APPENDIX

DESIGN AND MATURATION OF A SEAWEED MATERIAL

PIEK KÜPPERS
MASTER THESIS
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A. VALUE EXPLORATION CARDS

The value mapping cards were made as a tool for a conversation starter on values with stakeholders inside the seaweed industry in the Netherlands. The cards were spread at Stichting Noordzeepreparatie, Kick-off meeting: a seaweed eco-system, March 22, 2018.

---

Value mapping card
Name: H.A. van Elk
Company/initiative/sector: Stichting Noordzeepreparatie
Profession/function: Entrepreneur
Background: 

This value mapping card is part of my graduation research at the TU Delft on how to scale-up design with seaweed and stimulate its acceptance.

You might share or concern many of these values, but please tick only the 3 most important values for you, within your business.

☐ Local
☐ Certainty
☐ Transparency
☐ Customer education
☐ Recyclability
☐ Biodegradability
☐ Investing capability
☐ Newness
☐ Fundraising
☐ Financial growth
☐ Social contribution

Explanation/Comment:

Want to know more? Contact me: pielikuppers@gmail.com
Value mapping card

Name: Dick Jan-Van
Company/initiativesector: EANAVAN.
Profession/function: Director: Levensmid.
Background: HDA-Levensmid, Marketing.

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Explain/comment: [Handwritten notes]

Want to know more? Contact me: piekkuppers@gmail.com

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Value mapping card

Name: Hans Bloemink
Company/initiativesector: Xanix Group.
Profession/function: Director: Levensmid.
Background: Xanix Group.

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☐ Financial growth
☐ Social contribution

Explain/comment: [Handwritten notes]

Want to know more? Contact me: piekkuppers@gmail.com
## B. BENCHMARK ANALYSIS

### FOOD

<table>
<thead>
<tr>
<th>Name</th>
<th>Non Sushi</th>
<th>Agar agar</th>
<th>Surimi/crab sticks</th>
<th>Wakame salad</th>
<th>Weed burger</th>
<th>Spirulina burger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Natural, dried</td>
<td>Extract, comparable with gelatin</td>
<td>Alginate</td>
<td>Natural, fresh</td>
<td>Natural, dried</td>
<td>Natural, dried</td>
</tr>
<tr>
<td>Source</td>
<td>cultivated red seaweed</td>
<td>extract from red seaweed</td>
<td>extract from brown seaweed</td>
<td>cultivated green seaweed</td>
<td>cultivated green seaweed</td>
<td>cultivated algae</td>
</tr>
<tr>
<td>Maturity</td>
<td>Industrial</td>
<td>Industrial</td>
<td>Industrial</td>
<td>on market</td>
<td>on market</td>
<td>Industrial</td>
</tr>
<tr>
<td>Natural experience</td>
<td>Apparent naturalness</td>
<td>Low naturalness</td>
<td>Low naturalness</td>
<td>High naturalness</td>
<td>Apparent naturalness</td>
<td>Medium naturalness</td>
</tr>
</tbody>
</table>

### MEDICAL

<table>
<thead>
<tr>
<th>Name</th>
<th>Dent cast</th>
<th>Wound dressing</th>
<th>Medicins</th>
<th>Biocompatible implants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Alginate</td>
<td>Alginate</td>
<td>alg</td>
<td>Extract from green seaweed</td>
</tr>
<tr>
<td>Source</td>
<td>extract from brown seaweed</td>
<td>extract from brown seaweed</td>
<td>cultivated/harvested seaweeds</td>
<td>cultivated green seaweed</td>
</tr>
<tr>
<td>Maturity</td>
<td>Industrial</td>
<td>Industrial</td>
<td>Industrial</td>
<td>Research</td>
</tr>
<tr>
<td>Natural experience</td>
<td>Low naturalness</td>
<td>Low naturalness</td>
<td>Medium naturalness</td>
<td>Low naturalness</td>
</tr>
</tbody>
</table>

### FASHION

<table>
<thead>
<tr>
<th>Name</th>
<th>Algae fabrics</th>
<th>Dies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Cellulose</td>
<td>Color extracts</td>
</tr>
<tr>
<td>Source</td>
<td>Cultivated fresh water algae</td>
<td>Extracts from div seaweeds</td>
</tr>
<tr>
<td>Maturity</td>
<td>Development</td>
<td>Development</td>
</tr>
<tr>
<td>Natural experience</td>
<td>High naturalness</td>
<td>Apparent naturalness</td>
</tr>
</tbody>
</table>

### AGRICULTURE

<table>
<thead>
<tr>
<th>Name</th>
<th>Kettle feed</th>
<th>Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Sea seaweeds</td>
<td>Sea seaweeds</td>
</tr>
<tr>
<td>Source</td>
<td>Cultivated / harvested weeds</td>
<td>Cultivated / harvested weeds</td>
</tr>
<tr>
<td>Maturity</td>
<td>On the market</td>
<td>On the market</td>
</tr>
<tr>
<td>Natural experience</td>
<td>Medium naturalness</td>
<td>High naturalness</td>
</tr>
</tbody>
</table>
### Packaging

