technology)

At the start, the material that can be used for production will consist out of a mix of sargassum waste-material and industrially extracted alginate. When enough research is done on improving extraction processes naturally, industrial alginate can be replaced by bio-alginate, creating independence, lower material costs and empowerment to start a transparent industry.

When cultivation of seaweed has matured as well (under ethical conditions), washed ashore seaweed can be replaced by cultivated seaweed, making the material more controllable and efficient, which can make the material suitable for mass-production.

Production

The most low-cost and accessible production process (of small-scale batches) that copes best with the material characteristics of the material (that concerns fragility) will be mold-pressing. This production method will require no heat, which keeps the production costs low (see chapter 5: value chain for a description of the production principle). Low-cost local production workshops can be set up by using single-cavity wooden molds, which can be improved towards multi-cavities aluminium molds. In the next phase that concerns to create building material, it would be convenient to be able to produce large sheets of seaweed material. For this, the process and material need to have been explored to be able to control such a production process of larger products.

The final goal, is to be able to produce products on a mass-scale. For this, the characteristics of the material need to be understood to be able to adapt to industrial processes. Furthermore, the value chain needs to be transparent and part of a local global platform (that protects an ethical use of resources on a mass-scale) [G5].

Product

Product Design

The three product design themes are based on the markets that are explained in chapter 4.3: identification of markets and phases.

Narratives

Narratives are integrated into the product-layer to convince stakeholders and connect the different phases and markets. Through narratives from a prior phase, new market can be motivated and convinced. Arriving at the third phase, which strives for mass-products, the history of the material will be rich of stories and applications, which contributes to the acceptance of the material.

The quick start of product designs contributes to the first narrative that communicates the product advantages to the consumer [N1]. Then, values that concern a broader impact are communicated to larger-scale stakeholders [N2]. From the prototypes and evaluation, the customer response can be used in a narrative that communicates the acceptance towards retailers [N3]. After, more intensive analyses are performed concerning the market future and impact [N4][N5][N6]. This information is used to convince large-scale stakeholders within the first phase, as well as small-scale stakeholders within new markets. At the end of the first phase phase, the impact that was predicted is measured, which can be used as an input for investment requests for the next phase [N7]. This strategy repeats itself for the second phase: [N1 t/m N7].

After the second phase, enough time must have been created to be able to have determined exact material specifications, which can be used to convince industries to collaborate to combine techniques. [N8].

In the final phase, the first two narrative-themes are repeated [N1 and N2] (directed towards consumers and supporting stakeholders) and as a future goal, a narrative platform is created to facilitate transparency within the industry.
**Markets**

**Added values**
One of the principles of the strategy is to broaden impact, therefore value needs to be added on social, economic, environmental as well as on emotional level [G2]. The values that the phases adress are described below:

In the first phase, the material (or value chain) can add **functional value** through the of a natural fertilizer within products, as well as serving as a moisture holding agent for the soil [M1]. Secondly, it can add environmental value by providing a renewable alternative for plastic and improving the nutrient situation of the seaweed plague (through reducing the amount of nutrients in the water and avoiding the use of artificial fertilizer) [C4]. **Economical value** is added through the creation of a industry, by the rise of value of the seaweed and generation of exportable products. It can add **social value** by empowering local entreprenuers in eco-agriculture by generating new jobs and expertises and it can add **emotional value** by visualizing the impact through combining both contexts. This creates a clearer vision on the impact of a seaweed product, which could add to a feeling of contribution [C6].

In the second phase, the material can add **functional value** by serving as a flame retardant for building purposes [M4]. Since in this phase the knowledge on the seaweed and material is larger, the processes can be scaled up. This can create more impact and therefore here the value chain can add **environmental value** through alleviation of the seaweed plague. This growing industry can add **social value** since it empowers the community by creation of new jobs. Here, it can create more **economical value** as well for the production location, since the estimated value of building material is higher. Concerning **emotional value**, it could provide a feeling of safety, by using flame retardant, natural building materials.

In the third phase, the material can add **functional value** as a protective and healthy packaging material (this has to be proven still, but is expected to be more healthy than oil-based packaging). By then, it can add large **environmental value**, since it can serve as a replacement for up-scale plastic applications. It can add **social value** by empowering industries to realise transition. This does not sound very social, but is in fact really important to secure employment and local economies. When being able to recycle the alginate, it can provide more **economical value** since the resources become of more value. Finally, this final value chain/material can add value on an **emotional** level by providing healthy products and taking responsibility.

**Market segments**
The market segments are kept broad in order to be able to keep on designing for multiple applications.

The first market segments concerns eco-agriculture. Within this, markets can concern the segments of gardening, city-farms, farming education and industrial agriculture. On Sint-Maarten, the sub-segments of city-farms/eco-farms and farming education are currently the most accessible ones. In the Netherlands, the market will also concern the sub-segments of city-farms and farming education, and can be expanded to markets that concern gardening (hobby) and industrial agriculture.

The second market segment concerns building/construction. Within this, markets can concern the segments of DIY building, renovation building, workspaces, eco-villages or laboratoria.

The third market concerns (food)-packaging/disposables, which covers the broadest range of market-segments. Markets can concern the segments of fast-food packaging, packaging of fresh food, transport materials for flammable products.

**Locations**
In the first phase, the locations that are mentioned in the roadmap are the Netherlands and Sint-Maarten. Sint Maarten in the Caribbean is facing the problem of a seaweed plague and has a need for new independent industries. This makes this location suitable for production and use of seaweed products. Furthermore, St Maarten is strongly connected with the Dutch government. Since the market of St-Maarten currently is yet too small for a viable production (see cost price calculation, appendix xx), a comparable Dutch market is also directly included (see customer value chapter 5.2), therefore the Netherlands will be the second location to use the products.

In the second phase, other wastestreams on different locations will become interesting where seaweed plagues occur (all around the Caribbean area, but also
African coastal areas and on a smaller scale even in the Netherlands).

Later in the roadmap, when wild seaweed is meant to be replaced by cultivated seaweed, the strategy can still expand to locations that either fit the opportunities of the roadmap, or contribute with new opportunities.
Phase 1: From seaweed-waste to agriculture
Start where the seaweed, the capability is and a demand is

Market
Location
Location St-Maarten
Location x, y, z...
Netherlands

Segment
Eco-agriculture [M3] [C4]

Added value
Natural fertilizer
Renewable alternative for plastic & nutrient loop
Empowering local entrepreneurs in agriculture
Create a new local value chain
Empowering exchange between contexts: contribution

Product
Product Design
Narrative
Plant growth
Building safety & comfort

Technology
Production
Mold pressing (Conventional Evaporating method)
Large sheet pressing (Conventional Evaporating method)

Material
Industrial alginate + Sargassum composite
Eco-Alginate + Sargassum composite

Resources
Knowledge
Product evaluation & marketing strategy [A3]
Market analysis [A4]
Impact analysis [A5]
Advantages of transparency [G6]
Product market

Material
Caribbean plague (Sargassum) [C5]

Emotional

Functional

Environmental

Social

Economical

Values

Product advantages [N1]
Values [N2]
Customer Repsonse [N3]

Product horizon [N4]
Impact horizon [N5]
Material guidelines [N6]

Impact data [N7]

Impact data [N7]

Material specs [N8]
Product advantages [N1]

Values

Narrative platform [N9]

4.2.3 Roadmap Chart (overview) - image 56

TIME
Market
Location St-Maarten
Location x, y, z.
Netherlands


Segment
Added value
Functional
Environmental
Social
Economical
Emotional

Resources

Knowledge
Material

Product
Product Design
Narrative
Production
Material

Plant growth & comfort

Product advantages [N1]
Mold pressing (Conventional Evaporating method)
Large sheet pressing (Conventional Evaporating method)
Mass production (Thermo-mechanical Mixing method)

