MDP ABAM- an algae value chain in Chile

By Tim de Bakker, s2021498

1 Preface

The ultimate part of the master study "Industrial Engineering and Management" at the university of Groningen is to perform a Master Design Project. In this project the student is challenged to make a design in a social-technical context, to make use of his knowledge in both areas and apply everything he has learned. This document is the report of the Master Design Project of Tim de Bakker, in which a supply chain for products from algae is designed in the south of Chile.

2 Contents

3 Management summary

Purpose
To develop a value chain upgrading strategy to lift fishermen around Valdivia (in the south of Chile) out of poverty.

Design/methodology/approach
Action research based on a framework to overcome poverty in rural areas through value chain research by Riisgaard et al. (2008; 2010).

Findings
The analysis shows that the algae value chain (and thus the position of fishermen) can be improved significantly. The best bets selected to improve the value chain are to:

- exclude the intermediaries (who buy the algae, dry them and sell them to the processing industry)
- move production to the local fishermen community, and
- use algae processing industry waste stream to produce coasters from paper.

This will be achieved by: including the drying and selling algae and producing coasters in the fishermen community activities in a new dryer/processing plant that will be built.

This is done to:

- exclude the intermediaries, who have a monopoly position and enrich themselves by misusing this position,
- reduce storage and transport necessary, and
- involve the fishermen in the production process.

This will lead to:

- higher income,
- more security of income,
- more physical capital available to produce, and
- a better traceability of the final products.

Projected financial results are:

- a minimum of $149,87 (€0,20) extra added value per kg wet algae (to be distributed over paying of investments and more wages).
- With a maximal production capacity of 4000 kg per day → a maximal daily extra added value of $599.500 (€800).
- Slightly higher wages without assigning the extra added value to wages: an average of $5227,91 (€7,00) per person.
- Maximal around 18 persons with a fixed wages per day, where it is now 0.

- Investments of $218.000.000 (€290.000) are needed for the construction of the plant and of the dryer. For the construction of the paper and coaster producing plant, more investments are needed, depending on the business plan that has to be developed.

The upgrading strategy will be implemented by setting up the coaster plant within the algae drying plant that already will be constructed by another company at the fishermen community.

Research limitations/implications

This research is based on several assumptions that are hard to validate because there is little known about the studied value chain. The results however implicate that real change can be made and give direction in which way the fishermen community should move forward.

Practical implications

A coaster company should be set up and the raw material, process and customers should investigated further to really start the business. A model to start the business and give financial backbone to the business plan is built and can be used to apply for credit.

Keywords

Value chain research, action research, algae, Chile, coasters.

4 Introduction

In the south of Chile, fishermen are isolated from the modern world, technology and education. They live in poverty and have physical heavy jobs in which they earn little. This way of living has no place in the 21st century and should be changed.

In this research this poverty problem will be tackled. The question to be solved is: how can fishermen poverty in the south of Chile be minimized? This will be done by evaluating the value chains the fishermen are currently in, selecting the most promising one and upgrading (or improving) this. There are several ways to upgrade a value chain and therefore three different upgrade scenarios will be evaluated.

This research will follow the research of Riisgaard et al. (2008; 2010) in methodology and in structure. They have created a framework on how to do action research to overcome poverty in rural areas. The value chains will be analyzed using the value chain mapping guidelines of Rother & Shook (1999) and Jones & Womack (2002), who have developed a value chain mapping method. These maps are then used to evaluate the value chain.

With the result of this research, the fishermen will be given direction in where to improve their position in the value chain, what products to pursue and how to implement these changes. Overall, this research can lead to a better life for the fishermen involved in this project, in the south of Chile near the city of Valdivia.

In chapter 5, the problem that will be tackled in this research will be analyzed (including context description, stakeholder analysis, problem description and scoping). In chapter 6, a literature scan is performed on value chain analysis, poverty reduction, biomass value chains, algae value chains and implementing a new value chain as supply chain. In chapter 7 the research outline is given and planned in the timespan of this research. In chapter 8, the root of the problem is further investigated: the poverty of the fishermen and the broad value chain in which this is happening (horizontal aspects of the value chain). In chapter 9 the current value chain is analyzed (vertical aspects of the value chain) and in chapter 10 the possible upgrades are evaluated. Also a choice is made in what is the 'best bet' strategy to implement. This strategy is then implemented in chapter 11. In chapter 11.4, some other issues that can be improved easily are discussed.

5 Problem analysis: fishermen poverty in South-Chile due to value chain design

First the current problem is analyzed is this chapter, by looking at the context, defining the problem, identifying the stakeholders involved and determining the scope. A broad description of Chile itself can be found in appendix 15.1.

5.1 Problem context: the current fishermen value chains in the south of Chile

In the southern part of Chile, two value chains can be distinguished for the present fishermen.

5.1.1 Value chain: fish and shellfish

In the south of Chile, a lot of fishermen are present, who fish for fishes and shellfish. Because of the presence of a very long coastline and a lot of rivers and lakes, the south of Chile has a high amount of fishermen, organized in fishermen communities. Fish and shellfish can be found in great numbers and are therefore the main part of the income of the fishermen.

The fishermen lack the capacity of adding any other value to the fish and shellfish, because of a lack of equipment and access to the markets (which are provided by intermediaries). The fish and shellfish are collected with boats, mostly traditional and low-tech, and then sold locally to intermediaries. These intermediaries make sure the fish get to other markets, mostly in Chile and a few outside the country (the USA and Asia).

In a new project, a local plant will be constructed where the fish can be frozen, smoked or cooled, in order to add more value to the product. This project will be financed by the government of Chile and the plans of constructing the plant are now under revision of the investors. The plant will be located at the site of one of the fishermen communities and will also be operated by them. By the means of this new plant the market can be served directly by the community, thus cutting out a step in the value chain: the intermediary. In this way the community hopes to improve the value of their fish product, as well as that of other communities nearby.

5.1.2 Value chain: algae

Besides fish, the local fishermen communities are also collecting and selling (macro-)algae, which wash up on the shores from December till April. In this period, macro-algae (more commonly known as seaweed) grow a lot and they wash up on the shores in large quantities. They are therefore easily available in these months. Where during the whole year the men go out fishing most of the time, the women stay at home. The women are adding to the income of the household by collecting the algae and selling them. The different types of algae available in the south of Chile can be found in appendix 15.2.

After collecting the algae, they can be dried on the rocks in the sun, which has several disadvantages: 1) it has a very limited capacity, 2) when it rains the harvest is ruined, and 3) it is slow. Sometimes the drying is also done on the beach, resulting in a lot of sand mixed with the algae. This results in the fact that, especially in the summer, not all algae can be sold dry and a lot of their value is lost to the fishermen.

For every area, the primary buyer of the algae is an intermediary buyer with a monopoly position, who collects the algae from various communities, dries them (if not already done on the rocks) and sells them to the industry in big quantities. The intermediaries have gained their monopoly position by offering a higher price than the competitors, but when they left the intermediaries lowered the price again. In this way the intermediaries divided the areas in which they work. The intermediary passes through the villages with its van and buys the algae for a low price. It then brings it to its house, where he dries the algae. The algae are often not yet dried when bought since only a very low drying capacity is available in the communities. Once dried, the algae can be stored for a long time. This is also done at the intermediary, where he waits for a big truck of a processing company to come pick up the collected algae. This truck usually arrives once a week.

The next step in the chain are the algae processing companies, which consist mostly of companies producing two types of products: carrageenan (for the food industry) and alginate (also for the food industry, but has also other applications). These products are mostly fabricated from the algae collected by the fishermen communities (bought through the intermediary), but also use imported algae, especially in off-season months. The operations performed by the processing companies with the algae result in either carrageenan or alginate, and a waste stream which is use as farmland fertilizer. In the food industry the products produced from algae are mostly used as a vegetarian alternative for gelatin, but also other applications exist. Since the products only exist of a very small portion of algae, the remaining downstream the value chain is not discussed. An overview of the algae supply chain can be found in Figure 1.

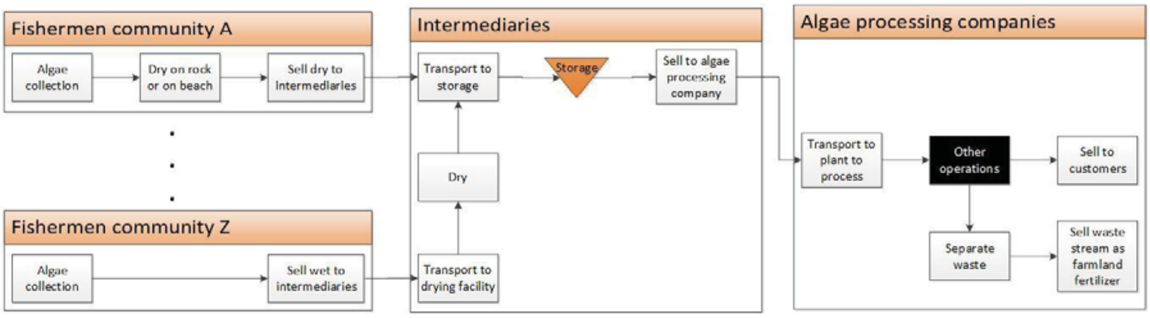


Figure 1- Current algae value chain

Since the processes involved in the algae processing companies are already advanced and well-regulated (and are therefore mostly already optimized), these companies are constantly looking for new opportunities to add more value to their products and the raw materials they use. This means that they are looking for ways to improve the value chain, as well as invent new products from algae.

A small technology company, linked to the local university, called ABAM is willing to help in the process of developing new technologies to improve the products from algae or invent new products. This company is a recently established company with only a small number of employees, most of them either graduating or just graduated from the Austral University of Chile (UACH). This provides the company with the latest technologies and skilled employees. It is involved in a project with a local fishermen community to help finding solutions for their problems with regards to the algae supply chain. To help in this project, this design project is performed.

5.2 Problem description: fishermen poverty due to value chain design

Currently, the fishermen live in a certain state of poverty, mainly due to the current value chain of their products. The state of poverty of the fishermen communities can be described as low education levels, low technologic availability, low commitment to innovation, and low hopes for better future perspectives. Furthermore, due to seasonality, their income is not a stable. The availability of money determines largely the level of education available in the country of Chile, as it does influence the infrastructure and technologies that are being made available to the communities. This implies that the value chain they are in (with low value of their products) is the main cause of the fishermen poverty.

The design of the value chain results in a low value for the products because of two reasons:

1. The intermediaries have a monopoly position and they use it the enrich themselves and not the fishermen, and
2. The products currently made of the raw material provided by the fishermen (fish, shellfish and algae) are of low economic value and therefore the prices of raw material are also low.

Both can be regarded as problems in the value chain design, since the design allows these problems to occur. The final problem statement is therefore the following:

The design of the current value chain is not adequate to lift fishermen in the south of Chile out of poverty, because of the monopoly position of intermediaries and the low value of final products form fish, shellfish and algae

To prevent the intermediaries from using their monopoly position or to improve the value of the products, more capacity, technical knowledge and access to the market are needed in the fishermen communities. They could be provided by external organizations, improving the position of the fishermen, instead of the intermediaries.

Furthermore, the exclusion of the intermediaries will lead to a change of coordination in the value chain: from market based to vertical integration. This is because the role of the intermediary will be replaced by fishermen, cutting out the market aspect in the chain. This is stated to be better suited for value chain research by Riisgaard et al. (2008).

5.3 Scope: focus on algae value chain in the region of Valdivia on a strategic level

The problem as stated in the problem statement is broad and thus has to be scoped. The scope is set to be the algae value chain in the region of Valdivia. This is done to focus the research on one single value chain to enhance the likelihood of a successful project and increase the chances of reaching an implementable solution. This choice implies that the value chain of fish and shellfish will be ignored. This follows from the analysis of value chain selection criteria from Riisgaard et al.

(2008), as presented in Table 1. They are assumed to have all the same weight, as they are considered of the same importance, nor do Riisgaard et al. (2008) indicate weights.

Table 1- List of selection criteria, derived from Riisgaard et al. (2008)

Selection criteria (all same weight)	Fish/shellfish supply chain	Algae supply chain
Chain structure	+ (simple)	+ (simple)
Position of smallholders	- (raw material supplier→low power)	- (raw material supplier→low power)
Coordination in chain	- - (market based→low control)	- - (market based→low control)
Power division	+/- (monopoly position intermediaries→opportunity to improve and possible problem)	+/- (monopoly position intermediaries→opportunity to improve and possible problem)
Market size & robustness	+ (medium sized and stable)	- (medium sized and not stable on input side prices)
Market development	+ (stable)	- (prices are dropping)
Market potential	- (mature→low upgrading potential)	++ (algae are heavily investigated and have new product potential)
Formal barriers	- (food quality checks)	+ (non-existent)
Performance requirements	- (freshness since raw material is almost directly consumed)	+ (less important since raw material will be dried & processed)
Local involvement in improvement	+ (fixed idea for improvement)	++ (locals as well as industry looking for new improvement possibilities)
Local knowledge on improvement	+ (fixed idea for improvement)	+ (ABAM specialized in chemistry and polymers and involved in the improvement of the value chain)
Total	-	+++

The geographical focus of this research will be the algae value chain in the south of Chile, in the area around Valdivia, specifically in the communities of Corral. The local fishermen are organized by a local federation of Corral and from within this federation there is an intrinsic willingness to improve this value chain and there are already some projects running to investigate the possibilities. Furthermore, ABAM is located in Valdivia and with Gelymar, there is a big algae processing company in the region that is looking for new opportunities.

The value chain of algae will be considered on a strategic level, and only if possible at some points at a tactical level. Since there are still a lot of uncertainties and a general strategic overview is missing in the current algae value chain, the feasibility of investigating the value chain at more detailed levels is low. This means that the operations are considered as a black box (for example: the operation ‘drying on rocks’ has an input of wet algae and delivers dry algae with certain qualifications). How the operations are performed is out of the scope of this project. However, certain suggestions will be made to enhance the operations and improve the processes.

5.4 Research goal: to improve the design of the algae value chain and create an implementation plan on a strategic/tactical level

With the scope and the problem as stated, the research goal can be defined as follows:

To improve (upgrade) the design of the algae value chain in the region of Valdivia by comparing different strands of the same value chain and create an implementation plan on a strategic level

By improving (or upgrading) the design value chain, an improvement of the value received for the algae collected by the fishermen is expected. A better design of the value chain can either 1) divide the value of the algae better, or 2) increase the total value within the value chain, 3) or both. This will all lead to a better value for the algae for the fishermen. In this way, it is expected that the fishermen will be lifted out of poverty.

The type of value chain research will be “comparing different ‘strands’ of the same value chain”. Riisgaard et al. (2008) state that this type of value chain research is suited when the same base product can be used for several different end products or to evaluate the possibilities for this. It is usually used to either compare mainstream value chains and strands for niche products or export oriented value chains and value chains that supply local/regional markets. Since the value chain to be researched will be the algae value chain, the base products is already set and thus the strands of this base products will be researched. Furthermore, this base products is where smallholders are involved in the value chain and where poverty can thus be fought.

The implementation of the value chain design will be done by recommendations and making a start in the implementation. When implementing the chosen value chain design, the topic switches to supply chain engineering. The operations and locations are chosen to add the most value.

5.5 Stakeholder analysis: who are currently involved in the algae value chain?

Already some projects are running to address the problem statement and several organizations and people are involved in these projects. In collaboration with them, this design project will be performed. The knowledge, capacities and availability of these organizations and people can be used to move the whole value chain forward to solve the problem. An analysis is presented in this section, where a detailed description of the stakeholders is given in appendix 15.3.