<table>
<thead>
<tr>
<th>Name</th>
<th>Ocho edible waterpackage</th>
<th>Algae water bottle</th>
<th>Algaspack</th>
<th>Evoware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Unknown extract</td>
<td>Agar agar</td>
<td>Fresh water algae</td>
<td>Agar agar</td>
</tr>
<tr>
<td>Source</td>
<td>Unknown seaweed</td>
<td>extract from red seaweed</td>
<td>Harvested from plagues</td>
<td>extract from red seaweed</td>
</tr>
<tr>
<td>Maturity</td>
<td>Development</td>
<td>Concept</td>
<td>Concept</td>
<td>on-market</td>
</tr>
<tr>
<td>Natural experience</td>
<td>Low naturiness</td>
<td>High naturiness</td>
<td>High naturiness</td>
<td>Apparent naturiness</td>
</tr>
</tbody>
</table>

### Interior

<table>
<thead>
<tr>
<th>Name</th>
<th>Glassware</th>
<th>Terroir</th>
<th>Zeewier lamp</th>
<th>Algopak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Unknown extract</td>
<td>Pulp + paper</td>
<td>Uva</td>
<td>Alginate</td>
</tr>
<tr>
<td>Source</td>
<td>Unknown seaweed</td>
<td>Collected from shore</td>
<td>Self-cultivated</td>
<td>Extract from brown seaweed</td>
</tr>
<tr>
<td>Maturity</td>
<td>On exclusive market</td>
<td>On exclusive market</td>
<td>On market</td>
<td>Industrial</td>
</tr>
<tr>
<td>Natural experience</td>
<td>Medium naturiness</td>
<td>High naturiness</td>
<td>High naturiness</td>
<td>Medium naturiness</td>
</tr>
</tbody>
</table>
C. TABLE OF CARBOHYDRATE CONTENTS OF MACRO-ALGAE

Table 3. Carbohydrates present in green, red and brown algae, microalgae and terrestrial biomass (Jung et al., 2013). Mind the division in polysaccharide and monosaccharide for macroalgae.

<table>
<thead>
<tr>
<th>Macroalgae</th>
<th>Green algae</th>
<th>Red algae</th>
<th>Brown algae</th>
<th>Micr algae</th>
<th>Lignocellulose biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysaccharide</td>
<td>Polysaccharide</td>
<td>Polysaccharide</td>
<td>Polysaccharide</td>
<td>Starch</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Mannan</td>
<td>Carragenan</td>
<td>Laminarin</td>
<td>Mannitol</td>
<td>Total carbohydrate</td>
<td>Hemicellulose</td>
</tr>
<tr>
<td>Ulvan</td>
<td>Agar</td>
<td>Agaritine</td>
<td>Arabinose</td>
<td>Fucose</td>
<td>Lignin</td>
</tr>
<tr>
<td>Starch</td>
<td>Cellulose</td>
<td>Fucoidin</td>
<td>Galactose</td>
<td>Glucose</td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>Lignin</td>
<td>Cellulose</td>
<td>Mannose</td>
<td>Mannose</td>
<td></td>
</tr>
<tr>
<td>Monosaccharide</td>
<td>Monosaccharide</td>
<td>Glucose</td>
<td>Glucose</td>
<td>Rhamnose</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>Glucose</td>
<td>Monosaccharide</td>
<td>Galactose</td>
<td>Ribose</td>
<td></td>
</tr>
<tr>
<td>Mannose</td>
<td>Galactose</td>
<td>Oligosaccharide</td>
<td>Xylose</td>
<td>Xylose</td>
<td></td>
</tr>
<tr>
<td>Rhamnose</td>
<td>Agarose</td>
<td>Uronic acid</td>
<td>Uranic acid</td>
<td>Mannoic acid</td>
<td></td>
</tr>
<tr>
<td>Xylose</td>
<td>Glucose</td>
<td>Mannuronic acid</td>
<td>Galacturonic acid</td>
<td>Glucuronic acid</td>
<td></td>
</tr>
</tbody>
</table>


Adjusted table by Boonstra (2015)
D. EXTRACTION OF ALGINATE

Steps of the extraction process of alginate, described in McHugh (2013)
E. MATERIAL TINKERING

Test 1: Forming material from alginate

Image 1: water and sodium-alginate

Image 2: mixing
Image 3: flexible gelled alginate

Image 4: dried alginate
Test 2: recycling of alginate

Test setup and steps
1. Salt solutions are made and blended with calcium-alginate in order to facilitate a possible ion-exchange.

   A) Natronloog solution
   [400 g water + 4 gr NaOH + 8 g Calcium-alginate]

   B) Soda solution
   [300 g water + <1 g Soda + 2 g Calcium-alginate]

   C) Salt (kitchen) solution
   [300 g water + 3 g salt + 2 g calcium-alginate]

   D) Salpeter solution
   [300 g water + 10 g Salpeter + 2 g calcium alginate]

2. After two days, the non-dissolved material is filtered. The residu is collected (this is the calcium-alginate that did not convert into sodium-alginate). The filtrate is evaporated (image 5). The residue should be sodium-alginate.

3. Then the dry powder is mixed with water again to see if new connections are made (Image 7)
Results solution & evaporation:
- Soda solution: only a small part of the calcium alginate is soluble in the solution. The remaining material after the steps of the recycling process is very small.
- Kitchen salt solution: more resulting material
- Salpeter salt solution: most resulting material
(image 6, previous page)

Note: it is not sure what part of the filtrate powder is salt that has not reacted with the alginate salt and what is sodium-alginate. There is no proof whether any calcium-alginate is converted into sodium-alginate at all.

Results re-producing:
The dried out material is very brittle, little connections seem to be made. From this, it is more likely that only salts were left in the filtrate (image 8).