Industrial alginate + Sargassum composite
Carribbean plague (Sargassum) [C5]
Waste streams from up-scale bio-refineries from cultivated seaweed [C1][C5]

Product evaluation & marketing strategy [A3]
Market analysis [A4]
Impact analysis [A5]
Material validation [A6]
Long-term product feedback [A7]
Improve odor, fragility [M2] and extraction process [M8]

Eco-Alginate + Sargassum composite
Eco-Alginate + Cultivated seaweed composite
Foodsafe packaging

Natural fertilizer
Renewable alternative for plastic & nutrient loop

Create a new local value chain
Empowering local entrepreneurs in agriculture
Empowering exchange between contexts: contribution

Seaweed plague alleviation
Natural building material for fire-safety
Reed plague alleviation
Power local communities

Create high-value material
Empower local communities
Renewable alternative for plastic
Healthy packaging & healthy environment
Closing loops
Health, responsibility

Phase 1: From seaweed-waste to agriculture
Start where the seaweed, the capability is and a demand is

Phase 2: Empowered building
Increase complexity and value

Phase 3: Industrial packaging
Adapt to industry/industry adapt

Safety, Health, responsibility

Values [N2]
Customer Response [N3]
Product advantages [N1]
Values [N2]
Narrative platform [N9]

Impact data [N7]
Material Specs [N8]
Product advantages [N1]
Values [N2]

Mass production (Thermo-mechanical Mixing method)

Eco-Alginate + Cultivated seaweed composite

Research Thermo-mechanical mixing & recycling of alginate [M2]
Material characteristics test: food safety & technical specs. [M7]

Waste streams from up-scale bio-refineries from cultivated seaweed [C1][C5]

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5. DESIGN IN PHASE 1

One of the principles of the roadmap is to be able to kick-start products quickly, by starting off with low resources and planning the contribution of those products to the next step, and finally to the end-goal of a mass-produced product that can be a substitute for oil-based plastics.

Therefore, to concretize this vision, the first quick-start product is designed for the first phase that concerns a design for eco-agriculture and a set-up for this value chain. From there, the input for next steps is determined.

5.1 Design brief
5.1.1 Approach
5.1.2 Positioning in roadmap
5.1.3 Customer value
5.1.4 Design brief

5.2 List of requirements

5.3 Design decisions

5.4 Product: Seaweed starters
5.4.1 Product description
5.4.2 Production

5.5 Company activities (value chain)
5.5.1 Approach
5.5.2 Value chain

5.6 Product evaluation

5.7 Narrative overview

Image 57: Prototyping: product mold
5.1 Design brief

5.1.1 Approach

The design brief describes the framework and the goal of designing a product within this first phase.

- In 5.1.2, the position of the design in the roadmap is described.

- Then, the main customers will be introduced in 5.1.3. The customers on both locations are interviewed to determine their activities (jobs), pains and gains.

- The framework, customers and stakeholders form the basis of the design brief, that is introduced in 5.1.4.

5.1.2 Positioning in roadmap

In image 58, the first phase of the roadmap is visible. Within this design, the focus can be read by starting below at the olive green block (Sargassum). From here the design positioning can be read by following the black arrows (see chapter 4 for the complete roadmap and explanation of the different elements).

The design will focus on the seaweed plague of Sargassum, the composite material of industrial alginate + Sargassum, the production process of mold-pressing, designing for plant growth, adding broad value, for eco-agriculture on Sint Maarten and in the Netherlands. From the product design, the product advantages can be used as a narrative, that will contribute to the second narrative.

From here, a closer look will be taken on the customers within this market segment in the Netherlands and Sint Maarten in 5.1.3.
Image 59: Eco-agriculture in the Netherlands (DakAkkers, Rotterdam). (Luchtsingel, 2018)

Image 60: Eco-agriculture at Sint-Maarten (Philipsburg) (sxmfreedomfighters, 2018).
5.1.3 Customer value

The customers concern the small-scale farm owners in Sint Maarten as well as the Netherlands. For both customers a customer value chart will be explained (image 63, image 66).

Customer value of Eco-farms (Sint Maarten)

Information retrieved from expert contact with Denicio Wyatte (a local entrepreneur in eco-agriculture located in St. Peters) formed the base of a customer value map (image 63). The information that is retrieved concerns the eco-farm called ‘Spaceless Gardens’ (image 61) and is part of the organisation ‘St Maarten Agriculture’.

Job/activities

The organisation ‘St. Maarten Agriculture’ focuses on increasing and safeguarding the agricultural sector as well as the tourism sector. This is done from the motivation to look over all aspects of poverty alleviation and food security. An important activity within this, is crop experimentation. By this, plans are made to cultivate larger quantities of more focused crops. Other activities on the farm are the preparation of the soil, seeding and selling the crops to the local community. Next to actual farming activities, a research and development center is being set up to research agricultural solutions, as well as solutions concerning the seaweed problem on the island. (D. Wyatte, personal communication, July 24, 2018).

Within this center, educational summer programmes are set up for local schools to learn about agriculture (image 62).

Pains

The soil is fertile and therefore so suitable for cultivation fertile, but water needs to be holded in the soil. Especially since very dry periods can occur. Currently, this is done with peat moss. Furthermore, seeds are started in plastic starters, which are wished to be replaced (D. Wyatte, personal communication, July 24, 2018).

A general difficulty is that there are little resources on the island (P. van der Veen, personal communication, May 23, 2018).

Gains

The farm could gain from the sharing of information/knowledge on agricultural solutions, ways to involve the community, new or improved eco-friendly methods for agriculture (especially methods for aquaponics, to save water) and the clean-up of the seaweed plague on the beaches.

“The only plastic we use are pots for plants or seedling trays. If seaweed-products that are in development can replace this, then I think we are headed in the right direction.” (D. Wyatte, 2018)
Customer value of Eco-farms (Netherlands)

In the Netherlands, there are multiple small-scale city farms to be found. The drivers of the farms are very much alike. Most act from a social driver, either to let citizens get familiar with cultivation, or to provide ecological grown food for the local community.

Job/ Activities
Most of the eco-farms are set-up in combination with workshop activities, events spaces, or horeca facilities (image 65). Activities/events are for example ‘growing workshops’, ‘farm-tours’ and ‘tasting-events’ (Uitjeeigenstad, 2018). Starting of seeds is often done in compressed soil, or in degradable seed starters. These are often from paper pulp, or peat. (Stek de stadstuinwinkel, personal communication, October 10, 2018).

Pains
Since many city-farms serve a niche market, they depend on side-activities for their revenue (Bliss, 2018), which can be a pain on the long term regarding their viability. Other visible pains concern the lack of space within cities or un-suitable soil, therefore, often techniques of vertical gardening or aquaponics (a cultivation method using a closed circle of water, without soil) are implemented. For example, at the cityfarm ‘Uit je eigen stad’ (image 64), the soil is only 50 cm’s deep, which they have to take into account. (J. Stammeijer, personal communication, October 22, 2018).

Gains
To support the viability of the farm, the farms can profit from more publicity, methods to make optimal use of the available soil and affordable tools for aquaponics.

Conclusion
Since the city-farms in both contexts cultivate on a small scale and serve niche-markets, they can both gain by a product that optimizes their process, that does not demands large investments, can gain publicity for the farm and can contribute in side-activity as workshops and education-programmes.