Donovan and Stoian (2012) identify a stakeholder definition especially for value chain analysis, which can be found in Figure 2. The method defines interactions and interventions. Interactions are defined as interactions between actors in the value chain (such as the buying and selling of goods), where interventions are inputs from outside the chain (such as funding or technological knowledge). Stakeholders can be divided into two types: 1) chain actors, and 2) service/input providers. They are roughly (but not strictly) related to the interactions and intervention: chain actors perform interactions and service/input providers perform interventions. The stakeholders and their interactions and interventions can be shown in a more detailed overview following the assessment of the situation, as presented in appendix 15.5 (Table 15).

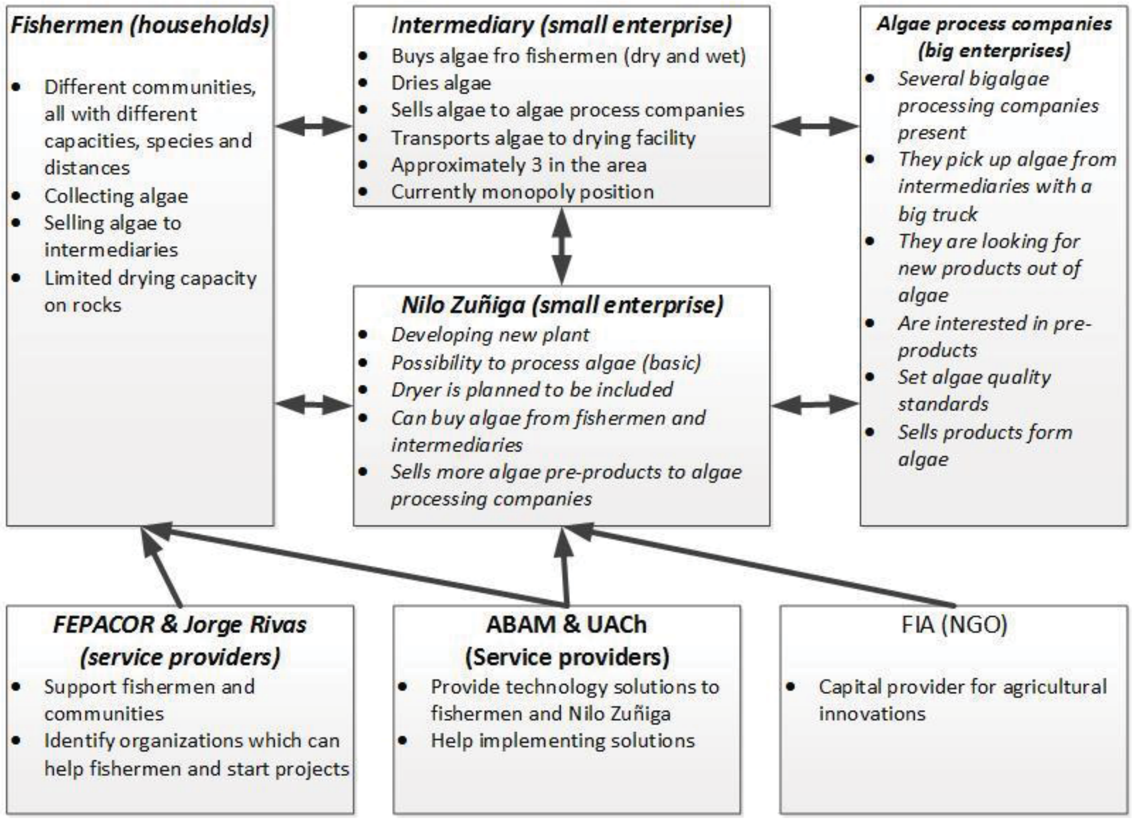


Figure 2- Stakeholder map algae value chain

To analyze the stakeholders on their importance in the research, they can be placed in an overview and visual with advised actions (Figure 3), following the lines of Varvasovszky & Brugha (2000) and the Imperial College London (2007). The most important stakeholders are marked in green. The values on the characteristics of the stakeholders are derived directly from the descriptions in appendix 15.3.

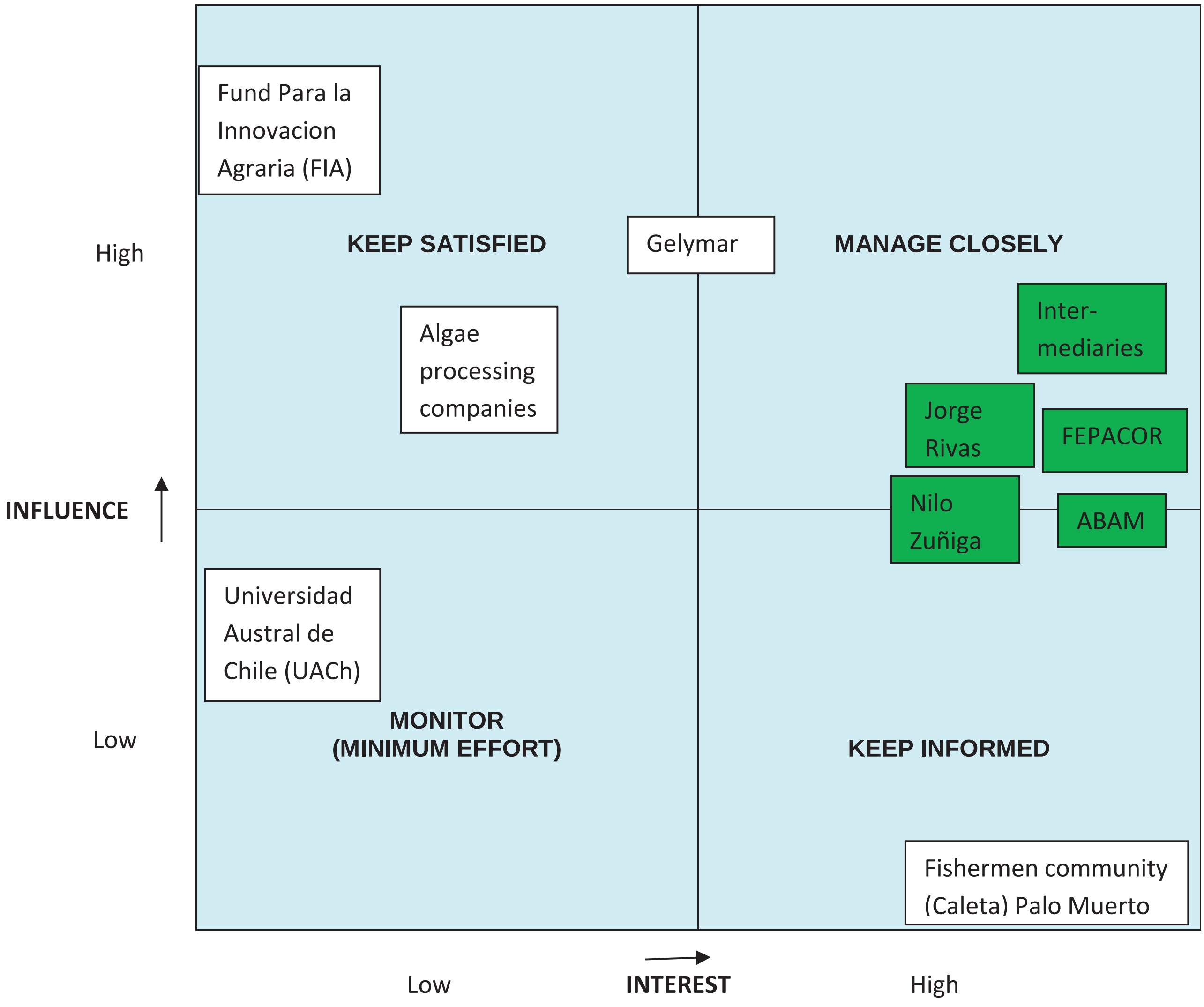


Figure 3- Stakeholder analysis by Imperial College London

6 Literature scan

To start the project on a scientific basis, a literature scan is performed on different levels. Firstly, a general value chain creation is researched, which is later connected to a value chain design to overcome poverty. Then the search is zoomed in to value (or supply) chains in biomass, which then is further specified as algae. After this the implementation of such a value chain is discussed in what is called 'Supply Chain Engineering' in literature.

6.1 Value chain research

"The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use" (Kaplinsky & Morris, 2001). These activities can add value to the product or service. Important is to map these operations and determine their value adding capabilities.

With these factors, a value stream or value chain can be mapped. It serves to show the overview and the supply chain calculations of each step in the chain in a figure. This can be done on several levels: within a factory (Rother & Shook, 1999) or of the whole product supply chain (Jones & Womack, 2002). In the overview, the connections between the several actors in the value chain are shown, as well as the information flows. To complete the overview, the relevant numbers about the chain are shown as well. These can include: shipment frequency, production time, stock available, capacity, et cetera. An important number is the actual added value, which can be described as output value minus input costs, rather than the gross value of sales/exports in each link of the value chain (Kaplinsky & Morris, 2001).

After the mapping of a value chain, the research can focus on how to improve a value chain, called upgrading the value chain. Kaplinsky & Morris (2001) describe several different types of upgrading:

1. "Process upgrading: increasing the efficiency of internal processes such that these are significantly better than those of rivals, both within individual links in the chain (for example, increased inventory turns, lower scrap), and between the links in the chain (for example, more frequent, smaller and on-time deliveries)
2. Product upgrading: introducing new products or improving old products faster than rivals. This involves changing new product development processes both within individual links in the value chain and in the relationship between different chain links
3. Functional upgrading: increasing value added by changing the mix of activities conducted within the firm (for example, taking responsibility for, or outsourcing accounting, logistics and quality functions) or moving the locus of activities to different links in the value chain (for example from manufacturing to design) (Figure 10)
4. Chain upgrading: moving to a new value chain (for example, Taiwanese firms moved from the manufacture of transistor radios to calculators, to TVs, to computer monitors, to laptops and now to WAP phones)"

Both Rother & Shook (1999) as Jones & Womack (2002) are upgrading the value chain though applying the ideology of Lean. They state that after the current value chain map has been drawn, a future state map should be drawn, where all wastes are out of the chain. This implies that only value-added operations should be included in the value chain design and that non-value-added activities should be eliminated. Taylor (2005) applies these methods in an agri-food supply chain, using the steps as can be found in Figure 4.

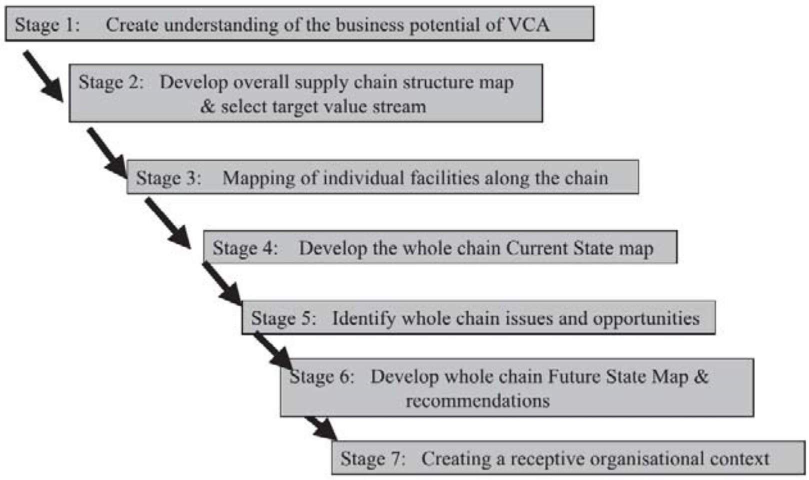


Figure 4- Research steps of Taylor (2005)

6.2 Value chain design to overcome poverty

"Value chain analysis is particularly useful for new producers – including poor producers and poor countries – who are trying to enter global markets in a manner which would provide for sustainable income growth" (Kaplinsky & Morris, 2001). Even with the current global markets, poverty still exists. Value chain research can help in overcoming this.

Stoian et al. (2012) discuss the research performed on the use of value chain research to reduce poverty. They advocate a holistic and asset-based approach in value chain research. An asset based approach can be compared with the rent based approach of Kaplinsky & Morris (2001). Stoian et al. (2012) also warn for possible ineffectiveness when this is not done. The most important factors to take into account in designing a pro-poor value chain are: 1) that the value chain must embrace the complex needs and realities of the rural poor, 2) the recognition that market-oriented activities are important but not exclusive elements of rural livelihood strategies, and 3) the specific challenges and needs of the very poor given their higher risk and vulnerability.

Several frameworks are developed to do a value chain analysis which include rural poverty and how to overcome this poverty by upgrading the value chain. Three articles are based on the same framework. This framework focusses on vertical (between links in the value chain) and horizontal (within a link in the value chain, usually referring to terms of participation, poverty, vulnerability, risk and inequality in the rural link in the chain) elements (Bolwig, Ponte, Du Toit, Riisgaard, & Halberg, 2010). This is represented in Figure 5. In their paper, Riisgaard et al. (2008) explain these elements further and relate them to research questions and an action plan. A definite framework based on these papers is given by Riisgaard et al. (2010), where steps in value chain analysis and upgrading are given. These steps can be found in Table 2. They distinguish 3 types of upgrading, which also interact. These can be found in Figure 6. These can be divided into horizontal (improve process, product or volume), vertical (change and/or add functions) or both (improve value chain coordination).