Conclusion:
The amount of water needed for recycling is enormous, if for 2 gram, 300 gram water is not even enough to make the alginate solve, it can be estimated that for a 2 gram product, around 2 L might be needed. Therefore, recycling does not seem worth it, seeing how much water and electricity it takes to actually down-cycle (material properties become less).

Recommendations:
Recycling could be done by grinding the calcium-alginate and adding sodium-alginate. This is also a form of down-cycling.
Test 3: Preparing raw seaweed

Image 9: Drying the seaweed with incubator at BlueCity,

Image 10: Grinded seaweeds: a) Sargassum muticum b) Ascophyllum nodosum c) Fucus vesiculosus
Test 4: Alcohol

The three types of seaweed were retrieved from the Eastern Scheldt (see Appendix F). The seaweeds were dried, grinded and treated with alcohol. After drying, changes were visible but no material connections were made. This method therefore will require to be followed by more steps.
Test 5: Rennet

To test the possibilities of rennet as a conversion enzyme, *Ascophyllum nodosum* was placed in a blender (because it is hard to grind, see previous tinkering test). The slimy substance that came out of the blender was a suitable base-material to add rennet to. Rennet seems to be a promising agent for material forming, but it needs less water content and more forming pressure. Another disadvantage that arises is the long waiting time before the enzymes starts working.
Test 6: Alginate + pulp

Image 15: first test of mixing pulp with alginate
Test 7: Preparing waste-pulp

Image 16: waste pulp from bio-refinery process

Image 17: Drying the waste-pulp
Why re-proportion?

Re-proportioning the biological content of seaweed shows advantages for material development and scaling up a seaweed material industry. It makes the material easier to control in the production process, it helps in the translation process of a concept to different contexts and it facilitates to integrate the newest research directly into product production.

Introducing the base ingredients:

- **Alginate**: functions as the binding element for the material.
- **Pulp** functions as the matrix filling.
- **Water**: is the starter of the alginate gelation reaction and opens the pulp fibers.
- **Glycerol**: adds a slight flexibility to the material.

Getting started

In this session the goal is to get familiar with the process of pressing and explore the effects of ingredient treatment and proportioning. The next card is going to help you to document your decisions.

To do what?

Pressed sheet material, forms a base material for experimentation. If pressed into shape, it can be used for agricultural purposes as self-fertilizing seed starters.

---

**NAME**  ........................................................
**DATE**  ........................................................
**SEAWEED + ORIGIN**  ........................................................
**SAMPLE NUMBER**  ........................................................

**PULP**
- Untreated
- Washed
- Washed + Extract

**PULP PREP**
- Pre-soaked

**GRIND**
- Course
- Medium
- Fine

**BINDER**
- BIO-alginate
- INDustrial alginate
- Agar
- Other: ........................

**PROPORTIONS**
- ... g ............
- ... g ............
- ... g ............
- ... g ............

**NOTES**

**MATERIAL CODE** [NAME-SAMPLENR]

---

**NAME**  ........................................................
**DATE**  ........................................................
**SEAWEED + ORIGIN**  ........................................................
**SAMPLE NUMBER**  ........................................................

**PULP**
- Untreated
- Washed
- Washed + Extract

**PULP PREP**
- Pre-soaked

**GRIND**
- Course
- Medium
- Fine

**BINDER**
- BIO-alginate
- INDustrial alginate
- Agar
- Other: ........................

**PROPORTIONS**
- ... g ............
- ... g ............
- ... g ............
- ... g ............

**NOTES**

**MATERIAL CODE** [NAME-SAMPLENR]
Image 19: Sheet of seaweed material, right after pressing

Image 20: Diverse proportions of pulp
Test 9: Tinkering with temperature

Image 22: Testing on diverse temperatures at Masters that Matter, Rotterdam.

Image 23: Range of samples based on temperature and pulp proportion
Material to compare with the seaweed materials were the natural materials cork, cardboard and mycelium (comparable weight and possible application as packaging (cardboard) or building material (cork, mycelium).

24) The base seaweed material does not ignite, the material carbonizes and this spreads slowly.

25) The thinner base material carbonizes more quickly. Carbonized areas crumble off.

26) Mycelium ignites and therefore has a higher flammability, but the flame is not easily spread.

27) Pure alginate does not ignite and spreading of carbonization is very slow.

28) Cork ignites quickly and the flames spread quickly.

29) Hardboard ignites quickly as well, and the flames spread quickly as well, but less quickly as cork.
Cardboard, the seaweed mix and pure alginate showed a hydrophilic character (cork did not seem to take up the water within 2 minutes). There were some differences visible in how fast the water was absorbed. Cardboard absorbed the water most quickly, then the mixed seaweed material, and finally the pure alginate.
When completely soaking the materials, the seaweed materials seemed to float at the start, but when water got absorbed, they sank eventually (the weight of these samples was doubled after 24 hour of soaking).

The seaweed materials retrieved their flexible character that was visible within the forming process (see test 1). After drying, characteristics of the dry material were retrieved again.
Test 12: Bending impact

Image 40: Test set-up of bending impact

Image 41: Compared samples: cork and cardboard
Test 13: Molding

Image 42: machining of the aluminium mold

Image 43: Pressing: cold
Test 14: Soaking of the end-product

Image 44: Product falls apart when soaked in water. Shows way less resistance than in tinkering test 11. (Might have to do with the changed proportion or with cold-mold pressing)
An exploration of seaweed was set up in the Eastern Scheldt in Zeeland on 23-03-2018, together with Lex Bekker (geography teacher by profession and a degree in nature conservation). This was done in order to gain insight on what species there are in the Dutch local climate, but also on how seaweed grows, in which proportions and in what circumstances.