Since the farms can still be considered as an un-stable market, it is especially important that the investments of the value chain should be held low.

A product that both contexts will need is seed starters. The farm at Sint-Maarten would be willing to replace the plastic ones by seaweed ones, and while the dutch eco-farms already use natural alternatives, they could still profit from starters that contribute to the quality of the soil.

Left: image 64: City farm ‘Uit je eigen tuin’ in Rotterdam, (Uitjeeigenstad, 2018)
Middle: image 65: Opening of City-farm Osdorp (Stadsboerderij Osdorp, 2018)
Right: image 66: Value chart of customer 2, city-farms NL.
The design considers the start of a new value chain, starting from the washed ashore Sargassum seaweed at Sint Maarten. On the way, the seaweed is processed into products that can replace plastic seed-starters and be used as a natural fertilizer. At the end of the value chain, the nutrients inside the seaweed are in the soil, to be supporting plant growth.

The product is designed for local eco-farms at Sint Maarten and in the Netherlands, that want to develop eco-agriculture through experimentation and education, but also create efficiency in their methods to become viable.

The value chain will be part of a new business, set up by a collaborative of small-scale entrepreneurs, consisting out of seaweed collectors, bio-hackers, material/product designers, and local entrepreneurs in small-scale eco-farms on Sint Maarten and in the Netherlands.

5.1.4 Design brief

In the design brief, the goal for the design is formulated, based on the roadmap focus and customer values.

“The design of a ‘low threshold’ value chain that adds value to the Sargassum seaweed plague at St-Maarten, by producing products from seaweed material that can be used as a fertilizer, soil improver and an alternative for plastic seed-starters, for an eco-farm at Sint-Maarten and city-farms in the Netherlands.”

What

The design considers the start of a new value chain, starting from the washed ashore Sargassum seaweed at Sint Maarten. On the way, the seaweed is processed into products that can replace plastic seed-starters and be used as a natural fertilizer. At the end of the value chain, the nutrients inside the seaweed are in the soil, to be supporting plant growth.

For who

The product is designed for local eco-farms at Sint Maarten and in the Netherlands, that want to develop eco-agriculture through experimentation and education, but also create efficiency in their methods to become viable.

By who

The value chain will be part of a new business, set up by a collaborative of small-scale entrepreneurs, consisting out of seaweed collectors, bio-hackers, material/product designers, and local entrepreneurs in small-scale eco-farms on Sint Maarten and in the Netherlands.

Why

To create quick-start valuable seaweed products, that support the development of a seaweed material as a replacement for plastics, by convincing stakeholders and creating practical insights.

When

The design will be successful when it allows first products to be produced, tested and used, and generates consumer reactions within the time scope of 6 months.

How

To create a viable process, that is valuable for its environment, competitive in its market and contributing to material development, the process is based on using low resources and little energy (cold mold pressing), generating jobs and expertise, generating products for export and communicating knowledge between contexts. This is elaborated on in the next chapter, where the requirements for the design are set.

To generate consumer reactions, test packs are sent to the first customers that can later be turned into workshop packages. This will contribute to the next narrating steps (see narrative overview at the end of this chapter).
5.2 List of requirements

The following requirements are based on a collection of findings of this project. Requirements concerning the function and the use of the product derive from zooming in more closely on the customer of the first step (see: customer description).

1. Function

1.1 The product allows the seaweed nutrients to function as a fertilizer.
1.2 The product allows roots to create space to grow after planted in the soil.
1.3 The product protects the seed when planted.
1.4 The product is able to withstand daily watering of 10 cl per time.
1.5 The product is able to absorb 1% of its weight on water, to serve as a reservoir for crops.

Desire 1.6 The product can be used for educational purposes as workshops / school lessons
Desire 1.7 The product is able to withstand complete soaking in water for at least a month (for possibilities within aquaponics).

2. Form

2.1 The product shape and appearance facilitates a straight-forwardness with how to use it.
2.2 Material thickness needs to be at least 4 mm.
2.3 The shape is round to facilitate least material waste.
2.4 The form facilitates to stack the products.

3. Use

3.1 The product can be transported around the farm or garden without damaging the seed starter.
3.2 The product is planted with the crop into the soil

4. End of life

4.1 The product degrades completely within one year to function as a natural part of the soil.
4.2 Degraded material does not contribute to salinisation of the soil on the long term.
4.3 The product has a positive impact on fertility of the soil on the long term

5. Price

5.1 To be competitive within the market of seed-starters, the material costs does not exceed 4 cents per piece (1/5 of the consumer price for competing products, see chapter 5.6 for the alternative products).

6. Production

To create a viable production process with a low impact:
6.1 One mold has a max. costprice of 100 euros.
6.2 The production time per pot is less than 1 minute.
6.3 The production requires a minimum amount of energy.

7. Ingredient resources

7.1 The Sargassum is harvested from the sea, to protect harvesters from potential health hazards.
7.2 The Sargassum is only harvested in times of abundancy.

Desire 7.5 Ingredients are imported from a supplier within a range of 3000 km (closest continent)

8. Transport

8.1 Products are able to be transported from Sint Maarten to the Netherlands without being damaged

Desire 8.2 Transport has a minimal carbon footprint
5.3 Design decisions

Product split: separate fertilizer and seed starter

The pulp that forms the basis of the material is a waste stream from the bio-refinery process, so in order to create local products from the seaweed at Sint Maarten, the bio-refinery process will take place there. The refinery process is required for the material, since the process to produce the designed seaweed material succeeds with waste pulp, but not necessarily shows the same results with fresh pulp.

Therefore, it is most logical to refine the seaweed into the following two streams: the initial stream of the biorefinery (used as liquid seaweed fertilizer) and waste-pulp (to be produced into seed starters). This will mean that the liquid fertilizer will function as the product that utilises the seaweed nutrients for eco-friendly plant growth (Requirement 1.1), and that the seed starters focus on the functions to protect the seeds (Requirement 1.3) and function as a moisture holding agent (Requirement 1.5). There can be some residual nutrients inside the material still, since the extraction process might not be completely efficient.

Product shape

Firstly, to protect the seed (requirement 1.3), the product needs to form a barrier between the soil around the seed and the main soil. Then, a hollow shape, can hold water before the alginate material can absorb it (since it is a slow absorber) (requirements 1.4 and 1.5). A slight slope in the product makes it stackable (requirement 2.4) (to make it easy to move around the farm and efficient to export), and it makes sure it is a releasing shape within cold-mold pressing.

Furthermore, round shapes have the least waste-material within the production process (requirement 2.3).

These solutions lead to quite a traditional shape of a planter. This is acceptable, since it needs to be recognizable as a seed starter (requirement 2.1). To add to the usability, the product has a collar to be able to hold the pots easily and to reserve a little space for the seed to grow.

The dimensions of the product are based on the sizes of seed starters on the market. The size of the prototypes are smaller due to 20% shrinkage (image 67).

The shape can be seen on image 67 and on image 69 on page 85.

Production

To meet the requirements for production with the least possible investments and costs (a durable mold below 100 euro, a fast production cycle, and low energy usage), the production will start with single-cavity molds, that are mounted to a simple hand-press to avoid unequal wall-thicknesses and speed up the production process.

The single-cavity molds can be machined with a simple lathe (see image 68 for mold prototype). The molds can be improved on the longer term by investing in multi-cavity molds.

The molds are not heatened. Because of this, the drying process will require more time (this can take place outside of the mold), but no energy will be required (see chapter 3.1). To facilitate the best air-flow during drying, drying racks are used that support the shape of the seed-starters to avoid shrinkage stresses. Along the drying process, the seed-starters show an average shrinkage of 20% (image 67), therefore the mold has to be 20% larger than the desired end-measurements.