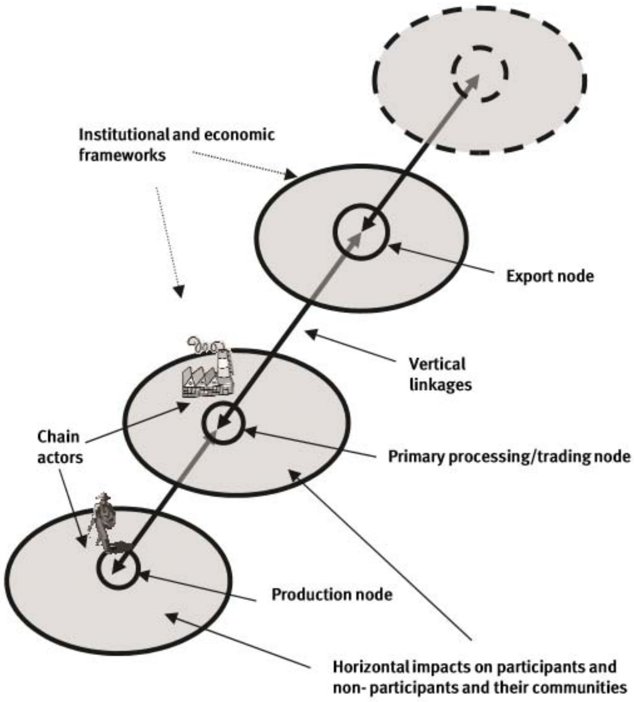


Figure 5- Vertical and horizontal elements in a value chain (Bolwig et al., 2010)

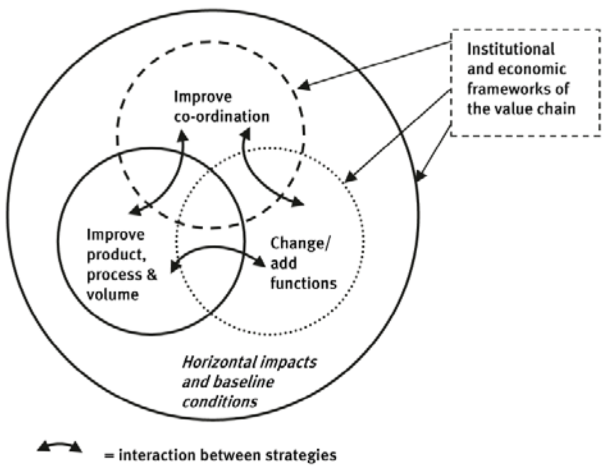


Figure 6- Different types of upgrading a value chain (Riisgaard et al., 2010)

Table 2- A 7-step framework for value chain action research Riisgaard et al. (2010)

Action research step	Main components of step
Step 1 – Choice of overall research design	Identify major issues to be addressed
	Choose value-chain type & geographical focus
Step 2 – Identification & engagement of the target group (setting boundaries of the research	Define & select the target group
	Identify local organizations with which to work
	Agree on action research process & define roles & responsibilities
	Agree on level of ambition & timeframe
	Consider local 'political' issues arising from choice of target group & how to deal with them
Step 3 – Address poverty, gender, labor & environmental issues (horizontal aspects of chain)	Conduct participatory & 'gendered' problem identification & prioritization
	Place the prioritized problems in the broader value-chain context
	Aimed for impacts of to-be-designed upgraded value chains
Step 4 – Conduct value-chain analysis (vertical aspects of chain)	Analyze & map the value chain
	Identify the position of the target group within the chain
	Identify the performance requirements, risks & rewards experienced by the target group
	Quantify key elements of the value chain in each relevant node (including assessment of the target group's competitiveness)
	Relate the problems identified in section 9.1 to the detailed value-chain analysis. Then eliminate problems that cannot be addressed through a value-chain approach & prioritize problems to address
Step 5 – Choice of upgrading strategy	Formulate promising upgrading strategies for ex-ante evaluation & select one 'best bet' strategy
	Identify promising 'action points' where change can be stimulated
	Establish a baseline for ex-post evaluation of the action research
Step 6 – Implementation of research & action (support activities)	Develop a concrete plan of action
	Implement research & strategy through support activities such as: collecting & analyzing data, building competences, mobilizing political & economic resources, organizing & creating alliances
	Collect, analyze & disseminate information (research & documentation)
Step 7 – Evaluation & adjustment (or exit)	Evaluate the results of the action research (ex-post). Distinguish between 'horizontal' impacts & immediate outcomes
	Formulate new/adjusted strategy & start new cycle of action research, or end the action research (exit).

Donovan & Stoian (2012) discuss a tool for value chain design. They present an extensive guide on how to do value chain design research and how to assess the impact of value chain design. They develop a way to identify different stakeholders (used for Figure 2 of this research) and then design an 'impact pathway on asset building' (as made in this research in Figure 9). This links several design choices to expected outcomes, all based on an asset-centered approach. Assets can be seen not only as physical assets, but also a human capital, social capital, et cetera.

6.3 Biomass value/supply chains

"Biomass is biodegradable products, wastes, and residues of biological origin from agriculture, forestry and aquaculture" (Holm-Nielsen & Ehimen, 2016). Biomass can be used to produce several types of products. The most common use nowadays is to produce ethanol from it. Holm-Nielsen & Ehimen (2016) have gathered several papers that elaborate on the uses of biomass (biofuel), the possible sources (forestry, agriculture, human waste), the problems (storage, rot, seasonality, etc.), and the supply chains (supply, demand, markets, processes, etc.). Also, several models are discussed and examples of supply chains are given. The impact, benefits and doubts of biomass value/supply chains and the processes and products are also discussed.

General problems with biomass are the high water content, which makes it costly to transport, vulnerable for rotting and hard to store. Besides that, the rotting that can occur, the seasonality and the difficulty of growing are issues. These and other issues are discussed by Fiedler et al. (2007) in a general description of a biomass supply chain. Gold & Seuring (2011) give an overview from the papers that discuss biomass supply chains. Hamelinck et al. (2005) focus on the transport in the supply chain of biomass (also considering the energy balance) and developed a cost model. This is based on an earlier, very extensive model by Suurs (2002). Rentizelas et al. (2009) focus on the storage problem and propose to use multiple sources of biomass to avoid the problem of seasonality.

Also, more specific cost models and optimization models are given, using case examples. Tatsiopoulos & Tolis (2003) include a location problem, Papadopoulos & Katsigiannis (2002) developed a computer program for proper site locations, Cundiff et al. (1997) developed a linear programming optimization tool where weather concerns are taken into account, and Zhu et al. (2011) developed a Mixed Integer Linear Programming (MILP) model. All of these specific papers also discuss the general issues and problems with a biomass supply chain.

These models can be used as basis and as sources for ideas how a cost model or decision model can be developed and which factors are to be taken into account.

6.4 Algae value chain

This project is focused on the use of algae as biomass. McHugh (2003) gives a general overview of the macro-algae (seaweed) industry, where the different products that can be made from algae (agar, alginate, carrageenan, human food, and others) are discussed, as well as the cultivation, harvesting, and fishing for algae. There exist three types of algae: brown, red and green. Every type has its own specifications, chemical content and thus end-use. An overview on the algae present in Chile is given by Avila & Seguel (1993).

There exist many models concerning the supply chain of algae to biofuel. General descriptions of (macro-)algae value/supply chains to make biofuel are given by Roesijadi et al. (2010), Nikolaisen et al. (2011), Burton et al. (2009), and Fusco & Dowding (2011). The last also discusses the possibilities of seaweed in Ireland and what the potential is. Philippsen et al. (2014) give an excellent schematic overview of the seaweed supply chain (Figure 7) and van de Burg et al. (2013) give detailed descriptions on the chemical components of the different types of algae.

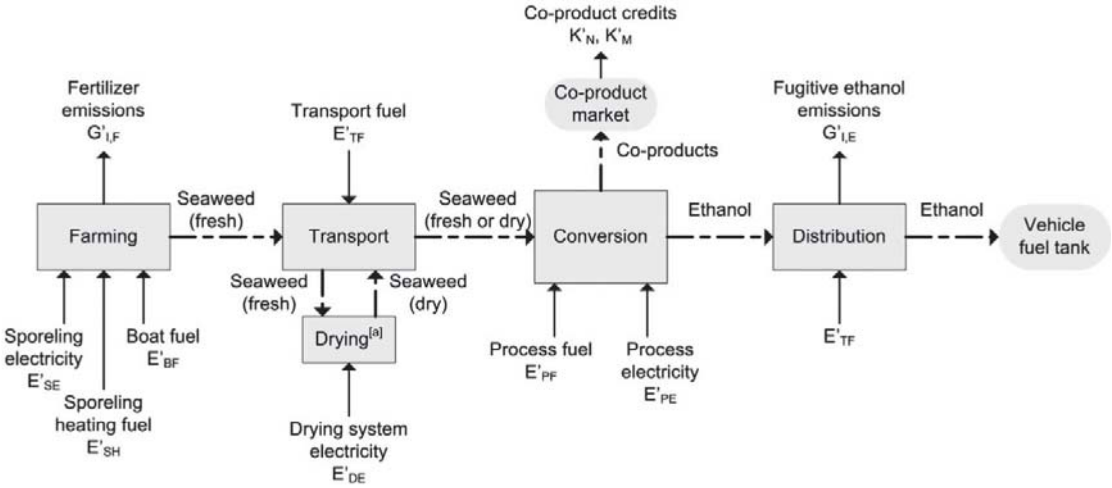


Figure 7- Algae supply chain example by Philippsen et al. (2014)

The different stages in the supply chain are also addressed separately. For example Lee & Ang (1991) discuss a model for seaweed growth and optimal harvesting, Gardner & Mitchell (1953) describe the drying process. A general biomass drying process is described by Daghigh et al. (2010). Storage of fresh seaweed is discussed by Black (1955) and the complete value chain structure and conduct by Krishnana & Narayanakumar (2010).

One specific research direction is the analysis on the feasibility of the cultivation of seaweed on the shores of the Netherlands, in combination with a windmill farm, researched by van den Burg et al. (2016) and Reith et al. (2005). The numbers given in these papers are very specific and can serve as a benchmark for this project.

6.5 Supply Chain Engineering

In the designing of a supply chain, several factors can be distinguished that are relevant in any supply chain. Literature provides several methods, models and guidelines to design a supply chain and overcome the problems that can occur. This is generally referred to as 'Supply Chain Engineering'.

An extensive book on supply chain engineering is provided by Govil & Proth (2002). In this book states that every activity can be categorized as one of the following: buy, make, move, store, and sell. For each category, they stated questions to be answered in designing a supply chain. Furthermore, they stress the importance of analyzing local decisions on the supply chain and its costs, and the analysis on how profit would be shared in the supply chain (the sharing process), which can be related to the power distribution in a value chain. Each module, corresponding to one of the five major activities, is defined by five characteristics: 1) its state variables, 2) the set of feasible controls, 3) events generated by external world, 4) physical constraints on control, and 5) operational costs. By looking to a supply chain following this structure, a supply chain can be designed in a structured way. Also included are tactical supply chain design and how to develop a new product in a supply chain.

More mathematical models and explanations behind supply chain engineering, including some analytics on frequent problems, can be found in the book of Dolgui & Proth (2010). A more general overview of supply chains and logistics is given by Christopher (2005), where Bowersox et al. (2002) and Goetschalckx (2011) give specific guidelines for analyses in supply chain engineering in extensive and complete books.

7 Research design: design and implement an improved value chain with the regulative cycle

Since the problem is now clear, defined within a scope and the research goal is determined, the research will be designed in this chapter based on the literature scan.

7.1 Methodology & structure: the regulative cycle following the framework of Riisgaard et al. (2010)

In solving a practical problem, the go-to methodology is the regulative cycle. The cycle was first presented by Van Strien (1997) and later by Wieringa (2009). It consists of four steps, where the first step (problem identification) is already done in the previous chapters. The remaining steps will be done in the remainder of this research. The regulative cycle can be found in Figure 8.

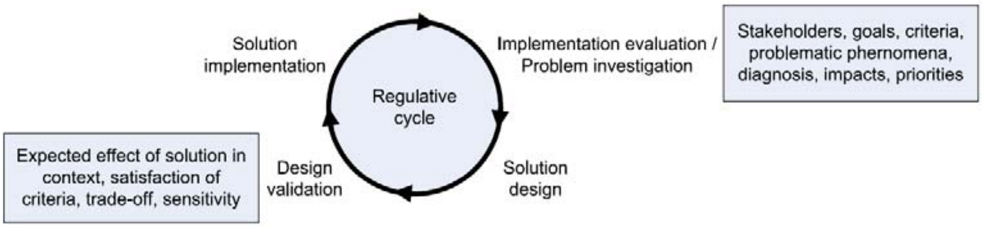


Figure 8- Regulative cycle, according to Wieringa (2009)

In the ‘Solution design’ step, the solution will be designed according to the research steps presented in Figure 4 and Table 2 (in the literature chapter) and the Lean ideology as discussed in Rother & Shook (1999) and Jones & Womack (2002). The ‘Design validation’, impact pathway and Stakeholder definition will be done according to the methods of Donovan & Stoian (2012). The implementation plan will be done following supply chain engineering principles as, for example, presented in Govil & Proth (2002).

The structure of the research will follow the research steps (1-7) from Riisgaard et al. (2010) as presented in Table 2. Since the framework describes a research from the start, the two first steps are already performed in earlier chapters. The remaining steps will be performed in upcoming chapters, by answering the research questions as stated in the next section.

The first steps can be related to earlier chapters as discussed here. Riisgaard et al. (2008) indicate that the research should be started as any other regular research: with an introduction and literature review (sections 3 & 6). This can be complemented with an addition in value chain research: stakeholder interviews. The information given in the problem analysis was obtained by performing these stakeholder interviews with all stakeholders involved (as specified in the stakeholder definition, section 5.5). The value chain research starts with a good general understanding of the current value chain. This step is already done in this research and can be found in section 5 (Problem analysis). In the scope, goal and stakeholder analysis the requirements of step 2 are fulfilled. The level of ambition is also described in the goal. Step 7 is omitted since this is out of the scope of this research.

7.2 Research questions

The several research questions, as defined according to the framework of Riisgaard et al. (2010), are stated here. They are separated per step.

7.2.1 Address poverty and broad value chain (step 3)

To understand the problem better, the way of poverty present in this study has to be examined, as well as the broad value chain in which this takes place. Furthermore, the impacts aimed for in this research need to be known. This leads to the following first research questions:

1. In what way is poverty represented in the fishermen community?
2. What does the broader context of the value chain looks like and how does that influence the research?
3. Which impacts are aimed for and how can the inputs in this research lead to these impacts?

7.2.2 Current value chain (step 4)

Then, the current situation has to be studied. The following questions are relevant in this:

4. What does the current value chain look like?
5. Which value added processes are there currently?
6. What are the relevant numbers in the current value chain?
7. How is the current information flow designed?
8. Which factors are fixed and cannot be changed (or only against high costs)

With the answers to these questions, a current state map can be drawn.

7.2.3 Upgrading value chain (step 5)

After the current state is drawn, possibilities for upgrading the value chain and adding more value to the algae need to be researched. This corresponds to the following questions:

9. Which ways of upgrading a value chain exists (follows from the literature scan) and how do these ways of upgrading translate to the practical case?
10. Where is the current value chain contributing the most to poverty and can the value chain thus be improved most?
11. How do the future state maps look with the different forms of upgrading?
12. Which Key Performance Indicators are most relevant and how do the different value chain score on these?

7.2.4 Implementing the value chain as a supply chain (step 6)

After these questions are answered, the value chain is ready and can be implemented. This can be done by answering the following questions:

13. How can the design be made robust and fool-proof?
14. How can the upgraded value chain be implemented?
15. What order of actions is best to follow?

8 Address horizontal aspects of chain (step 3): roots of fishermen poverty and aimed for changes

In this chapter, the general problem, poverty of the fishermen, is further explored and divided in different factors which can be seen as the roots. These factors can then be used to evaluate the upgrading strategies in step 5 (chapter 10). Also, the problem is placed in a broad value chain perspective to gain a general overview of the supply chain position in the local society. At the end these are combined in an overview of which improvements related to these problems are aimed for within this broad value chain view. This follows the method proposed by Donovan and Stoian (2012).

8.1 Poverty description: low income & general development of communities

As specified in section 5.2, the fishermen suffer from low education levels, low technologic availability, low commitment to innovation, and low hopes for better future perspectives. Also, they have a low personal attachment to the final product, which decreases the level of commitment to innovation. All of this leads to a low perspective that it will ever change and thus the hopes for a better future are low.

This can be related to a general low income and a low security of income, since the availability of money determines largely the level of education available in the country of Chile, as it does influence the infrastructure and technologies that are being made available to the communities. This also affects the physical capital that is available for the fishermen. Since the product is sold in a market situation, the final product (carrageenan) cannot be traced to the source, which makes the final product impersonal, especially since it also is not clear from view that the products are made out of algae.

Four general root problems can be specified from the analysis above, following the checklist to identify poverty as presented in Riisgaard et al. (2008). These can be found in Table 3. When these are solved, the problems in the fishermen community will also be solved. The biggest impact, however, is suspected to be made by the income related problems, thus implying that these have to be prioritized.