The other goal was to collect prototyping material to explore the possibilities of producing an industrial material beyond chemical seaweed extracts.

**Season & Location.**
The exploration was done at the dike of ‘Neeltje Jans’ in the start of spring. Types of seaweed were determined with help of the Wierwaaijer (Krijger, 2016) and Flora van de Nederlandse zeewieren (Stegenga, 1983) (this identification can contain mistakes).

**Observations**
The seaweeds that were abundant around the location were first of all *Ascophyllum nodosum* (image 33), followed by *Fucus serratus* (image 31) and *Sargassum muticum* (image 32).

The seaweeds grew on the rock-surface of the dike. Around locations with many shells (coming from mussel- and oyster-cultivation in the Neeltje Jans area) the seaweeds did not grow easily.

**Main insights:**
- *Sargassum muticum* is an exotic specie and grows abundantly in the Netherlands. This has strong influence on the eco-system, as well positively as negatively.

- Most is ‘knotswier’ and ‘bellenwier’, these seem to be brown weeds, but there is still some confusion on this following different sources.

- The slope of the dike is really important, on steep slopes there was much diversity on types of weeds, easy slopes had primarily one specy.
Image 48: Seaweed on the dike (Neeltje Jans)

Image 49: Diverse seaweeds.
G. STAKEHOLDER INTERACTIONS

Interaction 1
The Dutch government is interested in future proof solutions concerning healthy food, a clean environment and renewable energy. Initiatives and plans need be justified and fit the agenda’s. Plans with economic benefits for the country are evidently easier adapted. The government can offer support to the seaweed farms concerning funding and licensing. But to fit into transition programmes, the farms need to justify their technical readiness concerning consumer safety and viability.

The covering values that both can offer each other are societal prosperity, in trade for realisation. More complicated for the seaweed farms is to offer proof of viability in the stage that the industry is in. This makes that this value exchange has to be based on trust.

Interaction 2
Seaweed farms can offer the bio-refinery as well as the chemical refinery seaweed a relatively constant content, when cultivation circumstances are controlled. For the bio-refinery this can contribute to a viable process, for the chemical refinery the farming can contribute to sustainability goals due to more farming locations as well as less need to choose for harvest. Currently the farms are most interested in farming for food applications, but the bio-refinery can contribute to their future viability to address new markets with high valuable products. The chemical refinery can offer the up-scale market to the seaweed farm.

Interaction 3
Wild sources, from wild harvest or plagues, can offer the refineries content for a lower price which can have an economic advantage for the refineries. In the case of plagues, the refineries can offer the waste-content a purpose by creating a market for it.

Interaction 4
Biorefineries are still in development and want to scale up, it would be valuable for them to get help from an established algae industry like the chemical refinery. The chemical refinery has its market, but will have to change in the future to clean up its process, when environmental legislation will become more tight. It is valuable for them to invest in a transition towards more bio-friendly methods.
Interaction 5
Designers/researches can add value to the different matters that the refineries produce by creating new applications and markets. While for some matters there are already high-value applications, there is no application yet for example for the waste-pulp.
For designers, the refineries can produce more specific content than fresh material can, which makes it more easy to work with. The bio-refinery can supply eco-friendly material, while the chemical refinery can offer more controllability of the material. Between the chemical refinery and the designer/entrepreneurs often is a conflict of values concerning transparency of resource.

Interaction 6
The designer/researcher can offer entrepreneurs technologies, an entrepreneur can offer a strategy or adoption of the project in return. An emerging industry is interesting for entrepreneurs, there are still many possibilities to establish a competitive advantage. But it also has a high risk to enter and there is no market yet, so no money flow. Investors can help here. Investors in the field of MVO often value social contribution and viability of the project.

Interaction 7
From the project plan to the producer, the producer expects a certain consistency of the material characteristics. Also, they often require a certain scale to make it profitable.
Producers could be extra interested in projects with emerging materials/markets when their own market is at risk, for example through tightening legislation concerning plastics.

Interaction 8
Retailers require certification of their products to guarantee safety. Also it needs to be attractive and competitively priced. Retail can contribute to the product flow of the business.
H. IMPACT ASSESSMENT OF MATERIAL SCENARIOS

Scenario A
The first scenario concerns the life cycle of an alginate extract.

Industry size
The global market request for alginate used to be 500,000 tonnes raw material per year, which counts for 27,000 tonnes alginate per year (Indergaard & Jensen, 1991).

Resourcing
The scenario starts at the farming of brown seaweeds, which are most suitable for alginate production (H. Sletta, personal communication, February 16, 2018). Farming accounts for less than 1% of the total impact of the production process, sometimes it even has a positive impact (Langlois, 2012). (see image 38)

Extraction
The extraction/refinery in Europe takes place at Dupont’s in Norway, the large amount of seaweed comes from Asia, farms are set up around Norway too for alginate production in the future (Havard Sletta). The refinery takes up most of the impact concerning electricity use 39% and chemicals 26%, next to heating & cooling, wastewater, water treatment and use of fresh water (Langlois, 2012). (Image xx), Because of the use of chemicals for the extraction, used water gets contaminated which needs purification.