Because the molds are not heatened, they could also be made out of wood for a start to reduce costs. A finishing layer should then be applied to the mold to facilitate a good release.

Material composition

The proportion of pulp is high in this product, to create the lowest possible material costs and fastest degradation process.
Image 67: Shrinkage of 20%. Left: right after molding, Right: after 5 days.

Image 68: Failing through shrinkage (incorrect support).
5.4 Product: Seaweed starters

5.4.1 Product description
The seaweed starters function as a replacement for plastic seed-starters. They are single pots, to realise an easy to set-up production process for small-scale batches. The pots can be organised and transported by stacking the beds. The seed starters have a diameter of 70 mm and a height of 50 mm.

5.4.2 Production
At the start-up phase, production will be set up in a workshop, containing a mixing area, a hand-press with a single cavity aluminium mold and a drying area. Production consists out of the following steps (see image 69):

1. The seaweed pulp that comes from the refinery process needs to be prepared one day before production. Water is added to the dried seaweed to open up the fibres.

2. Ingredients (sodium-alginate, water, glycerol and waste-pulp) are mixed.

3. The mixed material is poured into the mold cavity and pressed into its shape with the hand-press.

4. The product is released and placed on the drying rack to facilitate air flow for equal drying.

5. After about 5 days (depending on air conditions, e.g. relative humidity, temperature and air circulation), the necessary moisture has evaporated and the products are ready for storage/use.

The processes of mixing, pressing and releasing can be performed within 2 minutes. The mold is directly reusable, but having only one cavity, it will be a rather slow process.

Investments
A hand press can be bought in new for less than 50 euro’s The mold (from which the machining costs are estimated on max. 100 euro’s) can be attached to the hand press to facilitate guidance of the mold parts. Then, drying racks need to be made. These can be simple 3Dprinted or thermoformed racks. All tooling for the seed-starter production is estimated to stay below 200 euros/set-up (see appendix M: cost estimations).

Material costs
When applying a high proportion of pulp (70%), the material costs are estimated on 3,4 cents per pot (32 grams). Within the material cost estimation (see Appendix M: cost estimations), prices for lower grade industrial alginates are sought, bottom prices for glycerol are assumed (because of an expected price drop of this ingredient) and the price of the Sargassum seaweed is expected to be at least half of the original market value, since it will be a waste stream (refinery waste) of a waste stream (seaweed plague).

Image 69: Production steps. circle 1: wetting pulp, circle 2: mixing ingredients, circles 3 and 4: pressing, circle 5: drying in racks
Image 70: Seaweed starter (prototype)
5.5 Company activities (value chain)

A value chain consists out of the activities of an organisation to add value to the customer (Porter, 1985). Within this project, for the primary activities is regarded how value is added to the customer as well as to other stakeholders, and how these can contribute to each other. The designed value chain will be ran from a collaborative of small-scale entrepreneurs, consisting out of seaweed collectors, bio-hackers, material/product designers, and local entrepreneurs in small-scale eco-farms both on Sint Maarten and in the Netherlands.

For this business, a company insight is formulated and activities to add value are explained within the value chain.

5.5.1 Approach

A company insight and brand proposition are formulated with the help of tools of Brand the Change (Miltenburg, 2017). The value chain is set up by defining the different steps to go from seaweed to products to new input for development (image 71).

For each step the determinants for this step are described, as well as the added value that the step creates, and which stakeholder profits from this added value.

In image 72 (p. 88), the value that is added is described per step, and the stakeholders that profit from this are illustrated below. These stakeholders consist out of additional stakeholders that are involved in this specific phase and context (see p.95 for an overview of these stakeholders).

5.5.2 Value chain

1. Collect Sargassum

The first step of the value chain is the collecting of the seaweed Sargassum. The amount of seaweed that washes up often has its peak in the summer. Once the seaweed is stranded on the beach, it starts rotting. The rotting could have a negative influence on work safety, and shoveling the seaweed from the beaches could disturb sea-turtle nests (P. van der Veen, personal communication, May 23, 2018). Therefore it will be desired to collect the seaweed before it reaches the shore. There are techniques developed to do this with boats, so called Sargator boats (Todaysxm.com, 2015) and experiments are running to place dams and nets around the coast (Maltese, 2016).

This first step adds value (image 72, next page), by contributing to a healthy and pleasant environment. It will not solve the seaweed plague, but it can provide some alleviation of it.

First of all, it is of value for the local community to live in a clean environment, for sea-life to have more oxygen in the water and for sea-turtles to nest at the beaches.

Then, it is of value for the tourism industry, especially for hotel owners, that depend on the aesthetics of the beaches. But also for citizens with jobs in the tourism industry, this is of value.

Also, it is of value for the fishing industry, since the seaweed has a negative effect on sea-life and destructs fishing vessels. Alleviation of this can contribute to a more healthy environment for fish. Besides, fishing vessels could contribute to the collection of the seaweed, creating temporary work with accessible resources.

2. Refine seaweed

The collected seaweed is brought to the local production facility. This can be set up in a local workshop. Here, the seaweed is processed into liquid fertilizer through bio-refinery processes. The rest product of this process is the seaweed pulp.

Refining the seaweed will add value because it turns the seaweed into a conservable (and therefore exportable) fertilizer, as well as into a basis for the seaweed material. Furthermore, a refinery creates a local industry and jobs. This is of value to the local community and for entrepreneurs and investors, since it adds to the viability of the value chain (See image 72).

3. Produce seaweed-pots

From the waste stream (coming from the refinery step), the pulp is used as a base to produce the seed starters. For this, industrial alginate is imported from the nearest source, which also counts for the glycerol. The production of the pots can be done at the same workshop as the refinery process.

A share of the products are produced for the local eco-farms, the other share are produced for export to other eco-farms, as for in the Netherlands. To export, a product packaging is designed and produced at the workshop to protect the pots (see chapter 6.2: Recommendations).

Producing a material from the pulp adds value by applying a simple production process with the use of low
resources (using partly waste streams and little tools/energy usage), which empowers the local entrepreneurs to build a production line with low investments, which creates local work. Therefore, this step is mainly of value for local communities and local entrepreneurs.

4. Export

Because eco-agriculture on Sint Maarten is a small market, trade with Dutch locations can support the project in its financial viability, but it can also promote the product. The pots are exported via wind-powered shipping, that follows the historical rum-trading routes. This wind-powered shipping is organized by the company Fair-transport and offers an affordable method for transport between the Caribbean and the Netherlands (estimatedly 0,003 c/pc. for 3 million seed starters) and guarantees 90% less CO2 emission than alternative transport methods (D. Meijer, personal communication, September 18, 2018). When transported with wind-transport, the product receives an ‘emission-free transport’ label.

Exporting the products is of value for the local government, creates the possibility to reach a larger market. It also creates the possibility to exchange knowledge on the material and the improvements between multiple contexts, which is of value for the farmers on eco-farms. The shipping label creates sustainable as well as emotional value for the product.
5. Sales

The price will be set differently for seaweed starters for the Sint Maarten market and the Dutch market, that could be calculated based on local income and expected sales per location.

6. Use

The first product (liquid fertilizer) that comes from the refinery step, can either be used to store the value of the product for local use, or it can be exported to different locations (the trade of fertilizer lies out of the scope of this project). The use of the product will be seasonal and will be used before seeding and once the plants start blooming.

The second product, the seedling starters can be used at local farms or at city-farms in the Netherlands. The use of these products will be seasonal as well and will be primarily be used during the seeding period. Next to this, this product will be used for educational purposes.