Table 3- Identified root problems, following the checklist of Riisgaard et al. (2008)

Important root problems	Other root problems
Low income	No physical capital to produce a more advanced product
Low security of income	A low traceability of the final products

8.2 Broader value-chain context evaluation

The broader value chain characteristics can help to understand the difficulties and favorable parts in the chosen value chain with respect to the overall lives of the fishermen. Here discussed and evaluated are the sensitivity and resilience of the supply chain, the involved capitals, the gender division, general organization, environmental risk and influence on global sustainability, which are suggested subjects by Riisgaard et al. (2010).

8.2.1 Sensitivity and resilience (+)

When changes are made in the value chain which turn at unfavorable for the fishermen, the value chain can easily return to its original state while it also is not the only form of income of the fishermen. This implicates a favorable sensitivity and resilience of the value chain: participants can easily exit and it is not only form of income. Also, a new value chain can help take away the high influence of seasonality, when a more stable product can be formed.

8.2.2 Capitals (-)

The current capitals of the fishermen are almost non-existent. They only possess some boats to fish and the algae wash up as a natural form of capital. The infrastructure in place is minimal and for example telephone service is almost completely absent, schools are located far away and are of low quality (hence low level of education).

8.2.3 Gender division (++)

While gender equality is still very low in Chile, women in fishermen communities are forces to help in earning money due to the low incomes. They are the main group of algae collectors while the men are fishing. This indicates that gender equality is not a priority problem to be solved.

8.2.4 General organization (+/-)

Fishermen are only loosely arranged through FEPACOR, and the fishermen are not contracted (they only sometimes work in teams for the village 'eldest'). This indicates a very loosely organized value chain, which is currently a bad influence but implicates a good prospect of improvement.

8.2.5 Environmental risks (+)

The local environment can have a risk of overfishing on algae when a profitable algae value chain is implemented. However, fishing for algae is difficult and labor-intensive. It is therefore not assumed to be a problem.

8.2.6 Influence on global sustainability (++)

Since algae are a natural energy/food source and little energy is needed to harvest them because they just wash up, exploiting an algae value chain could help in fighting climate change, possibly also changing the need for animals for food production. This is a speculative advantage of algae, but it is a general main aspect for researchers to investigate the algae value chains.

8.3 Aimed for impacts of to-be-designed upgraded value chains

As stated by Donovan and Stoian (2012), an impact pathway can be distinguished, which states the major impacts of the new value chain designs with respect to poverty. It states the expected inputs in a new value chain design (by the stakeholders discussed in previous chapters and displayed in Figure 2) and what impacts are suspected as a result of these inputs. The inputs will first lead to some capital outcomes, which then will result in these impacts. The overview can be found in Figure 9.

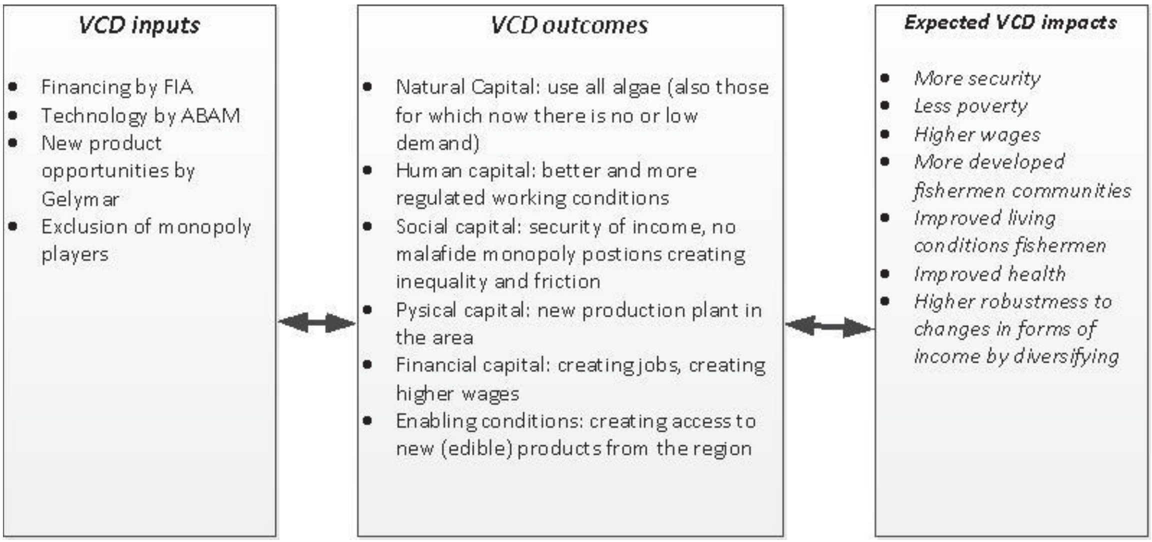


Figure 9- Value Chain Design impact pathway assessment

9 Address vertical aspects of chain (step 4): the construct and added value of current value-chain

In this chapter, the vertical aspects of the value chain (interactions between actors) are evaluated, resulting in an overview of the total value chain. This is done to 1) get an understanding of the selected value chain and a basis for promising value chain upgrades, 2) locate the smallholders of which the poverty will be reduced 3) define current quantitative performances to define the base line (added value per actor), and 4) address which problems can be realistically solved.

9.1 Analyze and map the value chain: construct, information flow and value-adding processes

In this section, the map of the current value chain is shown and analyzed. In his the information flow and value added processes are shown. Also included is an analysis of the value adding aspect of the processes, and the fixed processes which cannot realistically be changed and which, more flexible factors, can.

The mapping of the current is done following the books of Rother & Shook (1999) and Jones & Womack (2002) and can be found in Figure 10 and Figure 11. There are two slightly different value chains considered, since there are two options to come to the same results. These option are however so similar that they are both considered as the current value chain under research. To come to the current value chain, some assumptions had to be made since not all information was available and not all actors were willing to participate in the project. In appendix 15.6 (Table 16), every assumption can be found and an explanation on each choice.

The information flow is almost non-existent. All of the operations are performed on a 'push' basis and no feedback is given. In the current value chain, the buyers just show up when they know the season is right or at fixed dates (the large truck arrives once a week in the summer and fall). There is a small information flow from the processing companies to the intermediaries on when the truck will be arriving.

In the current value chain coordination, no contracts exists, meaning it is purely market based. This is an indicator for low prices and can be the base for improvement.

The fixed processes are the location of the fishermen communities and the intermediaries and the capacities as they are right now. The locations will mean moving whole communities or, in case of the intermediaries, whole drying facilities. Changing the capacities as they are is possible, but will imply high investment costs. Another problems that cannot be addressed is seasonality. Since the scope is chosen to remain on algae collecting, this seasonality will remain an issue. Traceability, advanced capital available and security of income are the factors that can be solved by changing the value chain.

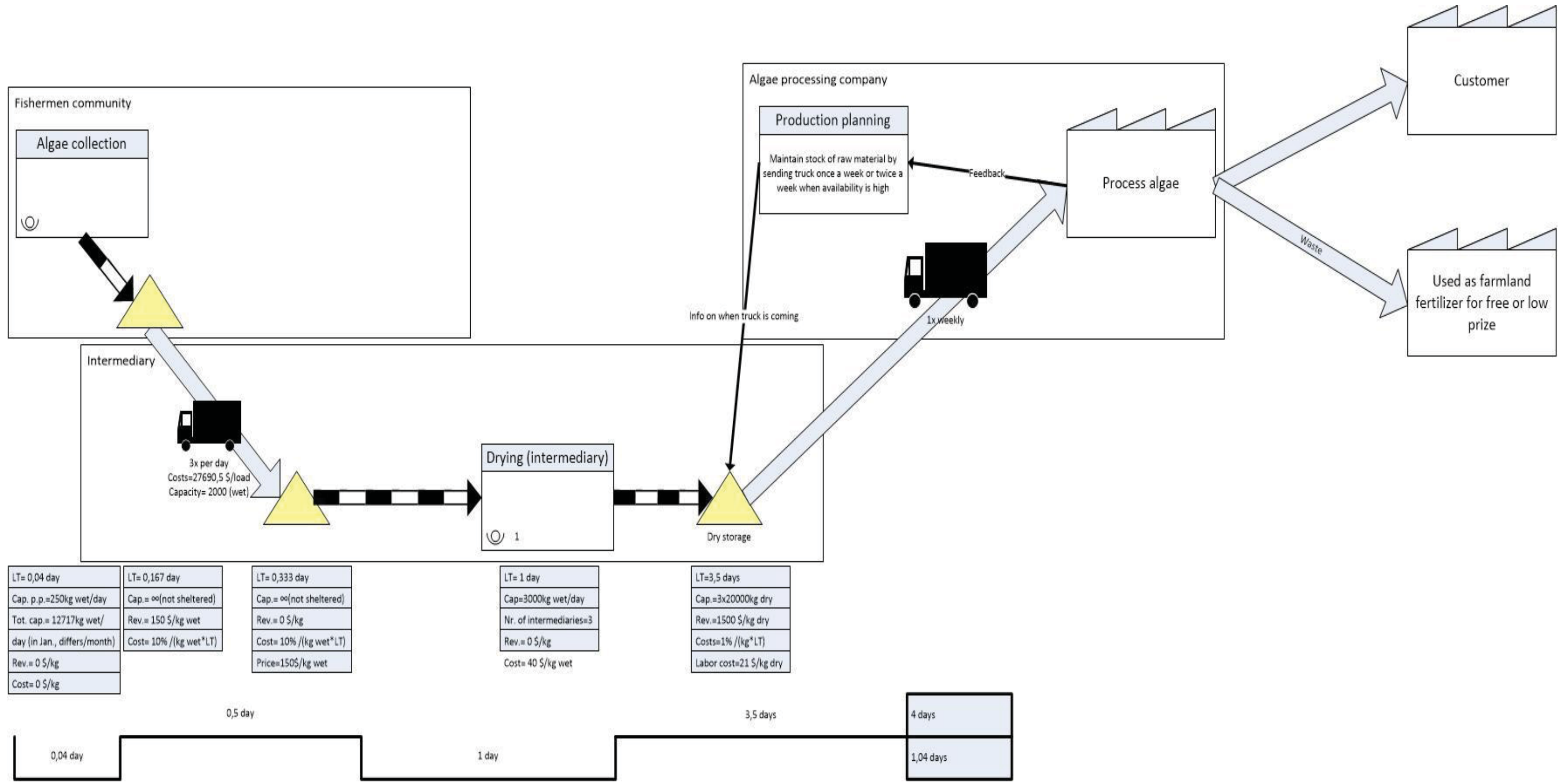


Figure 10- Current value chain map (with drying at intermediary)

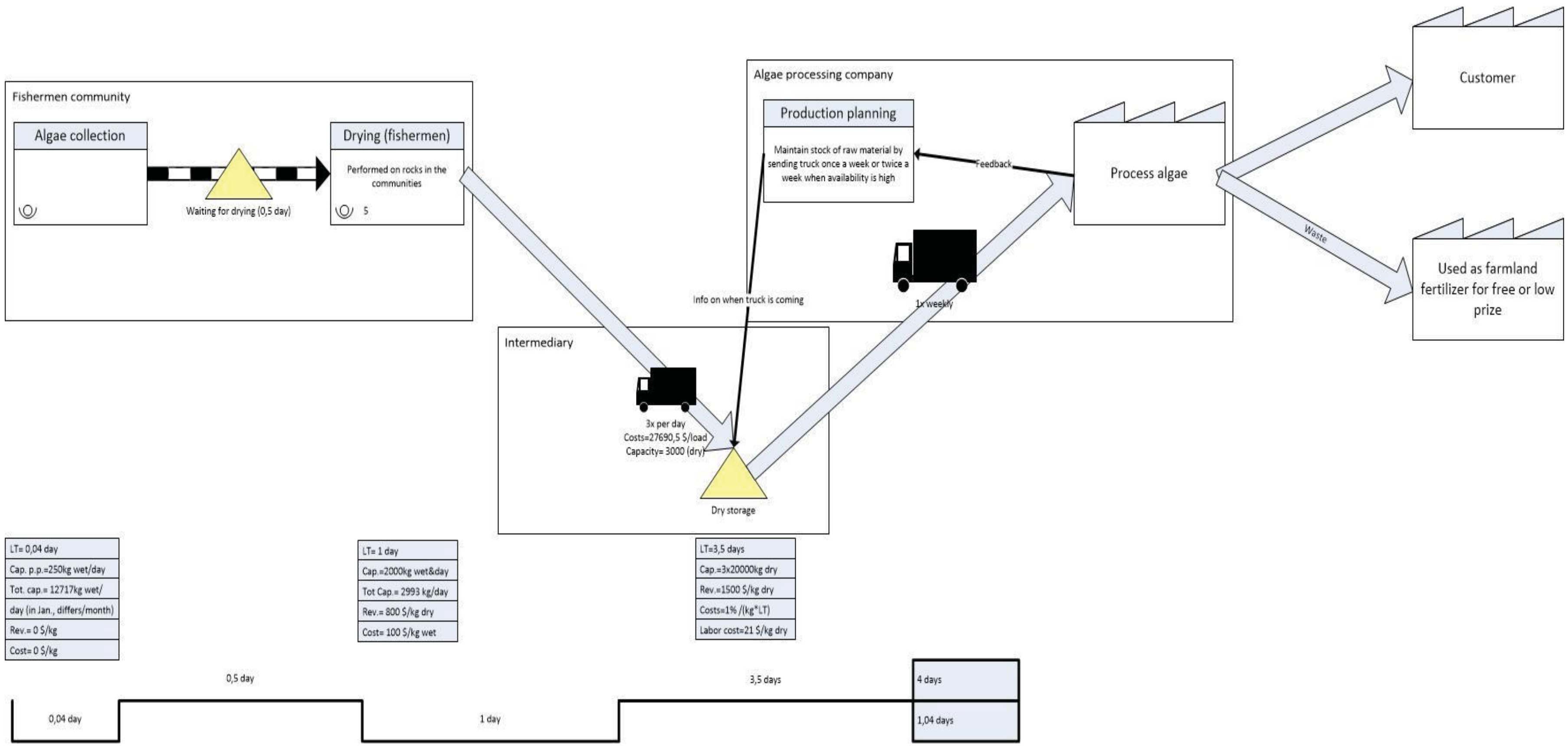


Figure 11- Current value chain map (with drying at fishermen community)

In the current value chain, most processes are value adding or necessary non-value adding (transportation and storage), which means that the total process time of the products cannot be shortened (and thus the value of the product cannot be increased) by eliminating unnecessary processes. This gives the hint that the form of upgrading of the value chain will not be by focusing on lean implementation. It can be seen from the timeline in the value chain map which processes are value adding and which are non-value adding (higher lines are non-value adding processes and lower lines are actual value adding processes). Processes can be divided in three categories: 1) value adding, 2) necessary non-value adding, and 3) unnecessary non-value adding. Of the current processes performed, the storage and transportation are non-value adding processes. They are however necessary for the value chain to operate. The process overview of this value chain will thus remain and shown at the bottom of the value chain map in Figure 10 and Figure 11.

However, if there were another way to avoid these non-value adding processes, the total lead time of the algae production would decrease drastically, hence improving quality of the algae. Currently only 20,63% of the lead time is value adding and the average lead time would decrease from 5,04 days to 1,04 days. This decrease will result in a higher freshness of the algae, which will improve the quality of the algae and prevent the loss of biomass (by rotting) and of beneficial nutrients (such as proteins).

9.2 Position of the target group within the chain: raw material supplier (low power)

To better understand the position of the actor where poverty should be reduced, this target group should be located in the supply chain. It can easily be identified from the value chain map as the very first actor: the supplier of raw material. This position comes with very little power, since the value chain is market based. The intermediary, which is the next actor in the chain, determines the price and controls the market for algae. They are in a highly powerful position.