Design
Designing with alginate knows many advantages. Material characteristics are predictable and controllable due to pure extraction. The prototyping can be relatively easy and accessible, through 3D-printing. Applications can therefore be reliable and suitable for up-scale. The disadvantage is that alginate is also used for food applications, while it is undesired to compete with the food industry. A less purified alginate powder could be a cheaper alternative which does not compete with the food industry, but this makes the material less safe and harder to recycle.

For retail, the products from alginate have the advantage that it has a clean look and feel. The natural characteristics are gone though, which might make the eco-friendliness less credible for the consumer.

Biodegradability
The material is theoretically recyclable through ion-exchange, but this takes much water and energy. Recycling does have opportunities by grinding the material and adding new alginate. The advantage of this is that there is no material loss and the material stays pure. The disadvantage is that new material needs to be added and the material loses its quality over time.

Scenario B
The second scenario concerns the life cycle of waste pulp from the bio-refinery. This scenario is based on scenario A, and adapted through insights from personal communication with the bio-refinery owner Dirk Jan Vos and other literature.

Industry size
There is much research going on concerning the viability of bio-refineries of macro-algae (Boonstra, 2014). ECN is one of the companies that is working on bio-refineries within the Netherlands (Zeewier kick-off event, personal communication, 2018). The only findable active bio-refinery is the small-scale enterprise DANVOS which is based in St-Maartensdijk. Its capacity currently is xx tonnes per year, and wishes to grow towards... per year.

Resourcing
Resourcing is the same for the the bio-refinery as well as for the alginate industry. The only difference is that the bio-refinery is a smaller industry, that is more likely to switch to cultivated seaweed as soon as this technique is ready.

Extraction
The active bio-refinery in the Netherlands is based at St-Maartensdijk. The technique makes no use of chemicals and the process works at room temperature, which lowers the electricity use and heating and cooling. There is no waste-water, on the contrary, the process generates clean water (Personal communication, Dirk Jan Vos). The waste-material of the process can be used as material for design.

Design
Designing with this waste stream is a new approach and because the extraction process is an evolving process, the material is as well which makes it less predictable and controllable. The material is not directly suitable as a material, so much experimentation and research is required. This makes prototyping more complex and makes designs less reliable for up-scale applications. The advantage is that the material is a waste-stream, which makes the material economically more interesting and forms no competition with other industries. The disadvantage for the consumer acceptance is that the material has an apparent scent due to the process. It communicates the eco-factor quite well but is not very attractive.

Biodegradability
The material is fully biodegradable. The same recycling methods can be used as in scenario A.
Scenario C
The third scenario concerns the life cycle of the mix of pure extracted alginate and the waste pulp from the bio-refinery. This scenario is based on scenario A & B, and adapted based on assumptions for the design.

Industry size
Assuming that the bio-refinery industry is translatable to different locations, the refinery can be expanded to locations close to industrial refineries. This way it is possible to create local/regional industries that combine the two materials.

Resourcing
Combining the two industries, the bio-refinery has access to the same local sources of seaweed as the industrial refinery, or can choose to have its own resource if the industrial resource does not meet certain value requirements.

Extraction
The impact of the process is spread out on the different extraction processes.

Design
Designing with the waste stream is a new approach and because the extraction process is an evolving process, the material is as well which makes it less predictable and controllable. But by adding the extracted alginate as a binding material, the material will be more controllable.

The material is not directly applicable as a material, but experimentation and research will required to make it suitable for mass production. Prototyping is possible, it only requires effort to prototype for industrial processes.

The material is still characterized by an apparent scent, but the feel is softer and feels more precious due the added alginate. It communicates the eco-factor quite well and can be experienced as more attractive than the pure bio-variant.

Biodegradability
The material is fully biodegradable. The recyclability depends on the method that is used to set the material. If proteins are also used for forming material connections, the process is irreversible, but if only alginate forms the material, the same recycling methods can be used as in scenario A.
### Table 1: Arguments for impact: scores by evaluation of different material scenario's

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Alginate (A)</th>
<th>Bio-refinery waste (B)</th>
<th>A + B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scoring scale</strong></td>
<td>-2</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td><strong>1. Eco impact</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Usage of waste-stream</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Waste stream cleanness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Recyclability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Local possibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 Water treatment/pollution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6 Competition with future food production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Upscale feasibility</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Material accessibility + scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 Production capacity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 International possibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Acceptation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Contribution to plastic problem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Competitive pricing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3 Communicative &amp; credible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4 Measurable value/effectiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 Cascade usage (viable process)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.6 Shareable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.7 Transparency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8 Contribution to research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Small-scale Feasibility</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Controllable characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2 Material availability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3 Tooling availability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4 Knowledge availability</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. MATERIAL SAFETY SHEET - ALGINATE

Safety data sheet (SDS) in accordance with Reg. 1907/2006/CE - 453/2010/CE
ALGINATES ed. 1.0 (ENG) _ 3/03/2015

1 Identification of the mixture and of the company

1.1 Product identifier
white alginate PLALBBI / pink alginate PLALBBIR

1.2 Relevant identified uses of the mixture and uses advised against
Alginate for dental impression material

1.3 Details of the supplier of the data sheet
GESSI ROCCASRADA srl
Loc. Tamburino snc,  I -58036 Roccastrada (GR)
Tel: +39 (0)564 564511     Fax: +39 (0)564 564532
e-mail of the responsible person: info@gessiroccastrada.com

1.4 Emergency telephone number
39 (0) 564 564511 (available only during office hours)

2 Hazards identification
This product is not dangerous under 67/548/EEc and 1999/45/EC directives.
Nevertheless, this mixture contains dangerous substances in concentration that must declared in section 3.