At the start the amount of users will be small and the time-of-use is short, since the product degrades after use. Therefore the impact will be small. Despite this, the use of seed-starters does add value by reducing the use of plastic in on the eco-farms. The use of liquid fertilizer on Sint-Maarten and around the Caribbean facilitates a local nutrient loop (to maintain or re-create a healthy eco-balance) and facilitates a natural source of fertilizers for farmers.

Image 72: Added value and concerned stakeholders
7. Research & Narratives

The input and output of narratives to next narratives is evolving over time. Narrative 1 and 2 that concern the convincing of the eco-farms as the first customers, and local entrepreneurs of the values, are told before realising this value chain (see narrative strategy, chapter 5.7).

Arriving at the stage that the value chain is set up, new markets or customers can be targeted which concerns narrative 3 (which again narrates the product advantages), designers are targeted to generate more seaweed-based designs through narrative 6 and knowledge gaps for research on material design and environmental impact are communicated to environmental organizations to support new research (narrative 7).

From both locations, product performance can be tracked in collaboration with the eco-farms.

From the location of Sint Maarten, this can be registered and improved at the research and development center for eco-agriculture (D. Wyatte, personal communication, July 24, 2018). In the Netherlands, this can be done by setting up a similar development center that is connected to the one in Sint-Maarten.

By combining the development center in the Netherlands with a local workshop and material shop, designers can be targeted to communicate the material's possibilities with. This facility will not as much be focused on production, but on material development and education.

The generation of stories and identification of knowledge gaps adds value by creating data for research and validation for application on a larger scale. Also, it contributes to the acceptance of the material from consumers. This mainly concerns research institutes and product/material designers.

8. Product Development

New product development will be done by combining research and practical insights from both locations.
5.6 Product evaluation

Functionality
The function of a natural fertilizer (requirement 1.1) is not applied in the seed-starter but integrated in the value chain as a separate product. Therefore, the seed starter does not meet this requirement, but the value chain does and might be able to do this even better (needs further analysis). The seed starter that is made from the waste-material from this process, still covers the functionality of protecting the seed (requirement 1.3), next to this, it improves the soil by serving a moisture holding agent.

Usability
The material shows better impact resistance (than sheet material) in this 3D shape, therefore the product can be worked with and carried around the farm without breaking (when handled with some care) (requirement 3.1). Also, the product is stackable (see image 74), but this is not quite optimal yet. This can be optimized by adapting the slope of the product. Also, because the shape was not supported in the drying process, the product deformed a bit because of its own weight, which also influenced the stackability negatively (see image 74). The product is recognisable as a seed-starter and the structure and color provide the indication that it will be alright to plant the pot together with the crop.

Reaction to water
When applying 10 cl of water, the product with the high proportion of pulp starts showing cracks (see image 73). This is because the pulp absorbs the water more quickly than the alginate can, which creates a variable (not uniform) swelling of the material. The prototypes showed that the product still manages to support the soil and most of the water, even with cracks. But, this depend son the location of where the material fails. Therefore the product does not meet requirement 1.4 (a daily 10 cl of water can be applied). The desire 1.7 (to withstand complete soaking in water) is not met at all: by doing this, the pulp swells way too quickly and the product completely falls apart (Appendix N: water test).

Freedom for the roots
The previous fault, does improve requirement 1.2. When cracks occur because of watering, space is created to make it easier for the roots to break through the material. From this it can be concluded that cracking of the material due to water is not desired, but a little bit of cracking will be convenient for the plant, and therefore acceptable. The actual interaction between the roots and the material needs to be tested further.

End of life
The requirements that concern the end-of-life need more time to be evaluated. The requirement to degrade within one year can be measured by a degradation accelerator. But the requirements to make sure that there are no harmful effects of salinisation and whether it has a positive effect on the soil on the long term, are to be predicted with the help of independent agricultural experts.

Costs
Requirement 5.1 that concerns the maximum material costs of 10 cents very well realisable. Looking further into the costs, difficulties will lie within the labor costs, this is mainly because the process is still rather slow (estimated 2 minutes per piece (not meeting requirement 6.2 of the maximum of 1 minute per piece). When producing 3000 pieces by one person that is paid 5 euro’s per hour in the Caribbean (which is expected to be to fulfill the market on solely Sint Maarten per year (D.Wyatte, personal communication, July 24, 2018)) the labor costs are 17 cents per piece. The production process will therefore need some optimization. Other production costs will be low, because the tooling investments are low (below 200 euro’s for a set-up served by 1 person) and the process requires no heat or electricity (see appendix M; cost estimations).

Ingredient resources
Requirement 7.1, that demands to harvest the Sargassum from the sea, is realisable to control since the harvest is done locally. Within the value chain, it is important to be prepared to harvest when seaweed flows in, and have sufficient stock when the situation is relatively stable. This is taken into account by processing the seaweed into conservable products directly (requirement 7.2). More thorough analysis is needed on the periods of seaweed plague invasions, to adapt the value chain to the seaweed flows. A supplier for alginate will need to be selected on alginate quality grade, its level of transparency, on affordability and being the nearest supplier, this will need a more thorough analysis.

Transport
Since the products are to be transported, and the method to have the lowest CO2 impact (desire 8.2) was by wind-powered sea transport, the products are going to have to withstand quite some forces and have to be protected well by their packaging. This packaging will also communicate the product advantages and will therefore be the narrative medium. This packaging has to be designed in a further stage (see chapter 6.2: recommendations).
Image 73: Cracks after adding water (the pulp absorbs the water faster than the alginate).

Image 74: Stackability is not optimal
Seaweed starters within the seed-starter market
Next to being a functional and producible product, a crucial question is whether it could replace plastic products within agriculture. Therefore it is regarded how this product performs in comparison with other seed starters within the context of a hobby gardening market (so not yet within professional agriculture).

Plastic seed starters are a financial attractive option, since they are reusable and therefore most affordable. But once they are damaged, they are disposed, or pieces of plastic end up in the soil. There are biobased alternatives on the market, so it will be regarded whether seaweed starters could be competitive here. Within the market, there are starters from plastic, peat, coir and paper. In image 75, these are compared on their price, biodegradability, whether it is from a renewable resource, its reusability and its moisture holding capacity.

Plastic seed starters are often made from LDPE or PP. The consumer price for these pots have a range of 14 cents to 40 cents per piece. As trays, the price per cavity can be as low as 8 cents (dehobbytuinder.nl, 2018).

Peat pots are made from pressed wood fibres, peat and chalk. The consumer price for these pots can also be as low as 8 cents per piece (dehobbytuinder.nl, 2018).

These pots are also meant to plant into the soil; they are biodegradable and roots can grow through the material. Peat has many advantages as a seed starter, by being a clean medium to grow in and by holding moisture really well. The downsides of peat is that it is a very slowly-renewable source. Furthermore, it is low in nutrients (Greenandvibrant, 2017).

Coir seed starters (from coconut fibres) are regarded as to be better for the environment, since they are biodegradable as well as renewable. They are available on the market for around 18 cents per piece. The disadvantage of these pots are that the soil dries out quickly, because the fibers enhance evaporation and mould seems to occur quickly (D.J. Vos, personal communication, April 25, 2018).

Seed starters from recycled paper-pulp are another alternative. These are also biodegradable and are available for 16 cents (Stek de stadstuinwinkel, personal communication, October 10, 2018).

Seaweed starters, are from a renewable source, theoretically biodegradable (needs further testing) and improve the soil by holding moisture. Regarding environmental values and soil wellness, this product can excel over the others. Seen price, the price should target at 0,20 per piece to act in the same price ranges.