9.3 Performance requirements, risks & rewards: intermediaries in control through monopoly position

To get a better understanding of the construct of the value chain and why it is built up in this particular way, the existing requirements on the product and risks and rewards experienced by the actor suffering form poverty have to be analyzed.

At this moment, there are almost no performance requirements, expect for the fact that a lower price might be given when the quality is lower. This, however, cannot be assessed properly at the moment and is thus not a common practice. This makes it unclear what the actual value of the product is, which can be turned against the seller of the raw material.

The risks as experienced by the target group in the supply chain are the low price as determined by the intermediary, all the power that lies with the intermediary to influence this price and the seasonality of their source of income. The low price invokes the poverty of the fishermen and is therefore the main risk for the wellbeing of the fishermen. The intermediary has all the power to influence this price and therefore the indirect risk of the lack of power can be seen as the root of the low income risk. The seasonality influences the stability of the income and is therefore also threatening the quality of life of the fishermen.

The total rewards experienced by the fishermen (consisting of only their income) are very low, since the money they earn is very few.

9.4 Quantitative assessment: added value calculations for a baseline

To obtain a baseline which can be used to analyze possible changes in the value chain, a quantitative assessment is done of the current value chain.

In quantifying the value chain, the results can be obtained from the bottom part of the value chain map and are summarized in Table 4. The assumed values used in the calculations are stated in Table 5 and a detailed explanation on the calculations (follow the assumptions as mentioned in appendix 15.6) can be found in appendix 15.8. The added value is calculated as follows: the output value minus input costs, following Kaplinsky & Morris (2001).

As can be seen when calculating added values, the fishermen prefer to only collect the algae and not dry them, since this results in a higher added value of their product. Drying adds only $50 per kilo extra (selling price of $150 for wet and $200 for dry algae) and has more input costs to dry on the rocks: $100 per kg (2000 kg per day by 5 workers who earn $40.000 per day). This is also what can be seen in reality: fishermen only collect algae, as long as there are sufficient available. Only when there are not enough algae on the shores to collect a full day (for example outside summer months), fishermen start to also dry the algae, which they do in the time that is otherwise unused.

In the current setting, when the drying is done by the intermediary, fishermen earn a maximum of $36.875 per day (250 kg per day, minus a little loss in storage, for $150 per kg), which is around four times the minimum wage in Chile. This seems a lot, but the season is only for a short time at this maximum. They have to build a buffer for the other months in these peak months. In the peak months, already around a fifth of the total amount of algae in a year wash up. With this relation, the total earnings per year can be estimated to $5.531.250 (€7.375).

For the intermediary, it does not really matter in which way it obtains the algae (dry or wet), since the added value is approximately the same for both (the input costs of drying and extra transport costs are approximately the output value). An advantage of buying wet algae can be that it provides an extra job as perceived by the intermediary, for a person drying the algae.

The intermediary can earn in this setting a maximum of $421.170 Chilean pesos per day ($175 revenue per kg, low operational costs and 3000 kg per day), while also creating jobs for $75.750 per day (which translates to 1,26 fulltime jobs of $60.000 per day) in drying and collecting the algae. This is the maximum (as in the calculations for the fishermen), accounting for one fifth of the total amount of algae. When corrected for this, the earnings are still very high: a yearly earning of €84.234. This reveals the problem that exists in the value chain, where fishermen earn around €375 per month and the intermediaries with a monopoly position can earn up to €7.019,50 per month.

In Table 4 a comparison with the minimum vital salary is made and it can be seen that the fishermen are currently earning below this level in both value chain scenarios. The minimal vital wages are the average living wages needed for a typical family living in Chile (2 adults, an average of 1,7 children and 1,8 adults working). The estimation is made by the organization called WageIndicator.org (2016) and is set for Chile between $434.200 and $622.100 per month for the average family (WageIndicator, 2017). In the calculations in the table, an average wage of $500.000 per month is used as reference.

Table 4- Added values current value chain and corresponding wages of the actors

Value chain	Actor	Added value per kg wet algae	Capacity kg wet per day	Max. daily earnings	Estimated annual earnings (% of minimum vital salary)	Annual earnings in €
Drying by fishermen	Fishermen	$90,00	250	$22.500	$3.375.000 (56,26%)	€4.500
	Intermediary	$147,39	3000	$442.170	$66.325.500 (1105%)	€88.434
Drying by intermediary	Fishermen	$147,50	250	$36.875	$5.531.250 (92,19%)	€7.375
	Intermediary	$140,39	3000	$421.170	$63.175.500 (1053%)	€84.234

Table 5- Used value and estimations in calculating added value

Description	Value	Base
Max. algae collection per person per day	250 kg wet algae	Fishermen interview
Max. drying algae on rocks per day	2993 kg wet algae	Fishermen interview in biggest community and smaller communities relative to this.
Capacity drying on rocks per person per day	2000 kg wet per 5 persons	Fishermen interview
Earning of a person drying on the rocks per day	$40.000	Related to the earnings of an average collector, based on fishermen interview
Loss of products wet storage per day	10%	Estimation
Loss of products dry storage per day	1%	Estimation
Capacity truck	2000 kg wet algae 3000 kg dry algae	Based on internet sources and estimation of fishermen
Average utilization of truck	50%	Safe bet
Pickup frequency intermediaries	3 times per day	Fishermen interview
Buying, loading and unloading time	Each 10 minutes	Fishermen interview
Van petrol efficiency	7 km/L	Safe bet
Price petrol	$800/L	Observation on the streets
Salary driver	$60.000 per 6 hours (2 hours rest)	More than fishermen to be safe
Capacity dryer intermediary	3000 kg wet algae per day	Estimation from fishermen
Electricity drying	$20 per kg wet algae	0,15 kWh (approx. ¼ of theoretically needed energy to vaporize the water)
Wage person drying at intermediary	$60.000 per day	More than fishermen to be safe
Wage person storing at intermediary	$60.000 per day	More than fishermen to be safe
Capacity storage	20.000	Indicated as adequate by fishermen
Pickup frequency truck algae processing company	Once a week	Interview fishermen

10 Choice of upgrading strategy (step 5): implementing a new carrageenan value chain combined with a paper product from the waste stream

In this chapter, the possible ways to upgrade the current value chain will be discussed and a definitive selection of an upgrading strategy will be made. First, the possible upgrading strategies are discussed and a best bet is selected. Then, handles where change can be stimulated are defined as 'action points'. These action points are combined with the upgrading strategies to come to three possible upgrading scenarios. Of these three scenarios, the best one is chosen to be implemented, based on the most important performance indicators to overcome poverty as stated in chapter 8.1.

10.1 Promising upgrading strategies & 'best bet' strategy selection: move part of production to fishermen community

The current value chain is evaluated on the four possible upgrading methods, as described by Kaplinsky & Morris (2001): 1) Process upgrading, 2) Product upgrading, 3) Functional upgrading, and 4) Chain upgrading. The possibilities for upgrading are identified, based on the current value chain map, lean principles as proposed by Both Rother & Shook (1999) and Jones & Womack (2002), and the possibilities provided by a former study of ABAM on the minimal viable products possible from algae. This last study resulted in the discovering of two possible new products from algae: 1) produce a pre-product for flour from algae and 2) produce paper from the algae industry waste stream. The results of the upgrading strategy analysis can be found in Table 6.

The changes that can be expected when implementing these upgrades can now be compared and a few 'best bets' selected. These best bets can then be evaluated more thoroughly to select the best new value chain. The upgrades should be evaluated on the way they could resolve the problems as mentioned in section 8.1. There it is stated that the 'income' and 'security of income' are the most important problems to solve. Also important, but less, are the available 'physical capital to produce' and 'traceability of the final product'. Therefore, the upgrading possibilities are assessed first on the two more important factors (in bold), and then on the other two factors (in normal). The results of this evaluation can be found in Table 7.

As can be seen from Table 7, the most favorable option is to include part of the production in the local fishermen community. This however raises the question which process(es) need to be included. This can be the current process that is performed in the algae value chain (making carrageenan), but can also be one of the new processes as described as other possible upgrading strategies (flour or paper from algae).

The production of paper from algae waste stream also seems a promising upgrading strategy, since this offers great financial possibilities. This can be expected because the waste stream will be very cheap, since it is now hardly used.

These best bets should be the main upgrading strategies, but combinations of other upgrading strategies can lead to even better value chain upgrading. Therefore, in the selecting of a definitive strategy, all upgrading strategies should be included in the evaluation.

Table 6- Upgrading possibilities

Upgrading method	General description	Possibilities in current value chain
Process	Increase efficiency of internal processes	Elimination storage
		Eliminating transport
		Improve algae quality
Product	Introducing new products or improving old products	Use algae waste stream of algae processing companies to produce paper with 30% algae and 70% conventional base material
Functional	Insourcing / outsourcing	Move part of production process to fishermen community
		Quit/improve drying by fishermen communities
		Cut out intermediary
Chain	Move to new value chain	Use algae to produce flour

*Table 7- Evaluation upgrading possibilities (**+ or - (bold)** = important factor, + or – (normal) = less important factor, in brackets the total accumulative number of + or -)*

Upgrading possibility	Most important Income	Security of income	Others Physical capital to produce	Traceability of the final products	Total
Eliminate storage	**+**	**-**	+	-	0
	Less costs	More difficult process	Liberates space	Stacking results in unclear ownership	
Eliminate transport	**+**	**+**	+/-	+	**++**(2) +(1)
	Less costs	More robust supply chain	No effect	Less transport improves traceability	
Improve algae quality	**+**	**++**	+/-	+/-	**+++**(3)
	Higher prices	More trust in product	No effect	No effect	
Use waste stream to produce paper	**+++**	**+++**	+/-	+/-	**++++++**(6)
	Use currently valueless waste to create profit	Create business from valueless waste	No effect	No effect	
Move part of production process to fishermen community	**++**	**+++**	+++	+++	**+++++**(5) ++++++(6)
	More value added by fishermen	More control by fishermen	Production location created	Product origin clear	
Quit/improve drying by fishermen communities	**++**	**++**	+	+/-	**++++**(4) +(1)
	Non value-adding processes improved or quitted	More robust value chain	Improved drying facility is a new asset	No effect	
Cut out intermediary	**+++**	**+**	+/-	++	**++++**(4) ++(2)
	Cut out usurper of most added value	More stable market and more control	No effect	Traceability gets lost at intermediary	
Use algae to produce flour	**+**	**++**	+	+++	**+++**(3) ++++(4)
	Promising product and market	Security because of involvement of Gelymar	Machines needed	Clear what product comes from algae	

10.2 Promising ‘action points’ where change can be stimulated: projects around ‘Palo Muerto’

At the beginning and during the project, several developments occurred which can be used to facilitate change in the value chain. At these action points, the upgrading strategies as mentioned in the previous section, can be stimulated. The action points are listed here.

At the beginning of the project, there was already an ongoing project to construct a new drying facility for algae, together with a new processing plant for fish and shellfish. Furthermore, it will also include some space for a (small) algae processing facility and storage space. This project, when executed correctly and funding is granted, will provide the opportunity to implement five upgrading strategies:

1. To ‘improve drying by fishermen communities’. This strategy will immediately be implemented since it is the primary goal of the new dryer.
2. To ‘move part of production process to fishermen community’. This will be presented as an opportunity, since the plan for the processing facility is not yet specified. This Master Design Project will give answer to the question what to do with this space
3. To ‘cut out intermediary’. The operations of collecting, drying and storing the algae can be performed by the fishermen themselves with the new drying facility in place. This should be handled carefully to indeed exclude the intermediaries from the value chain.
4. To ‘eliminate transportation’. The processing facility will be placed right alongside the location where the most algae are collected in the region.
5. To ‘eliminate storage’. With eliminating the need for most transportation, also the need to store algae waiting for transportation will be eliminated. The dryer will be a continuous process and thus no storage time due to batch processing will be needed before this dryer (in contrast to the storage before transportation).

Besides this new plan, there is currently a fairly newly constructed dryer available at the fishermen community ‘Palo Muerto’, which however is not functioning and therefore not used. The dryer was constructed in a project financed by a government fund and executed by two students of the university. The project was however never finished properly and the students disappeared with the funding money. The fishermen are therefore left with an unusable dryer, which at the moment can only be used to store some algae protected from the rain. This dryer could be revised, thus adding to the drying capacity and capability in the fishermen community.

In the region, a big algae processing company, Gelymar, is looking to diversify their portfolio and is therefore looking for partners to develop these new products. This can be used a potential buyer and partner in implementing new value chains in the following two ways:

1. Gelymar has indicated to be interested to produce flour from algae and have started a project to develop this product. They would be helped by a pre-product of algae, where these algae have no color nor smell, and are willing to help in this development. The specifications needed for this pre-product are however still very unclear since the project has just been started.

2. Gelymar also possesses the waste stream that can be used to produce paper and is willing to sell this back to the fishermen. They are however themselves not interested in producing paper. In this way the upgrading strategy to produce paper from algae can be implemented, if the fishermen or another interested partner will produce the paper inhouse.

To find external funding, the government of Chile has several funding programs for the promotion of agricultural or aquacultural projects for which can be applied with a solid business plan. When this projects results in a solid implementation plan, these funds can be used to provide (part of) the initial investment needed.

The last action point that can identified is the fact that there is a high willingness to exclude the intermediary from the value chain by the fishermen, since the intermediary has a bad reputation in the fishermen community. The intermediary is viewed to be one of the main causes of the low value the fishermen get for their algae. To exclude them and thus implementing this upgrading strategy will be supported greatly by the fishermen community, making this upgrading strategy easier to implement.

The aforementioned action points can help in choosing the upgrading strategy.

10.3 Choose upgrading strategy: carrageenan + paper value chain best bet on qualitative and quantitative indicators to overcome poverty

With the best bet upgrading strategies (section 10.1) and possible action points (section 10.2) known, three achievable combinations of upgrading strategies can be determined:

Scenario 1: To produce carrageenan from algae (as is done at the moment), but without interference of the intermediaries, with inclusion of drying the algae at the fishermen community. This last part will also assure that there will be less need for transport and storage.

Scenario 2: To produce flour from algae, where the fishermen community deliver the pre-product. This will include drying at higher level in the community, but will also include part of the production process in the fishermen community. Furthermore, the need for storage and transport will diminish (as in scenario 1).

Scenario 3: In this scenario, the algae will be used to produce carrageenan and will exclude the intermediary (as in scenario 1). The difference will be that in this scenario the waste stream of the production of carrageenan will be used to produce paper. This will also include part of the production process in the community.

The qualitative assessment of the three scenarios considered, as combinations of the upgrading strategies, can be found in Table 8. In this table, it is shown which upgrading possibilities are included in which scenarios. The evaluation scores of the upgrading possibilities are shown (as calculated in Table 7), to be able to sum the evaluation of each scenario to come to a final score for each scenario. These final scores give the expected total influence on fishermen poverty.

From Table 8, it can be seen that scenario 3 is expected to solve the problems the best, but it will only be implemented if it is assessed positively on the quantitative indicators as well. A balance has to be found and therefore all three scenario are evaluated also on the quantitative indicators in the next sections.