2.1 Classification of the substance on ingredients, Label elements

According to Regulation (EC) n. 1272/2008

<table>
<thead>
<tr>
<th>CAS:</th>
<th>14464-46-1</th>
<th>Cristobalite</th>
<th>SiO₂ crystalline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danger</td>
<td>H373</td>
<td>May cause damage to lungs through prolonged or repeated exposure</td>
<td></td>
</tr>
<tr>
<td>STOT RE 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAS:</th>
<th>68855-54-9</th>
<th>Diatomaceous Hearth</th>
<th>SiO₂ amorphous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danger</td>
<td>H373</td>
<td>Harmful if inhaled</td>
<td></td>
</tr>
<tr>
<td>STOT RE 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAS:</th>
<th>16919-27-0</th>
<th>Potassium Fluorotitanate</th>
<th>K₂TiF₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>H332</td>
<td>Acute Tox. 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H312</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H302</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAS:</th>
<th>7722-88-5</th>
<th>Tetrasodium pyrophosphate</th>
<th>Na₄P₂O₇</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>H319</td>
<td>Eye Irrit. 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H335</td>
<td>STOT SE 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H315</td>
<td>STOT SE 3</td>
<td></td>
</tr>
</tbody>
</table>

3 Composition/information on ingredients

<table>
<thead>
<tr>
<th>CAS:</th>
<th>EINECS:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14464-46-1</td>
<td>272-489-0</td>
<td>Cristobalite SiO₂ crystalline</td>
<td></td>
</tr>
<tr>
<td>68855-54-9</td>
<td>240-969-9</td>
<td>Diatomaceous Hearth SiO₂ amorphous</td>
<td></td>
</tr>
<tr>
<td>16919-27-0</td>
<td>231-767-1</td>
<td>Potassium Fluorotitanate K₂TiF₆</td>
<td></td>
</tr>
<tr>
<td>7722-88-5</td>
<td></td>
<td>Tetrasodium pyrophosphate Na₄P₂O₇</td>
<td></td>
</tr>
</tbody>
</table>
4 First aid measures
4.1 Description of first measures
   General information
   No known delayed effects. Consult a physician for all exposures except for minor instances
   After eye contact
   Wash immediately eye with clean water. Seek medical advice if irritation persists.
   After skin contact
   Wash off immediately with soap and water, promptly remove clothing if soaked, get medical attention
   if irritation persists after washing.
   After inhalation
   Remove person to open air. Ensure supply of fresh air. Seek medical advice.
   After ingestion
   Get medical attention immediately. Induce vomiting only if indicated by the doctor.
4.2 Most important symptoms and effects, both acute and delayed
   No acute and delayed symptoms and effects are observed.
4.3 Identification of any immediate medical attention and special treatment needed
   See above, bring this document if you contact a doctor.

5 Firefighting measures
5.1 Extinguishing media
   Non combustible. Use extinguishing media appropriate for surrounding fire.
5.2 Special hazards arising from the mixture
   The product is fire resistant, but packaging may burn.
5.3 Advice for fire fighters
   Product hardens in contact with water.

6 Accidental release measures
6.1 Personal precaution, protective equipment and emergency procedures
   Avoid contact with eyes and skin. Use protective goggles and gloves. See Sections 7 and 8.
6.2 Environmental precautions
   Keep out of drains, sewers, ditches and waterways. Minimise use of water to prevent contamination.
6.3 Methods and material for contained and clearing up
   Scoop up material and place in a disposal container. Take up spilled product in dry condition. Product
   hardens in contact with water.
6.4 Reference to other sections

7 Handling and storage
7.1 Precautions for a safe handling
   Avoid contact with skin and eyes. Provide good ventilation
7.2 Condition for safe storage, including any compatibilities
7.3 Specific end use
   Mixture of crystalline silicon dioxide, sodium alginate ad additives for dental impress – see sect. 1.2.
8 Exposure controls / personal protection

8.1 Control parameters
For the Occupational Exposure Limit of respirable crystalline silica dust SiO₂, consult the local regulatory authority. The currently Time Weighted Average of silica dust in Italy is 0,025mg/m³.

8.2 Exposure controls / personal protection

General protective and hygiene measures
To control potential exposures, generation of dust should be avoided. Further, appropriate protective equipment is recommended. Eye protection equipment (e.g. goggles or visors) must be worn. Additionally, face protection, protective clothing and safety shoes are required to be worn as appropriate. No drinking, eating and smoking at the workplace.

Respiratory protection
In case of prolonged exposure to airborne dust concentrations, wear a respiratory protective equipment that complies with the requirements of national legislation.

Skin/Body protection
Wear category I professional long sleeve lab coat. Protect hand with category I work gloves.

Eye/Face protection
For powders, tight fitting goggles with side shields, or wide vision full goggles (refer to EN 374).