Image 75: Alternative products: LDPE (tuinadvies, 2018), Peat (Bakker, 2018), coir (North-pole exporters, 2018) and seaweed prototype
Image 76: Seaweed seed starter (enlarged)
5.7 Narrative overview

**Narrative & stakeholder overview**

The stakeholders that are mentioned in chapter 2.3 form the basis of the narrative strategy which is explained in the roadmap, which concerned the stakeholders within a Dutch seaweed industry. Focusing on the combination of markets (of Sint-Maarten and the Netherlands), additional new stakeholders are desired to reach, that will be strongly involved concerning the development of a new value chain within eco-agriculture. The goal is to create an overview of these stakeholders, what part of the story of the seaweed starters they are interested in, and with what means these stakeholders can be reached.

Image 77 shows the overview. The inner circles mention the stakeholders. The outer circles mention firstly the main interests for each stakeholder (based on stakeholder interests in chapter 2.5 and the added values within phase 1) and secondly, the means on how to communicate these interests, which are explored through a brainstorm session (appendix O: Narrative brainstorm). The order of convincing stakeholders is based on the narrative strategy (chapter 4) and can be read by following the circles clockwise. The colors represent the different narratives on which the order is based on (see the legend).

**Eco-farms (Sint-Maarten & Netherlands)**
The targeted consumers are eco-farms, on Sint Maarten and in the Netherlands. Since eco-agriculture is still in development on Sint-Maarten, Spaceless Gardens is one of the few/the only initiative. The interests of the eco-farm on Sint Maarten is expected to be on the contribution of the product to eco-agriculture and on knowledge exchange (see chapter 5.1.3: customer value). The main interest of eco-farms in the Netherlands is expected to be on the contribution to eco-farming, as well as a contribution to events/activities, and on how they can expandSCALE their impact as a local farm on a viable way. These interests can be communicated by firstly facilitating test-packs of the product, in order to experience the product advantages. These test-packs can be converted into workshop material later that the farms can use to spread insights.

**Entrepreneurs (Sint-Maarten)**
The next stakeholder to reach are entrepreneurs at Sint Maarten, which are involved closely in a new value chain. These are entrepreneurs in the tourism- and fishing industry. These industries, that used to be the main industries on the island, have suffered largely from the seaweed plague and hurricane damage. Their main interest would be in the possible impact of a value chain on the improvement of the environment and on the possibilities to create new industries with new jobs and possible export products. A medium to communicate this can be informative meetings that discuss long-term visions, the viability of the value chain and impact on the environment.

**Hobby gardeners**
If the market of the small eco-farm is saturated in these two contexts, the market can be expanded to new customer segments. The segment that is closest to the city farms is ‘gardening’ since gardeners are often visitors of the city-farms. The product advantages that this consumer is interested in does not necessarily concern the informative background, but to create an easier process of growing vegetables at home as well as the eco-friendliness of the product, and ways to expand impact. This customer can be reached by exposing the product on events or workshops on the city-farm, it can be sold in the city-farm shops or gardening centers, and the product can be promoted by gardening vloggers or on public billboards.

**Designers**
The next stakeholders, that is relevant for the development of the material, are designers/developers. Their interests concern accessibility, usability, and producibility of the material. The material can be made accessible through the set-up of local seaweed shop/workshop combinations, where different materials can be bought and experimented with. Here, designers and students can receive updates on the origins, developments, and possibilities. Next to this, via expositions and material workshops, the material can generate exposure to multiple designers.

**Environmental organizations**
The end of the stakeholder circle concerns environmental organizations as well as research institutions. Their main interest is the impact of the set-up value chain on pollution alleviation of fertilizers and seaweed, as well as sea life protection. Also, knowledge gaps are an interest to set up new research. This can be done by broadcasting video’s on the beach, taking cyclic water samples and keeping up impact reports.

**Towards new locations and new phases**
All the input from the previous narratives can be used to discover and convince new locations with the same product and value chain, or if the material has developed sufficiently, a new phase can be entered to a higher value-application.
6. WRAP UP

6.1 Discussion
6.2 Recommendations
6.3 Reflection
6.1 Discussion

Within the discussion, the results of this project are linked back to the topics of the three main research questions (see chapter 1.2). For some of the topics, important side notes are highlighted, among which possible side effects/points of are highlighted. These side notes were retrieved through own reflection, as well as reflection together with Tjeerd Veenhoven (designer/material designer) and Dirk Jan Vos (Seaweed biorefinery, with experience in the industrial sector).

Is the designed seaweed material suitable for industrial applications?

Because most industrial processes (within the plastic industry) are not designed to work with the alginate material yet, it is not directly suitable for industrial applications. Since research is currently done on thermo-mechanical mixing of alginate (Gao, 2016), it could very well be that techniques will become available that can slow down the reaction of alginate, making it possible to realize more complicated production processes. If this time is there, and the characteristics of this material are known through many practical insights, it will be suitable for industrial applications.

Therefore I think that currently the material is not suitable for industrial applications, but could very well be in the future.

In the meantime, the material is suitable for scaling up, through a local-global approach. Whereas with low threshold value chains, multiple initiatives can be realized, with smaller enterprises but an overall scalable impact.

Can you design around value clashes?

Within the project, value clashes are identified between small-scale and large-scale stakeholders. The difficulty within the design of the roadmap concerns how to deal with those. The solutions that are integrated into the roadmap are either based on empowering small-scale stakeholders to convince large-scale stakeholders, others to create more independence from large-scale stakeholders. But one way or the other, the value clashes are going to occur somewhere in the roadmap once the material would be industrialized. So I do not think it is possible to design around value clashes, but I think that the material development does not have to be disturbed by them.

Can the material be considered as mature at the end of the roadmap?

Within the project, a mature material was defined as being mature, when it is accessible to consumers and other businesses, serving viable business cases that are independent of funding and applicable for up-scale applications, with respect to its environment.

At the end of the roadmap, the goal is to adapt to industrial processes, therefore the material will be accessible to a large group of consumers. Also, by then the material has been applied to multiple markets, so it will be accessible to different businesses.

The points of discussion concern firstly whether the material would be viable. The applications that are of low economic value, could lower even more in value per piece, when they are scaled up. The question then is whether the value chain can remain viable, or that more high valued applications need to be implemented. In the roadmap, this is addressed by introducing more highly valued applications (building and safety material) in the second phase. It is still questionable whether this will be of enough economic value.

Secondly, a point of discussion concerns the methods on how to protect the exploitation of resources once being adapted to industrial processes. Within the roadmap, this is addressed by creating a platform in which knowledge can be shared, but also which members can control each other on careful handling of resources. For this, concrete guidelines will have to be formed to create a realistic view of what use of certain seaweeds on certain locations is acceptable (see recommendations). At this point, it is too early to form an opinion on this.

What are the risks of introducing new value chains and scaling bio-based industries through a local-global approach??

For seaweed materials, a local-global approach will be almost the only way to deal with the variable accessibility of resources, but this approach is also a popular and idealistic way of scaling up. Because it is this new, and not proven yet, it is a risky decision that needs further considerations on the consequences of pushing such a new strategy.

If this transition would be successful, it will mean that traditional value chains will be disturbed, which will disturb the economy as well. This can have large effects on local entrepreneurs and citizens. Next to this, the rising demand for bioplastics will form competition with food. The richer population will have access to bioplastics, but the poorer population will notice the consequences of food scarcity. For the project I chose for alginate to have least direct competition, but in the end are brown seaweeds also edible and therefore also competition with food.