*Table 8- Scenario description and expected benefits (**+ or - (bold)** = important factor, + or – (normal) = less important factor, in brackets the total accumulative number of + or -, colored cell = included in scenario)*

Upgrading possibility	Scenario 1 (carrageenan)	Scenario 2 (flour)	Scenario 3 (carrageenan + paper)
Eliminate storage	0	0	0
Eliminate transport	**++(2)** +(1)	**++(2)** +(1)	**++(2)** +(1)
Improve algae quality			
Use waste stream to produce paper			**++++++(6)**
Move part of production process to fishermen community		**+++++(5)** ++++++(6)	**+++++(5)** ++++++(6)
Quit/improve drying by fishermen communities	**++++(4)** +(1)	**++++(4)** +(1)	**++++(4)** +(1)
Cut out intermediary	**++++(4)** ++(2)	**++++(4)** ++(2)	**++++(4)** ++(2)
Use algae to produce flour		**+++(3)** ++++(4)	
Total expected benefits	**++++++++++(10)** ++++(4)	**++++++++++++++++++(18)** ++++++++++++++(14)	**+++++++++++++++++++++(21)** ++++++++++(10)

Following the upgrading scenarios possible, new maps value chain maps can be drawn (as presented in Figure 12, Figure 13 and Figure 14). The differences with the current value chain are explained below. The calculations and assumptions corresponding to these value chains can be found in appendix 15.9, appendix 15.10, and appendix 15.11.

For the sale of dry algae as raw material for carrageenan (scenario 1 & 3), there are no extra processes needed. However, a connection to the market, coordination with the customer and the actual sales have to be performed. This is thus included as an extra process, performed by an employee in the plant, who earns $60.000 per day.

For the production of the flour pre-product (scenario 2), several additional processes are needed and thus the added value has to be divided over more processes. The processes in the production process (Chop, Bleach, Remove Smell, Pulverize, Pack, and Sell to customer) are each considered as a separate, value adding process and also the washing process is new.

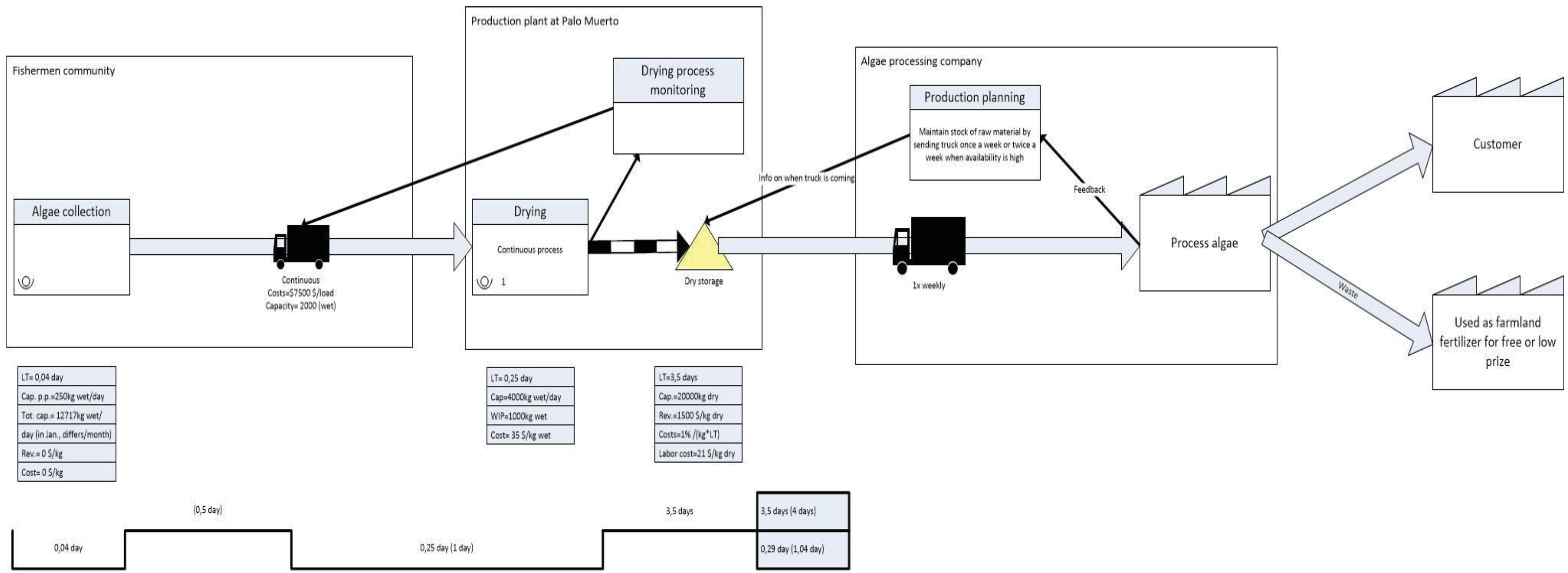


Figure 12- Value chain map scenario 1

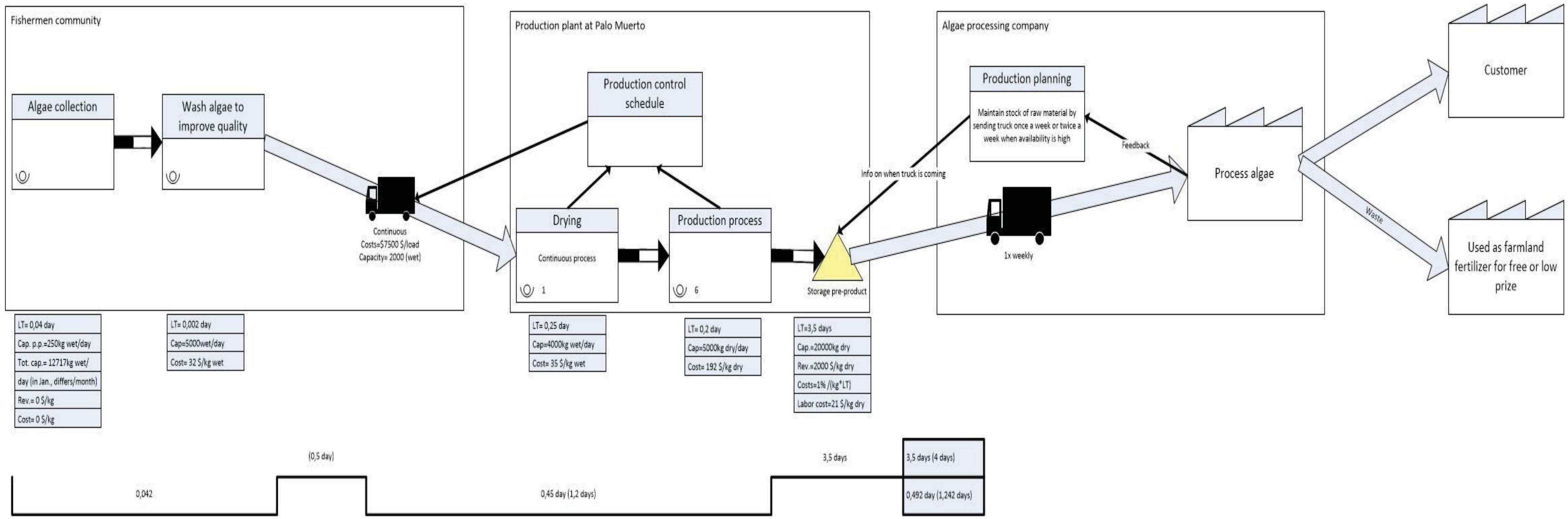


Figure 13- Value chain map scenario 2

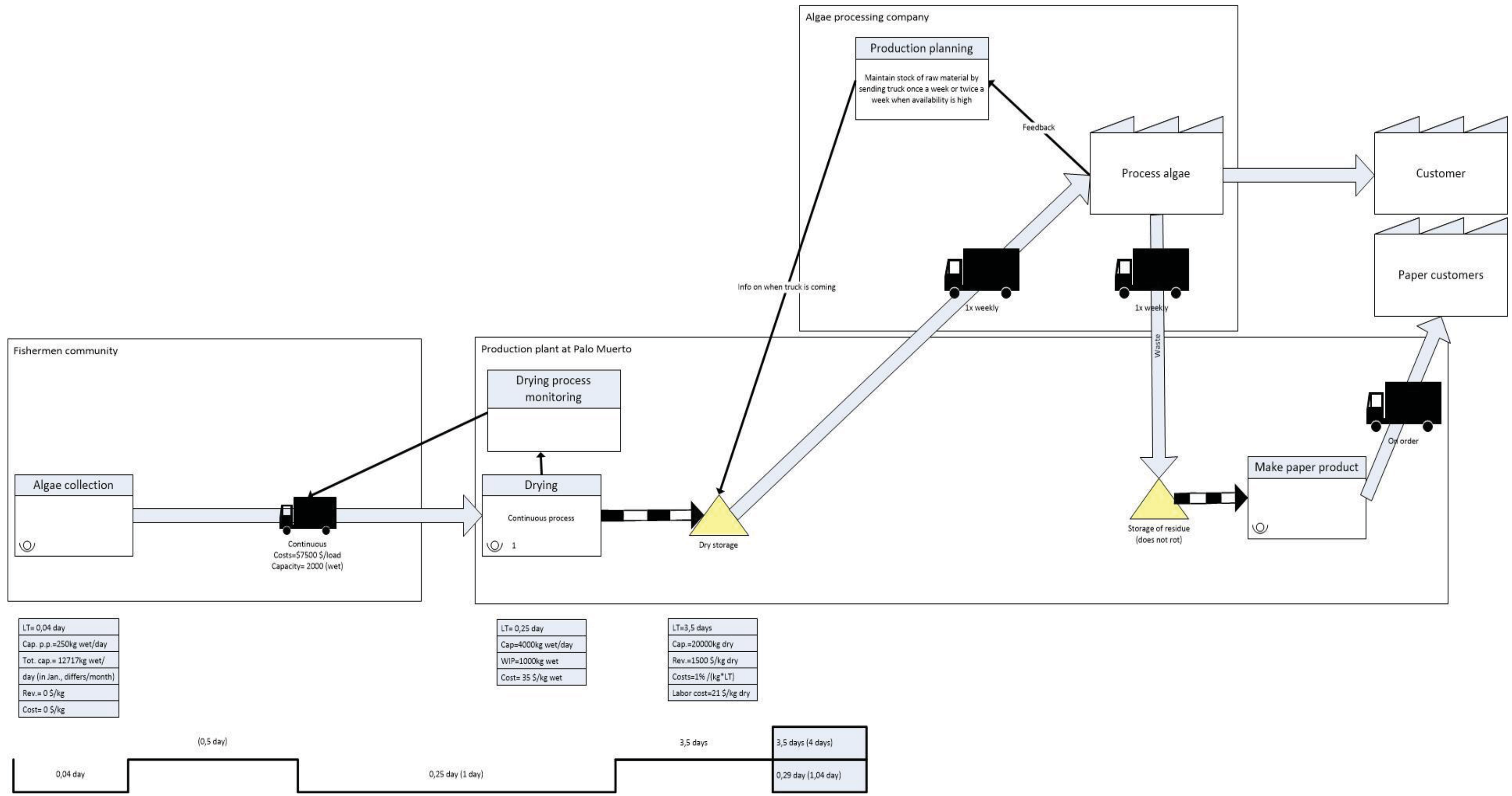


Figure 14- Value chain map scenario 3

In determining the performances of the proposed upgrades of the value chain, it is important to also assess them on several relevant quantitative performance indicators. The outcomes of the value chains should be as much as possible in line with the aimed for outcomes of the Value Chain Design (VCD) impact pathway to guarantee the expected VCD impacts. These are stated in Figure 9 (page 27). These indicators are then complemented with other, general indicators as stated by Riisgaard et al. (2008), resulting in the following list:

- Financial capital: added value to algae
- Physical capital: investments needed
- Human &financial capital: employment created
- Social & natural capital & enabling conditions: the robustness of the value chain and hence the security of employment& other advantages/disadvantages

Of these indicators, the added value is discussed in depth below, since this is the most important assessment indicator. The discussion on other indicators can be found in appendix 15.12.

Added value calculations

In order to determine the added value, the added revenue has to be subtracted from the added costs. The costs can be calculated following the assumptions as discussed in appendix 15.9 and 15.10, and are calculated in appendix 15.11 (Table 20).

The added value is harder to calculate directly, since the value chain is newly designed. This means that the distribution of added value has still to be determined. This is usually determined by power (Kaplinsky & Morris, 2001; Riisgaard et al., 2010), but since the value chain does not yet exist, this can be managed on beforehand. Determining the value added by each process, at first the actors are assumed to get a salary which is based on the current situation. Since this is then subtracted from the added revenue, the remaining added value can be distributed over the involved actors by either increasing their wages or by distribute the added value as profit over the actors. The distribution of added value will be done in order to reach the desired outcomes as stated in the VCD impact pathway (Figure 9) and in general to overcome the poverty of the fishermen.

There is no consensus in literature on how the division of value over the different processes has to be done. Therefore, a new way of dividing the value over the processes involved is proposed. The base of the new method are the prices of the already existing value chain. This is chosen because it will still be in place even when the new value chain will be implemented, thus ensuring the possibility of changing value chain and obtaining the same price as in the old situation. In the current value chain there are three products with known prices: 1) wet algae ($150/kg), 2) dry algae ($800/kg dry) and 3) dry algae as raw material for carrageenan ($1500/kg dry). When translated to the harvested material (wet algae) this relates to $150/kg, $200/kg and $375/kg respectively (using a factor 4 to switch from wet to dry).

The new way of dividing value divides the value added equally over all the processes needed to produce that product. This means that for wet algae the division is simple: all the added value goes to the collection of algae, since this is the only process needed to come to this product. For dry algae, the added revenue is the difference between the value the product already had ($150/kg as wet algae) and the value of the resulting product ($200/kg as wet algae). This is then divided over the processes needed to come to this product, which are collecting the algae and drying them. Collecting the algae is again included, to increase the importance of upstream processes. Without the collection of algae there would not be production nor added value at all, thus should this be valued more. This is repeated for the sold algae as base for carrageenan. In the value chain for the pre-product of flour, the added revenue is calculated as the difference between the value of dry algae (the base material) and the value of the pre-product, which is estimated to be $2000/kg dry algae ($500/kg wet algae).

To finish the calculation of added value, the costs made to perform the processes have to be subtracted from the added revenue to come to the added value. An overview of the added revenues of each product of the different value chains can be found in Table 9. The calculations of the added values, also specified per process, can be found in

Table 10 for the new carrageenan value chain (scenario 1 & 3) and in Table 11 for the new pre-product for flour value chain (scenario 2). In brackets the added value when drying by the algae collectors (on the rocks) is chosen instead of drying in the new plant.