9 Physical and chemical properties

9.1 Information on basic physical and chemical properties

- **Appearance**: White or pink powder
- **Odour**: Characteristic
- **Flash Point**: Not available
- **Bulk density**: 0,35 – 0,45 gr/cm³
- **Solubility in water**: Partially soluble in water
- **pH value**: 10-12 (at 20 °C)
- **Flammability**: Not available
- **Explosive properties**: Not available
- **Vapour pressure**: Not available
- **Vapour density**: Not available
- **VOC**: 0

9.2 Other information
No other information.

10 Stability and reactivity

10.1 Reactivity
No materials to avoid known.

10.2 Chemical stability
Keep dry. Stable under normal storage conditions.

10.3 Possibility of hazardous reactions
No hazardous reactions.

10.4 Conditions to avoid
Stable if stored in dry conditions.

10.5 Incompatible materials
No particular incompatibility.

10.6 Hazardous decomposition products
In the event of fire, potentially dangerous vapours may be produced.

11 Toxicological information

11.1 Information on toxicological effects
Based on available data, the classification criteria are not meet.

Sensitization
ACGIH limit for powders inhalable fraction TLW: 10mg/Nm³
ACGIH limit for powders breathable fraction TLW: 3mg/Nm³
12 Ecological information
12.1 Toxicity
Not relevant
12.2 Persistence and degradability
Not relevant for inorganic substances
12.3 Bioaccumulative potential
Not relevant for inorganic substances
12.4 Mobility in soil
Negligible
12.5 Results of PBT and vPvB assessment
Not relevant for inorganic substances
12.6 Other adverse effects
Keep out of drains, sewers, ditches and waterways.

13 Disposal considerations
13.1 Waste treatment methods
Keep out of drains, sewers, ditches and waterways. Do not co-dispose with municipal waste, but dispose at an authorized site in accordance with local Environmental Regulations.

14 Transport information
Not classified as dangerous in terms of transport regulations (IMDG, ADR, RID, IACO/IATA)
14.1 NU number
Not applicable
14.2 NU proper shipping name
Not applicable
14.3 Transport hazard class
Not applicable
14.4 Packing group
Not applicable
14.5 Environmental hazard
Not applicable
14.6 Special precaution for users
Not applicable
14.7 Transport in bulk according to Annex II of MARPOL 73/78 and IBC Code
Not applicable

15 Regulation information
15.1 Safety, health and environment regulations/legislation specific for the mixture
This Safety Data Sheet complies with Regulation (EC) 1907/2006 – (REACH)
National Regulations:
Italy: Decreto Legislativo n. 81/2008
Users must observe the measures of their own workplace health and safety risk assessment. Regarding personal protection devices, see Section 8.

European Inventory of New and Existing Chemicals Substances (EINECS):
This product is a medical device and not subject to chemical notification requirements.

European Community Labelling: Not a dangerous mixture

15.2 Chemical safety assessment
No safety assessment has been accomplished on the product itself.
16 Other information

As the conditions or methods of use are beyond our control, Gessi Roccastrada srl does not assume any responsibility and disclaim any liability for any use of the material. The information and data herein are believed to be accurate and have been compiled from sources believed to be reliable. It is offered for you consideration, investigation and verification. Buyer assumes all risk of use, storage and handling of the product in compliance with applicable state and local laws and regulations.

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This SDS is a translation of the Italian version and refers to the legal requirements in Italy.

16.1 List of modify
None

16.2 Abbreviations and Acronyms

ACGIH: American Conference of Governmental Industrial Hygienists  www.acgih.org
TWA: Time Weighted Average
PBT: Persistent, Bioaccumulative, Toxic chemical
vPvB: very Persistent, very Bioaccumulative chemical
IMDG: International Maritime Dangerous Goods
ADR: Agreement on the transport of Dangerous goods by Road
RID: Regulations on the International transport of Dangerous goods by Rail
IATA: International Air Transport Association
### Typical Analysis

**Physical Properties**

<table>
<thead>
<tr>
<th>General Description</th>
<th>Seaweed Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Application</td>
<td>Soil Conditioner</td>
</tr>
<tr>
<td>Raw Material</td>
<td>Ascophyllum nodosum</td>
</tr>
<tr>
<td>Appearance</td>
<td>Olive coloured, fine powder</td>
</tr>
<tr>
<td>Particle size</td>
<td>Min 85% through a 1.4 mm sieve</td>
</tr>
</tbody>
</table>

**Average Composition**

<table>
<thead>
<tr>
<th>Results</th>
<th>Units</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>8-14%</td>
<td>A.O.A.C. 950.01</td>
</tr>
<tr>
<td>Alginic Acid</td>
<td>10-20%</td>
<td>Gravimetric White Method</td>
</tr>
<tr>
<td>Mannitol</td>
<td>4-8%</td>
<td>GC-MS Internal Method</td>
</tr>
</tbody>
</table>

**Macronutrients**

<table>
<thead>
<tr>
<th>Results</th>
<th>Units</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>0.8-1.5%</td>
<td>Kjeldhal Method</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.05-0.15%</td>
<td>Gravimetric Fertilizer Method</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>&lt;2%</td>
<td>IC Internal Method</td>
</tr>
<tr>
<td>Potassium Oxide (K2O)</td>
<td>1.0-2.0%</td>
<td>Gravimetric Fertilizer Method</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>1-3%</td>
<td>IC Internal Method</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>0.5-3.0%</td>
<td>IC Internal Method</td>
</tr>
</tbody>
</table>

**Micronutrients**

<table>
<thead>
<tr>
<th>Results</th>
<th>Units</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (Cu)</td>
<td>1.0-10 mg/kg</td>
<td>Atomic Absorption</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>150-1000 mg/kg</td>
<td>Atomic Absorption</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>10-50 mg/kg</td>
<td>Atomic Absorption</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>40-200 mg/kg</td>
<td>Atomic Absorption</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>20-100 mg/kg</td>
<td>A.O.A.C. 949.03</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>1.5 mg/kg</td>
<td>ICP-MS</td>
</tr>
</tbody>
</table>

**Vitamins**

- Ascorbic Acid
- Biotin
- Folic Acid
- Niacin
- Riboflavin
- Thiamin

---

Valagro Business Innovation Department (on behalf of Algea A.S.)