Seaweed does have an advantage over biomaterials coming from land, because there is more sea-surface available for cultivation.

Another risk of scaling biomaterials is that nutrient flows can be disturbed when nutrients/elements are retrieved from one location and end up on other locations. This could exhaust particular areas.
The Sargassum could be contaminated with plastic, oil, and metals, so it needs careful research on the safety of the processing to guarantee no contamination of the eco-farms.

Another risk by introducing this value chain on Sint Maarten is that people become dependent on a possibly not permanent industry, because the seaweed is a plague. Therefore there must be plans for times when the seaweed plague is over (like cultivation plans).

What are the risks of introducing this product right away?

What should be the time scale of the roadmap?

The Sargassum could be contaminated with plastic, oil, and metals, so it needs careful research on the safety of the processing to guarantee no contamination of the eco-farms.

Another risk by introducing this value chain on Sint Maarten is that people become dependent on a possibly not permanent industry, because the seaweed is a plague. Therefore there must be plans for times when the seaweed plague is over (like cultivation plans).

The time scale depends a lot on the empowerment of the roadmap. With a large collaborative and investments that can be used for the needed researches, I think that the first phase should be completable in 4-5 years. The further phases are very difficult to predict since it will depend on the readiness of still to be developed techniques.

Since there is a lot of pressure on the time for a transition towards a biobased economy (according to the UN, transitions towards a bio-based economy should be realized within 12 years in order to maintain a livable environment), I think that it is important to start with implementations and trials (while taking into regard and being open about the risks) and not wait for the development of advanced techniques. So I think it will be a viable investment to invest in any strategy that points towards a bio-based material that can be applied to multiple markets.
6.2 Recommendations

The recommendations that come forth from this project first of all concern the required researches and analyses for the 'knowledge' steps that are proposed within the roadmap (chapter 4). Secondly, recommendations are proposed concerning product design improvements of the product for the first phase (seaweed starters). Then, recommendations for packaging design are proposed, which concern the first narrative of the strategy. From the value chain design, recommendations concern a supplier analysis and an analysis to determine the right seasons of seaweed flow for harvesting and processing. Furthermore, the roadmap demands for extension of locations, so it is recommended as well to set up an exploration for other fit locations to possibly extend to.

Required researches and activities within the roadmap

**Product evaluation and marketing strategy [A3]**
From the first prototypes, the first reactions, the first product and process validation, and improvements come forth. When validation is sufficient, it is valuable to set up a marketing strategy for the customers within the first narrative circle (eco-farms and hobby gardeners). To do so, it is recommended to create a brand identity and a branding-strategy to reach the right audiences with the right message. This can be supported with tools within the method 'Brand the change', (Miltenburg, 2017) and cooperation with marketing experts.

**Market analysis [A4]**
A market analysis is performed to specify and validate future markets, within agriculture but also within the building industry and the packaging industry. Here, it is recommended to also explore more high-value applications, for example, medical or wellness products (see: risks of scaling in Chapter 6: Discussion').

**Impact analysis [A5]**
For the impact analysis, it will be recommended to prospect on firstly the environmental impact (which concerns CO2 reduction, plague alleviation and alleviation on nutrient pollution, but also possible salinization of the soil and the risks of polluted seaweed). Secondly, it will be needed to prospect on local economic impact (which concerns the creation of exportable products, but also should concern the economic dependency of the community on a new industry). Thirdly, it will be needed to prospect on social impact (concerning the creation of jobs, but also the job safety, and possible health hazards that could accompany the application of seaweed processing activities or the application of seaweed products in agriculture). Besides this, it would be really interesting to do a life cycle assessment (LCA) on the seaweed seed starter and compare this with the alternatives of plastic, peat, paper, and coir.

**Material validation [A6]**
The material characteristics that were explored within the project through tinkering, should be validated before communicating the material characteristics to other designers/businesses. It is recommended to do this through careful repeated testing with multiple samples.

**Long-term feedback setup [A7]**
Throughout the roadmap is kept track of practical feedback of the impact. It is recommended to plan beforehand what feedback will be most important for impact analyses to avoid large quantities of data in later stages.

**Advantages of transparency [G6]**
The value clash that concerns transparency (see value clashes chapter xx), is going to occur somewhere along the roadmap once the material is adapted by industrial processes. May it be concerning transparency of the process, finances or resources. It is estimated that it takes time to explore the advantages for businesses of transparency, in order to convince large-scale stakeholders. Therefore, within the first activities, it is recommended to explore these advantages and provide practical prove and narrate how this transparent way of working would look like for large-scale stakeholders (in the narrative: values in phase 2, see roadmap chapter 4).

**Material improvements: odor, fragility**
Odor and fragility will need improvements to reach new markets in the further phases. For fragility, it is recommended to explore and experiment with other additives or fillers and different alginate qualities. For odor, repeated washing of the seaweed is recommended as well as fast processing of the seaweed (to avoid rotting).

**Process improvements: extraction process, thermo-mechanical mixing, recycling of alginate**
Important process improvements to realise the roadmap steps are an improvement of the extraction process of alginate (how can the alginate be extracted locally on a through viable and environmental friendly methods), exploration of thermo-mechanical mixing (how can this method be applied to the designed material?) and possibility exploration of the recycling of alginate (how can the material be recycled in a cost-efficient way and for what applications could this be valuable?). For all these themes, a close collaboration with experts and researchers within these fields are recommended.

**Material characteristics tests: flame retardancy, food safety**
Concerning thorough material characteristics tests, flame retardancy and food safety, close collaboration with laboratories is required.
The narrative platform is going to play an important role in sharing knowledge between enterprises and different locations, in attracting new enterprises and locations, but also in being able to control different enterprises on the use of their resources. For this, it is recommended to explore the required guidelines for acceptable industries.

Exploring other locations and markets
When expanding to different locations, it is recommended to map out possible resources of abundant seaweed, knowledge, and markets, that could be fit for this approach.

Seasons of seaweed flow
Concerning the steps in the designed value chain, it is recommended to plan these steps according to the seaweed flows. The seaweed plague knows several peaks around the year. Therefore, it should be best to gain insight on the timing of these peaks and have the capacity to process the seaweeds around these times.

Supplier analysis
To produce the material, alginate and glycerol will have to be imported. Here it is recommended to do a thorough supplier analysis, evaluating price, process transparency and distance to Sint-Maarten.

Design from a consumer approach
Within this design process was mostly focused on a technique and on the circumstances of the material, followed by stimulating the acceptance of stakeholders. Designing from this approach can be regarded as a push-approach.

If the focus will be laid a bit more on the consumer (pull-approach, which is compatible with the Material Driven Design method), it could result in different products/markets. It would be interesting to do a design project with such an approach, and see if there are markets that show overlap. Maybe these overlapping markets could be the strongest ones.
6.3 Reflection

Process

Broad approach
The start of the project consisted out of very broad questions. They concerned a new material from seaweed, an application of it, the question on how to scale this for industrial applications, and the question of how to protect values within scaling. I chose this broad approach because biomaterials and industrialization felt contradictional, which it also appeared to be. Taking the broad approach, which I was warned for, made the project complicated at certain points, but it did provide me with way more understanding on why this was a complicated question.

The disadvantage of the broad approach was that I spend a lot of time out of my comfort zone, by trying to find my way in strategic design, and in the fields of biology and chemistry and in markets as agriculture in the Caribbean. I did find some comfort in material tinkering, whereas this feels like a more natural approach. Unfortunately, I did not manage to dive that deeply into the material, because my scope was really broad and demanded much of the time.