Table 9- Calculations added revenue per process

Product	Raw material value	Product value	Added revenue (product value - raw material value)	Number of processes needed	Added revenue per process
Wet algae	$0	$150	$150	1	$150
Dry algae	$150	$200	$50	2	$25
Raw material carrageenan	$200	$375	$175	3	$58,33
Pre-product flour	$200	$500	$300	9	$33,33

Table 10- Added value calculations new carrageenan value chain (scenario 1 & 3)

Product / Process	Added revenue per process			Costs process	Added value per process
	Wet algae	Dry algae	Raw material carrageenan		
Collect algae	$150	$25	$58,33	-$160	$73,33
Transport	X	X	X	-$3,75	-$3,75
Store	X	X	X	-$18,38	-$18,38
Dry algae	X	$25	$58,33	-$35 (-$108,75)	$48,33 (-$25,42)
Sell as raw material carrageenan	X	X	$58,33	-$8	$50,33
Total	$150	$50	$175	-$225,13 (-$298,88)	$149,87 ($76,12)

Table 11- Added value calculations new pre-product for flour value chain (scenario 2)

Product / Process	Added revenue per process Wet algae	Dry algae	Pre-product flour	Costs process	Added value per process
Collect algae	$150	$25	$33,33	-$160	$48,33
Wash	X	X	$33,33	-$32	$1,33
Transport	X	X	X	-$3,75	-$3,75
Store	X	X	X	-$22,75	-$22,75
Dry algae	X	$25	$33,33	-$35 (-$108,74)	$23,33 (-$50,42)
Chop	X	X	$33,33	-$8	$25,33
Bleach	X	X	$33,33	-$8	$25,33
Remove Smell	X	X	$33,33	-$8	$25,33
Pulverize	X	X	$33,33	-$8	$25,33
Pack	X	X	$33,33	-$8	$25,33
Sell as pre-product flour	X	X	$33,33	-$8	$25,33
Total	$150	$50	$300	-$301,50 (-$376,99)	$198,50 ($123,01)

The added values of the two value chain options, both enhance the current situation. Both possible future value chains add value to the product. This value is completely an addition to the value of the current value chain, since the wages of the collectors are already included in the costs. This added value can be seen as profit for the actors or as extra salary for the workers involved. Also, this added value can be invested in new material and machines, or to pay debts of former investments.

In the new carrageenan value chain (scenario 1 & 3), the values are fairly evenly divided amongst the two actors in the value chain, resulting in a better division of wealth and profit in the area. In the flour value chain (scenario 2), the division is different, since there are a lot more processes needed, almost all to be performed in the production plant. This results in the fact that the added value of the production plant is determined to be higher, which result in a less beneficial value chain for the algae collectors.

In both new value chains, it can be seen that drying on the rocks by the algae collectors has a negative added value, as in the current situation. This is therefore only considered an economical decision when the capacity of the dryer in the production plant is fully used and this is the bottleneck (since the algae still have added value with the drying on the rocks but less).

Comparison upgrading scenarios

In Table 12, the three scenarios are evaluated on both the added value indicator as well as other performance indicators. All performances are assessed with an indicator (+ or -) and with explaining text. The + and – are then summed (+ = 1 and - = -1) to come to a total score.

As can be seen from the both evaluating tables (qualitative: Table 8; quantitative: Table 12), scenario 3 is favored in both evaluations. Therefore, this scenario is chosen to be implemented.

Table 12- Comparison between possible new value chains

Performance indicator	New value chains Carrageenan (scenario 1 & 3)	Flour (scenario 2)	Carrageenan + Paper (scenario 3)
Added value	+	++	+++
	+$149,87 total added value per kg more than current value chain. Equal added value fishermen (+$73,33) and plant (+$76,54).	+$198,50 total added value per kg more than current value chain. More total added value than carrageenan value chain ($48,63 more). Less added value fishermen (+$49,66) and more added value plant (+$147,09) than in the carrageenan value chain.	At least the same as scenario 1 Expected more added value from the company producing paper products
Investments	++	+++	+
	$218.500.000. 2,5 years ROI.	$225.000.000. Slightly more investments needed than carrageenan value chain ($6,5M more). 2,0 year ROI. Lower ROI (-0,5 years).	Starting with the same as scenario 1 ROI of paper processing machine comes from own profit, probably more than 2,5 year.
Employment	+	++	++
	17,88 more employees than in current value chain. +$93.475 per day more wages than in the current value chain.	21,35 more employees than in current value chain. More employees than in the carrageenan value chain (+3,47). +$173.718,75 per day more wages than in the current value chain. More added wages per day than in carrageenan value chain (+$80.243,75).	At least the same as in scenario 1 Every person working in paper plant is added to scenario 1 Not expected to be more than 21,35 (as in scenario 2)
Robustness of the value chain	++	-	+
	Supply: little unsure, because of possible competition on algae. Production process: known and stable. Demand: sure and stable, because the market is already existing.	Supply: a lot more easy than in the current value chain, because the algae needed are currently not collected and sold. Therefore, the price can be lower and the competition will not exist. Production process: unknown and unsecure due to uncertainty in final product demands Demand: expected to be sure and stable, because algae processing company is developing the product with a dedicated project. However not certain at this moment	Includes the sureness of scenario 1 Supply: very secure due to high amount and stability of waste streams Production process: unclear at industrial level, only laboratory scale Demand: interest in the region but no confirmed customers
Total	++++++(6)	++++++(6)	+++++++(7)

11 Implementation of research and action plan (step 6): implementing a coaster producing company

In this section, the implementation plan to implement the new value chain of scenario 3 will be presented. In this scenario, the raw material for carrageenan is dried and managed only by the fishermen and paper will be produced with the waste stream of the carrageenan-producing companies. A concrete plan of action is defined and this is supported by a financial business model, presentations to mobilize fishermen, potential customer meetings and the planning of a meeting with the local government representative and several funds. The plan with this support is analyzed and evaluated on its potential.

11.1 Concrete plan of action development: manage supply, processing and customers of products in value chain

To develop a good action plan, all actors and processes of the value chain have to be covered. Since the new value chain will be built up of two products (supply of dry algae for carrageenan and paper from the waste stream), this will be two times the general parts of a production process: 1) supply, 2) processing, and 3) customers. These factors will be discussed below on how they will be involved or prepared for the project. In Table 13, a summary can be found of the action plan, also indicating timeframes and eventual desired states.

11.1.1 Supply for algae product

The supply of wet algae will remain the same as it is now, with the only change that algae collectors now have to sell their product to the new drying facility (or can even be contracted by it). This will be an improvement for the fishermen and it is thus not expected to be very hard to convince them to cooperate in this.

The location of the dryer will be placed at the community which collects the most algae per year. With only this amount of algae, the new dryer will already be using its full capacity in peak months and even in December and April. In the other months, the algae can be bought also at other communities. The person who is supposed to transfer the wet algae from the beach to the dryer will now also have the responsibility to go and look for wet algae at other communities and buy them there. This person has to be found and contracted from within the fishermen community

11.1.2 Processing for algae product

This is the bottleneck at the moment, since the new dryer is still under construction. When it is constructed, the owners have to look for people to operate the dryer and then sell the dry algae to the algae processing companies. This process has to be monitored carefully and is currently in the hands of Nilo Zuñiga. He has to be informed on the importance of his role in the development of the value chain.

Table 13- Summary of action plan

Category	Necessary involved party	Already completed task	Next to be completed task	Timeframe (1-7)	Eventual desired state
Supply for dry algae product	• Fishermen	• Inform on new dryer • Motivate for exclusion intermediary	Contract algae collectors	(4) When dryer is almost completed	Create sufficient supply to utilize dryer maximally
Processing of dry algae product	• Nilo Zuñiga • Employee to work with dryer • Employee to gather algae from the fishermen and feed to dryer	• Plan for the dryer under evaluation • Nilo Zuñiga is informed and knows what is expected of him	Construct dryer	(1) As soon as possible, because high season is coming	Operate dryer with skilled employees and steady supply
			Look within fishermen community for employees	(4) When dryer is almost completed	
			Train employees in operating dryer	(6) After construction of dryer	
Customers of dry algae product	• Gelymar	• Made contact with Gelymar	Inform Gelymar on availability new seller of dry algae	(7) When algae drying process is functioning	Contractual stable and steady sales to Gelymar
			Possibly make contract for buyer/seller relationship	(7) When algae drying process is functioning	
Supply for paper product	• Gelymar	• Showed interest in waste stream • Asked for prices and other data on waste stream • Tested waste stream	Use waste stream to do more testes	(3) When production process is investigated	Steady supply with fixed contracts
			Created fixed buyer/seller relation	(7) When production process is ready to run	
Processing of paper product	• Paper producing company (CMPC) • Machine vendors • Fishermen	• Made contact with CMPC • Asked machine vendor for specifications and price • Explained plan to fishermen who eventually have to execute it	Identify production process steps needed	(1) As soon as possible	Smooth production with skilled employees producing good quality products
			Test production process	(2) When production steps are known	
			Buy machines	(5) When test results are positive and production location is ready	
			Train employees	(6) When machines are bought	
Customers of paper product	• Local beer producers (Cuello Negro, Kunstmann, etc.) • Local beer cafes (Growler, Bundor, Árbol, etc.)	• Cuello Negro and El Growler are informed and are interested • Listed first requirement • Listed first potential market order	Update on progress and requirement	(1) Along the way repeatedly	Stable, big demand for paper product with fixed prices and orders
			Establish fist sale	(4) After first test batch to give a try-out	
			Establish steady and stable buyer/seller contract	(7) When production process is in place	

11.1.3 Customers of algae product

The customers are the algae processing companies, represented mainly by Gelymar. They have to be informed that there will be a new seller of dry algae, where the algae are dried directly after harvesting, with a reliable and stable drying process and without the intermediary. Since they were already interested in a project with ABAM, this will be best to be done by ABAM.

11.1.4 Supply for paper product

To create the paper, the waste stream of the algae processing company is needed. There has already been contact with Gelymar and they have provided ABAM with part of the waste stream to perform laboratory scale tests. It is therefore expected to be easy to convince them to get involved in the project and sell their waste stream to the paper production plant at the fishermen community.

Besides this waste stream, also 70% of conventional raw material for paper has to be obtained, with which ABAM has made contact to obtain information and prices. Since the paper industry is big in Chile and there also exist a paper plant in the region with which ABAM has had contact in the past, this will not be complicated. ABAM has contacted a person selling this material to obtain information and prices.

11.1.5 Processing of paper product

This process has so far only been tested on laboratory scale by ABAM (which resulted well) and thus has to be studied and developed further. This can be done by approaching a paper producing plant in the region (of the big paper processing company CMPC), with which ABAM has had contact in the past to explore the possibilities with paper products from algae. They are experienced in producing paper and can maybe help in doing some trial or in investing in the process.

Also the machines have to be obtained. ABAM already reached out to a person selling a paper making machine to ask for the specifications and price. Also the paper processing company can be asked for an old or used machine.

Besides the paper making, also the other processes needed for the eventual product that will be made from this paper will have to be examined and tested.

11.1.6 Customers of paper product

Paper is a product which can be used in various ways. It is therefore important to find a specific market which can be served by the relative small factory at the fishermen community. ABAM and the author of this design project stumbled on the market which could fulfill this potential recently.

Valdivia, the city close to the fishermen communities, is the self-proclaimed beer-capital of South America (probably due to the influence of the German settlers in the 19th century) and there are several artisanal beer producers and many beer cafes present. What is however not available are coaster for the beer, or only in low quantities which are imported form the United States of America.

A meeting has taken place with the owner of the second largest beer brewery (and proud winner of a gold medal in ‘best beers of America’ in 2017), Cuello Negro, and the owner of the second largest beer café, El Growler, in Valdivia. They indicated to be very interested, since they support local and environmentally friendly initiatives and are now paying a high price to get the coaster from the USA (if they even order them).

The enhanced experience of beer drinking with a coaster (no wet tables) and the marketing possibilities are the main reason to buy coasters. These were pointed out to the first potential customers and they indicated directly to be interested in buying around 20.000 a month. These conversations should be continued to create a stable and big market for coasters locally. When this market is satisfied, the possibility to extend to the region or maybe to the whole of Chile could be explored. Also, since environmentally friendly products are much more popular in ‘first world’ countries, the potential interest in Europe could be evaluated.

The choice of this products implies the need of cutting coaster from the paper and then printing the logo of the beer brewery. Also a layer of white cellulose can be added to enhance absorbing qualities and easiness of printing.

The coasters then need shipment to their customers, but since this will initially be local (close to Valdivia), a small truck or van delivering the coasters will not be hard to arrange.

11.2 Research implementation & strategy through support activities: using presentations, meeting and a financial business model

To convince the involved parties of the idea, several meetings are already held, accompanied with several PowerPoint presentations, specific for each group. Groups informed are: FEPACOR, Nilo Zuñiga and potential customers.

The most important presentation that still has to be performed is a presentation that is planned to be held for the representatives of several governmental funding institutes. These institutes will have to provide the needed investment money in order to be able to implement the project.

To help building the case for this business, a financial business model is built. This model is based on the information currently obtained from the stakeholders, the laboratory test on making paper, information from machine vendors, and conversations with potential customers. In the model, the input parameters can be adjusted to test scenarios or update real information, and the model calculates automatically the obtained revenues, costs and profits, as well as the number of employees needed. An example input and output can be found in appendix 15.13. The number of employees needed in this model is set to be quadratic and not linear, to implement scale advantages in productivity for employees. The difference in employees needed can be found in appendix 15.14.

11.3 Prospect analysis of available information: positive prospects

The carrageenan value was already found to be economically interesting when cutting out the intermediary and drying locally, but with the financial business model, it can be shown that producing coasters is also a profitable option.

It can be shown that, with the current information on all the costs and variable values, a quantity of 25.000 coasters per month for a price of $54,75 per coaster (without the print) would give a return on investment rate of 5 years. The amount is around what the customers that are talked to up to now have indicated to be a real number (and many more customers can be reached). The price is comparable to what right now is paid for coasters to be shipped from the USA and an ROI of 5 year is reasonable.

It can therefore be concluded that the proposed upgrade of the value chain with the action plan should be pursued, since it will lead to a profitable organization and higher incomes and more work for the poor fishermen communities.

11.4 Other small improvement options: applying industrial thinking

As a bonus, some minor improvement ideas along the way are identified for the whole value chain. These can be implemented easily and are outside and extra of the value chain upgrading. The topics are listed below and a detailed description can be found in appendix 15.15.

- Use the rest-heat of the freezer of fish and shellfish to dry the algae.
- Dry the paper in the same dryer as the algae.
- Combine the picking-up of algae as base material with the dropping-off of algae residues (since they have to be transported to and from the same company).
- Use infrastructure of the fish/shellfish value chain (such as employers and computers) to obtain economies of scale.
- Since increasing the capacity of the dryer will greatly influence the profitability of the value chain, this can be enlarged by installing small local dryers on the beaches of the fishermen.

With this plan and these extra improvements, as solid company should be able to be set up.

12 Conclusion

In this research the algae value chain as it is right now in the south of Chile is mapped and evaluated. The intermediaries were found to claim most of the value added in the value chain, leaving the fishermen who collect the algae poor and vulnerable.

The poverty of the fishermen was analyzed and in the impact pathway it could be seen that increasing income and job security would lead to the most improvement in the fishermen's poverty status.

The current value chain is then upgraded to overcome the fishermen poverty in the best way possible. Three scenarios were evaluated on different quantitative and qualitative indicators and the best upgrading scenario was chosen to execute. This turned out to be to exclude the intermediary from the value chain and incorporate a dryer at the fishermen community in the value chain.

Besides the exclusion of the intermediary and the inclusion of a local dryer, also the waste stream of algae could be used to make paper, of which coasters can be produced. These coasters have good market potential in the area of the research, since the city is famous for its beer. The business case has been evaluated and found to be promising to become profitable.

Besides these main recommendations, some small recommendations are also provided to improve the value chain. These include to exploit the rest-heat of the freezing process of another value chain in the same plant, use economies of scale in production of different value chain at the same location, avoid empty trucks arriving at the plant, and to increase bottleneck capacity by implement local solar-powered dryer on the beaches.

13 Reflection

In reflection on this research several obstacles can be pointed out.

At first, it was winter when the project started. In the winter the weather is really bad, in the sense that it rains very much. Most agriculture and aquaculture stops in this season in the region, especially the algae collection since there are few algae washing up the shores and they are almost impossible to dry due to the humidity of the air. Because of this, the project really could be started only a few weeks after I arrived.