Chemical Laboratory: Dott.ssa Donata Di Tommaso

Business Innovation Manager: Dott. Alberto Piaggesi

Issue date: September 22, 2014
Print Date: October 8, 2014
## Material costs

<table>
<thead>
<tr>
<th>Resources</th>
<th>Amount</th>
<th>Price in euro per unit</th>
<th>Price in euro</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium alginate (kg)</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>The prices for alginate are very different concerning their grade. Since it is not necessarily needed to use a very pure grade, here, is chosen for a middle range, this can be around 3 euro's/kg. The tinkering material is 18 euro's/kg consumer price in de Beeldhouweninkel Den Haag (see fact sheet in appendix xx). (<a href="https://www.alibaba.com/product-detail/The-best-price-is-sodium-alginat-60774456954.html?spm=a2700.7724836.20117115.15.68817845XFK4Ze&amp;s=p">https://www.alibaba.com/product-detail/The-best-price-is-sodium-alginat-60774456954.html?spm=a2700.7724836.20117115.15.68817845XFK4Ze&amp;s=p</a>)</td>
</tr>
<tr>
<td>Sargassum (dry) (kg)</td>
<td>20</td>
<td>0.20</td>
<td>4</td>
<td>The price for dried Sargassum on the market is around 0.43 euro/kg (<a href="https://www.alibaba.com/product-detail/Best-Price-in-year-for-Sargassum_50037776957.html?spm=a2700.7724836.20117115.107.602a47afAnZ76p">https://www.alibaba.com/product-detail/Best-Price-in-year-for-Sargassum_50037776957.html?spm=a2700.7724836.20117115.107.602a47afAnZ76p</a>)</td>
</tr>
<tr>
<td>Glycerol (kg)</td>
<td>2</td>
<td>0.02</td>
<td>0.04</td>
<td>Currently at Ali baba for 0.18 euro/kg (<a href="https://www.alibaba.com/product-detail/Hot-Sale-crude-glycerine-80_-50040868973.html?spm=a2700.7724836.20117115.255.6d4c379omOu6Kj">https://www.alibaba.com/product-detail/Hot-Sale-crude-glycerine-80_-50040868973.html?spm=a2700.7724836.20117115.255.6d4c379omOu6Kj</a>). It has known cheaper times (2 cents/kg in 2011). As glycerol is a by-product of the production of biodiesel as well, the price of glycerol is expected to drop largely by 2020, since there will be produced 6 times more glycerol than the demand is, to produce enough biodiesel to replace fossil fuels. (Christoph (2006) &quot;Glycerol&quot;, Ullmann's Encyclopedia of Industrial Chemistry. Ullmann's Encyclopedia of Industrial Chemistry.)</td>
</tr>
</tbody>
</table>

### Material costs for 1000 pieces

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount</th>
<th>Price in euro per piece</th>
<th>Total price</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium alginate (kg)</td>
<td>10</td>
<td>3.4</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Sargassum (dry) (kg)</td>
<td>20</td>
<td>0.20</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Glycerol (kg)</td>
<td>2</td>
<td>0.02</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

### Investment costs (ex. refinery and harvest)

<table>
<thead>
<tr>
<th>Resources</th>
<th>Amount</th>
<th>Price in euro per unit</th>
<th>Price in euro</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handpress</td>
<td>1</td>
<td>50</td>
<td>50</td>
<td>Amazon (2018) (Retrieved from: <a href="https://www.amazon.com/HHIP-Heavy-Arbor-Multiple-Options/dp/B00E0NFKP8?keywords=arbor+press&amp;qid=15407507568&amp;sr=8-6&amp;ref=sr_1_6">https://www.amazon.com/HHIP-Heavy-Arbor-Multiple-Options/dp/B00E0NFKP8?keywords=arbor+press&amp;qid=15407507568&amp;sr=8-6&amp;ref=sr_1_6</a>)</td>
</tr>
<tr>
<td>Mold</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>Machining of aluminium part (3 hours).</td>
</tr>
<tr>
<td>Racks</td>
<td>20</td>
<td>1.5</td>
<td>30</td>
<td>3D printed forms.</td>
</tr>
</tbody>
</table>

### Total investment costs per setup

| Investment/3000 pieces     | 0.06 c. |

### Labour costs

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time required p. p.</th>
<th>Price per hour</th>
<th>Price in euro/pc</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing, pressing, releasing</td>
<td>2 minutes</td>
<td>5</td>
<td>0.17</td>
<td></td>
</tr>
</tbody>
</table>

### Labor costs/3000 pieces

| 0.17 c. |

### Transport SXM to NL

<table>
<thead>
<tr>
<th>Activity</th>
<th>Amount of pieces</th>
<th>Price</th>
<th>Price in euro/pc</th>
<th>Argumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>3,000,000</td>
<td>8000</td>
<td>0</td>
<td>Quote of Fairtransport (D.Meijer, personal communication, september 18, 2018)</td>
</tr>
</tbody>
</table>

### Transport costs for 3000 pieces

| 0.003. |