Practical approach
Because the themes within strategic design were sometimes too abstract to me, I turned into a very practical approach. By talking to many stakeholders, doing material tests together, and asking for feedback, I think I gained a lot of realistic insights. But, these insights are also retrieved within a certain bubble within the industry. I tried to compare the insights with existing literature, but I think that it is difficult to capture values and strategies in a scientific approach since it is variable per situation, person and moment. In my approach, I tried to validate certain values with other stakeholders to see if they would agree. I think that this was a faster and more efficient way of validating to facilitate decision making, but to make it concrete, qualitative tests should have been conducted.

Converging
Because of the broad approach, it cost me a lot of time to converge all the insights into a clear story. It took a couple of iterations to lay new links and to improve the communication of it. I think this is also because the start of the roadmap is quite concrete, but by going further into the roadmap it becomes speculative. The balance of what to keep abstract and what to elaborate on was quite difficult.

Methodology

Material tinkering
Tinkering was a pleasant approach to experiment with the material and continue on practical insights. Sometimes it is difficult to understand what is happening because biologic or chemical insights are missing. On one side it was an advantage that I missed certain biologic or chemical insights, resulting in more explorative experiments. On the other side, sometimes blunt assumptions are made by not completely understanding a phenomenon. For instance, the hypothesis was set that alcohol can break down the cell-walls and activate alginate, or that seagull-poop might be able to reverse the binding reaction of alginates and facilitate recycling. This kind of thoughts formed the basis of most experiments. In reality, they are way more complicated than an opportunistic approach can reply to. This can be of value when exploring new insights, but not suitable for drawing hard conclusions.

Benchmarking
Within the project, benchmarking served as a functional tool to get familiar with the industry and active designers in the field. I found it an important step but it was also a frustrating step because it was never finished. Firstly because it is a fast-emerging field and new applications keep on appearing. Also, because along the way, an understanding of the material and project grew, and my understanding of the benchmark changed as well. I first saw it more as a tool that is used at the beginning of your project, but in future projects, I think I will apply this more as a side activity to create an understanding of the material and source you are working with, understand specific choices of other designers and keep up with developments.

Value exploration tool
To explore the values of stakeholders that are involved in a possible dutch seaweed industry, I set up an own format of values to use as a conversation starter. I deliberately did not draw direct conclusions from the ‘value exploration tool’, since the tool was not elaborated enough to provide a fair judgment. It did help me to talk to many people on the networking event, as I did not have to introduce to all people myself because the forms did the work of introducing the subject and the matter and people could approach me as well when they were interested.

Narratives
At the start of the project, I focused on narratives to support the convincing of stakeholders. In the design phase, I started on the writing of a more general narrative, before I finished the narrative strategy. This narrative had the form of animation episodes. Unfortunately, I lost the file of the narrative, which was quite a set-down, but I also realized then that a general narrative that communicates the impact, as well as the advantages, as well as the possible markets, was not going to convince specific customers separately. Therefore it was better to spend more time on a suitable outline for the narratives that
focus on specific interests of stakeholders, than trying to re-make the original narrative. It would have been a more concrete story when I would have had the time to write one of the narratives in the form of the packaging for the first product. Unfortunately, this did not fit in the time scope anymore and was not of added value to the initial research questions.

**Harris profile**
This classic tool helped me to cluster my argumentations for different materials. I struggled a lot to find my way through different arguments for different extracts and organizing these arguments into themes clarified the situation. Normally, a Harris profile assesses multiple concepts on requirements. Because I used arguments to judge multiple scenarios, the arguments were not all measurable and therefore can only be regarded as a decision guideline.

**Context Variation by Design**
This method helped me to identify opportunities and challenges that arise from combining two contexts. I think that when I would not have used this method, I would have focused more on Sint Maarten. Being quite a small market and therefore difficult to create a viable value chain, I think I would have faced stuckness there. The other way around, I think that if I only would have focused on the Netherlands, I think that also not all the required resources would have been accessible. CVD was useful here to generate an overview of the possibilities of how markets/products/activities can be combined or contribute to each other.

Furthermore, I think that a multi-context approach can be valuable within the development of natural materials in general because it occurs more often that it is necessary to combine contexts to exploit certain resources. Also, it was also useful within material design because context insights and material insights could be linked.

Thirdly, I used the ‘context variation’ mentality of ‘embracing complexity’ to be able to address certain value clashes between stakeholders within the strategy. Within this, I allowed the material to be developed on different levels of complexity, designed for multiple applications so that industries can more easily find common ground with the material.

**Roadmapping**
Roadmapping was quite a complex process at the start, but after some iterations, it helped me in keeping an overview on the relations between the different elements.

**Stakeholder overview**
The stakeholder overview that was used to visualize the narrative strategy for phase 1, was a useful format in visualizing the stakeholders in a certain scope (here, phase 1).

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**Personal development**

**Strategic design**
It took quite some time and iterations within the design to understand certain strategic concepts that I wanted to apply. The concept of a value chain was abstract for me and it was sometimes confusing to distinguish between ‘value exchange within stakeholder interactions’, ‘adding value to the material’, and ‘identifying values of stakeholders’, which were all quite different concepts that were addressed within the project. I am quite happy with the result of identified values for small and large-scale stakeholders on the one hand (that appeared to be recognizable among stakeholders), and the designed value chain of the material, in which I feel to have succeeded to make a distinction between the two and in eventually finding the right terminology and format to communicate the insights.

With technology roadmapping I was already familiar from a previous course, which was quite helpful and hopefully served as a link between the technical and strategic approach.

The aspect that I can improve on is to develop a better insight into the viability and financial side of concepts. I noticed I got really stuck when I was asked to think of a business plan. I talked to many people about it that had more understanding of business plans, and I did some attempts to write something useful on it, but in the end, this area is still fuzzy to me. I do not have the ambition to write business plans myself, but it would be nice in the future to take certain aspects into account in the process.

**Biotechnology**
Working with the seaweed material drew my attention to biodesign and biotechnology. Throughout the project, I got in touch with many inspiring projects within this field and I would find it really interesting to develop further within this direction.

**Better understanding of transitions**
During the project, my attitude towards transitions changed in a way that I have a better understanding of why certain parties make certain decisions. Before, I felt as if my industrial stakeholders were not willing to make a transition for financial and power-related reasons, now I realize that it is a bit more complicated and understand the importance of creating the right circumstances before starting a transition.

**Realistic planning**
Many times, I underestimated the time that was required for certain activities. Then I also tended to continue to new subjects before working out the earlier actions, which resulted in quite a pile of writing-work to get through at the end of the project. But then I am also glad that I had this freedom of exploring many sides of the subjects and trying out all different kind of things in different places and with different people and opinions. I enjoyed that part!
7. References


Zurlo, F., Cautela, C. (2014) Design strategies in different narrative frames. Massachusetts Institute of Technology, Design Issues: Volume 30, Number 1

8. Contact list

The following contacts were involved in the value analysis, strategy analysis, context exploration, validations and reflections throughout the project.

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E-mail contact, 16-02-2018

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Veenhoven, T.
Material designer, Studio Tjeerd Veenhoven
Reflective discussion, 09.10.2018

Vos, D.J.
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Designer and operator of a seaweed refinery
In cooperation with Huberts Biological Flowerbulb, St-Maartensvlotburg.
Meeting, test-sessions, reflection,
25-4-2018, 10-8-2018, 11-10-2018

Wouters, J.
Consultant and entrepreneur (The Seaweed Company)
Meeting/discussion, 4-6-2018

Wyatte, D.
Agricultural entrepreneur at Sint Maarten
Email contact, 24-7-2018