The working culture in Chile is really different from what I was used to in the Netherlands (especially in the winter). With bad weather people just do not work in the agricultural sector. Also, the workers in ABAM were not very dedicated at this time of the year and arranging meetings and getting something done was sometimes hard.

The company selected to do the Master Design Project in, was not wat I expected on beforehand. The company is really small and is actually a group of scientists writing their thesis in the laboratory of the university. A few employees are contracted (and thus do not study), but they were working on other projects, mostly really focused on chemical research. The driving force of the company is the owner (and full-time professor at the university). This however gave me a lot of freedom and responsibility to bring the project forward. In the beginning I struggled with this, but when one of the other employees was also put on my project (but in the chemical direction) we teamed up and I took charge of the project.

In Chile people do not speak English, only the students from the university speak some. Even at the university the level of English can differ a lot. Luckily I spoke already some Spanish when I arrived, but Spanish from Spain and Spanish from Chile appeared to be two very different things. Furthermore, the fishermen I had to deal with, spoke even more Chilean (instead of Spanish) and were thus harder to understand. Since I was mostly alone in the project, this was sometimes hard for me to advance. In the end I learned more Spanish (and Chilean) then I could have imagined on beforehand.

In the setting of the scope of the research, the owner of ABAM said that the producing of paper was a possibility but that I should not focus on that, since he found that making the connection with the industry was hard and there were too many constraints. I left it therefore out of the scope, but at the end it turned out that coaster were possible to produce and I therefore had to include them later. This could have turned out in missing the best solution for the problem and what I learned is that you should not set your scope too narrow too soon.

When I arrived, nobody actually knew what the value chain or supply chain of the algae collection looked like. Therefore, a large part of the beginning of the research was understanding and discovering these processes. This was hard since everything was in Spanish and the value chain stopped working in that time of the year.

In general I can say I learned a lot and it was a great experience to do the project in Chile.

14 Bibliography

References

Avila, M., & Seguel, M. (1993). An overview of seaweed resources in chile. *Journal of Applied Phycology, 5*(2), 133-139.

Black, W. (1955). The preservation of seaweed by ensiling and bactericides. *Journal of the Science of Food and Agriculture, 6*(1), 14-23.

Bolwig, S., Ponte, S., Du Toit, A., Riisgaard, L., & Halberg, N. (2010). Integrating poverty and environmental concerns into value-chain analysis: A conceptual framework. *Development Policy Review, 28*(2), 173-194.

Bowersox, D. J., Closs, D. J., & Cooper, M. B. (2002). *Supply chain logistics management* McGraw-Hill New York, NY.

Burton, T., Lyons, H., Lerat, Y., Stanley, M., & Rasmussen, M. B. (2009). No title. *A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland,*

Christopher, M. (2005). *Logistics and supply chain management: Creating value-adding networks* Pearson education.

Cundiff, J. S., Dias, N., & Sherali, H. D. (1997). A linear programming approach for designing a herbaceous biomass delivery system. *Bioresource Technology, 59*(1), 47-55.

Daghigh, R., Ruslan, M. H., Sulaiman, M. Y., & Sopian, K. (2010). Review of solar assisted heat pump drying systems for agricultural and marine products. *Renewable and Sustainable Energy Reviews, 14*(9), 2564-2579.

Dolgui, A., & Proth, J. (2010). *Supply chain engineering: Useful methods and techniques* Springer Science & Business Media.

Donovan, J., & Stoian, D. (2012). 5Capitals: A tool for assessing the poverty impacts of value chain development. *Turrialba: CATIE,*

Fiedler, P., Lange, M., & Schultze, M. (2007). (2007). Supply logistics for the industrialized use of biomass-principles and planning approach. Paper presented at the *Logistics and Industrial Informatics, 2007. LINDI 2007. International Symposium On,* 41-46.

Fusco, E. J., & Dowding, T. J. (2011). An alternate source of energy: The production of biofuels from seaweed. *International Journal of Business Insights & Transformation, 5*(1)

Gardner, R. G., & Mitchell, T. J. (1953). Through-circulation drying of seaweed. 1. laminaria-cloustoni stipe. *Journal of the Science of Food and Agriculture, 4*(3), 113-129.

Goetschalckx, M. (2011). *Supply chain engineering* Springer Science & Business Media.

Gold, S., & Seuring, S. (2011). Supply chain and logistics issues of bio-energy production. *Journal of Cleaner Production, 19*(1), 32-42.

Govil, M., & Proth, J. (2002). *Supply chain design and management: Strategic and tactical perspectives* Academic Press.

Guzi, M., Kahanec, M., & Kabina, T. (2016). *Codebook of the WageIndicator cost of living survey*. Amsterdam: WageIndicator Foundation.

Hamelinck, C. N., Suurs, R. A., & Faaij, A. P. (2005). International bioenergy transport costs and energy balance. *Biomass and Bioenergy, 29*(2), 114-134.

Holm-Nielsen, J., & Ehimen, E. A. (2016). *Biomass supply chains for bioenergy and biorefining* Woodhead Publishing.

Jones, D., & Womack, J. (2002). Seeing the whole. *Lean Enterprise Institute, Brookline,*

Kaplinsky, R., & Morris, M. (2001). *A handbook for value chain research* IDRC Ottawa.

Krishnan, M., & Narayanakumar, R. (2010). Structure, conduct and performance of value chain in seaweed farming in india. *Agricultural Economics Research Review, 23*, 505-514.

Lee, C. S., & Ang, P. (1991). A simple model for seaweed growth and optimal harvesting strategy. *Ecological Modelling, 55*(1-2), 67-74.

McHugh, D. J. (2003). *A guide to the seaweed industry* Food and Agriculture Organization of the United Nations Rome.

Nikolaisen, L., Daugbjerg Jensen, P., Svane Bech, K., Dahl, J., Busk, J., Brdsgaard, T., . . . Bangs Nielsen, H. (2011). No title. *Energy Production from Marine Biomass (Ulva Lactuca),*

Papadopoulos, D. P., & Katsigiannis, P. A. (2002). Biomass energy surveying and techno-economic assessment of suitable CHP system installations. *Biomass and Bioenergy, 22*(2), 105-124.

Philippsen, A., Wild, P., & Rowe, A. (2014). Energy input, carbon intensity and cost for ethanol produced from farmed seaweed. *Renewable and Sustainable Energy Reviews, 38*, 609-623.

Reith, E. H., Deurwaarder, E. P., Hemmes, K., Curvers, A., Kamermans, P., Brandenburg, W. A., & Lettings, G. (2005). No title. *Bio-Offshore: Grootschalige Teelt Van Zeewieren in Combinatie Met Offshore Windparken in De Noordzee,* Rentizelas, A. A., Tolis, A. J., & Tatsiopoulos, I. P. (2009). Logistics issues of biomass: The storage problem and the multi-biomass supply chain. *Renewable and Sustainable Energy Reviews, 13*(4), 887-894.

Riisgaard, L., Bolwig, S., Matose, F., Ponte, S., Du Toit, A., & Halberg, N. (2008). *A strategic framework and toolbox for action research with small producers in value chains* DIIS Working Paper.

Riisgaard, L., Bolwig, S., Ponte, S., Du Toit, A., Halberg, N., & Matose, F. (2010). Integrating poverty and environmental concerns into value-chain analysis: A strategic framework and practical guide. *Development Policy Review, 28*(2), 195-216.

Roesijadi, G., Jones, S. B., Snowden-Swan, L. J., & Zhu, Y. (2010). No title. *Macroalgae as a Biomass Feedstock: A Preliminary Analysis,*

Rother, M., & Shook, J. (1999). Learning to see. *Lean Enterprise Institute, Cambridge, MA,*

Seghetta, M., Romeo, D., D'este, M., Alvarado-Morales, M., Angelidaki, I., Bastianoni, S., & Thomsen, M. (2017). Seaweed as innovative feedstock for energy and feed–Evaluating the impacts through a life cycle assessment. *Journal of Cleaner Production, 150*, 1-15.

Stoian, D., Donovan, J., Fisk, J., & Muldoon, M. (2012). Value chain development for rural poverty reduction: A reality check and a warning. *Enterprise Development and Microfinance, 23*(1), 54-60.

Suurs, R. (2002). No title. *Long Distance Bioenergy Logistics.an Assessment of Costs and Energy Consumption for various Biomass Energy Transport Chains,* Tatsiopoulos, I. P., & Tolis, A. J. (2003). Economic aspects of the cotton-stalk biomass logistics and comparison of supply chain methods. *Biomass and Bioenergy, 24*(3), 199-214.

Taylor, D. H. (2005). Value chain analysis: An approach to supply chain improvement in agri-food chains. *International Journal of Physical Distribution & Logistics Management, 35*(10), 744-761.

van den Burg, Sander WK, van Duijn, A. P., Bartelings, H., van Krimpen, M. M., & Poelman, M. (2016). The economic feasibility of seaweed production in the north sea. *Aquaculture Economics & Management, 20*(3), 235-252.

Van Strien, P. J. (1997). Towards a methodology of psychological practice: The regulative cycle. *Theory & Psychology, 7*(5), 683-700.

Varvasovszky, Z., & Brugha, R. (2000). A stakeholder analysis. *Health Policy and Planning, 15*(3), 338-345.

WageIndicator, 2. (2017). Living wage series - chile - october 2017 - in CLP per month. Retrieved from https://wageindicator.org/main/salary/living-wage/chile-living-wages-2017-country-overview

Weiss, W., & Buchinger, J. (2012). Solar drying. *AEE INTEC Publication, A-8200 Gleisdorf, Feldgasse, 19*

Wieringa, R. (2009). (2009). Design science as nested problem solving. Paper presented at the *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology,* 8.

Zhu, X., Li, X., Yao, Q., & Chen, Y. (2011). Challenges and models in supporting logistics system design for dedicated-biomass-based bioenergy industry. *Bioresource Technology, 102*(2), 1344-1351.

15 Appendix

15.1 A general description of Chile and the problem context

The broadest context is the general economy of (South-)Chile. Chile is one of the most developed countries in South-America. This however still means it is considered the third world. The main economy of Chile consists of copper mines, to which it owes its relative wealth compared to its neighbors. Other important economies are those of wine and salmon. In conclusion, Chile´s production is focused on selling raw material. Chile has a very open market, with trade agreements with almost 60 countries and very little market protection, making it an interesting country for businesses to deal with and to set up a company.

Chile is one of the longest countries in the world and therefore has a very long coastline. It is however not very wide and therefore has a very irregular, long shape. This complicates general transportation in Chile. Roads are widely available and usually in a decent state. They however sometimes belong to private owners, which ask money for the usage of the roads. Trains are little to not available in Chile. Since their peers do have large train networks (New Zealand, Europe) this has become one of the main focal points in the Chilean transport sector. Also the use of shipping, which is an evident solution with such a long coast and many direct links to the water, is not used to its full potential and is therefore also further studied. Airports are available but the transport is, as in any country, expensive.

In the south of Chile, in the regions "Los Ríos" and "Los Lagos", agriculture is the biggest economy. This consists, amongst others, of cultivation of weeds, animal farming, salmon cultivation and algae collection and processing. The south of Chile is characterized by volcanoes, but also large valleys, lakes and rivers, a lot of rain but mild temperatures. These conditions make it ideal for crops to grow, for animals to graze and for fish to develop.

15.2 Algae types in South-Chile

There are several different types of algae present on the coasts of South-Chile:

- Cochayuyo (Durvillaeaantarctica)
- Luga Negra (Sarcothaliacrispata)
- LugaRoja (Gigartinaskottsbergii)
- Pelillo (Gracilaria)
- Luche (Porphyracolumbina)
- Huiro (Macrocystispyrífera)
- Huiro Palo (Lessoniatrabeculata)

Some of them are edible without processing (Cochayuyo, Luche), others are more used in other products (Luga, Pelillo). For some there is no current market (Huiro).

15.3 Detailed stakeholder descriptions

15.3.1 FEPACOR, the fishermen community and main problem owner

FEPACOR is a federation of several fishermen communities and is the organization that issued the problem. FEPACOR is short for Federación de Pescadores Artesanales de Corral, which translates as Federation of the craft of fishermen from Corral. Corral is a small village in the south of Chile, but still the largest town in the region of a few fishermen communities and functions as the local governmental town. It is located near Valdivia, a medium-large city (approximately 150.000 inhabitants). The federation consists of a board and has regular meetings with the head s of all communities under its organization. A list of the communities under the federation and a map of their location can be found in appendix 15.4.

FEPACOR has a high interest in the project and is very supportive due to high impact the project will have on them, but has only a medium influence due to its organizational structure. FEPACOR itself has no real power over the communities (they serve as a unified front for them) and thus the communities are only loosely organized and mobilized. Since the result of the project directly influences the financial position of their members, the impact of the project will be high on this stakeholder.

15.3.2 Universidad Austral de Chile (UACh), provider of knowledge

FEPACOR issued the problem to the nearest university, which started several projects were started to help the local fishermen communities with their problems. The UACH is a respected university within Chile with approximately 11.000 students. Currently, two projects are running separately by three different teams:

1. Construct a plant where fish can be frozen, smoked or cooled and algae can be dried and processed.
2. Design a new process to add more value to algae.

The university can be seen as a secondary stakeholder, because it is not involved in the projects, solely providing the students and knowledge for the projects to be executed. It therefore has a low interest in the project and the project has almost no effect on the university.

15.3.3 ABAM, provider of technology

The project of the university to design a new process for algae is executed by ABAM, a small technology company. This is the company which asked for a student with a background in logistics and operations and in which this Design Project is done. The owner of the company, a professor at the UACh, has several contacts with the market for algae and has a very high understanding of polymers and chemistry. The company is even located within the university, where it occupies a laboratory (for polymers) and is also giving classes to students, as well as providing space for research.

Since ABAM is directly involved in the project but it will play no part in the production process once it is running, the impact is medium to high, the involvement is high, but since it is only a small company, the power is medium.

15.3.4 Algae processing companies, final product producers

The current algae processing companies built their business on the current situation and are therefore not interested in big changes in their supply chain, but they are also looking to diversify their portfolio and investigate new possibilities with algae. Most of them will however only be secondary stakeholders, since they are not invested in the current projects directly. These companies include, amongst others, of Gelymar, Kimica, ProAgar and Algas Marinas.

15.3.5 Gelymar, provider of new market opportunities

Gelymar, one of the algae processing companies, is developing up a new product line (to make flour from algae) and is very interested in a pre-product from algae where they have no color and no smell. This will make the production process easier and the final product better for them. They are however not directly involved in the project to enhance the value of the algae, they have to be considered as a possible future buyer of an enriched product.

15.3.6 Intermediaries, part of the value chain with a monopoly position

These businessmen will not like the fact of entering a new player who is also going to buy algae, possibly for a higher price, since they now have a monopoly position on buying and collecting the algae from the fishermen communities and sell them to the industry. Little support and information is expected from this stakeholder, whilst their power is high in the communities as is the impact of the project on them.

15.3.7 Jorge Rivas, cooperating intermediary

Jorge Rivas is partially doing the work of an intermediary, but is also involved with the fishermen communities and wants to help with the project. He is supportive in the project to enhance the value chain of the algae. He is leading the first project of the university, to build a new drying facility to add value to the algae, and works together closely with a student from the university to achieve this.

15.3.8 Nilo Zuñiga, project leader of a new production plant

Nilo Zuñiga is leading a project to design a production plant where fish can be frozen, smoked or cooled and algae can be dried and processed, in a fishermen community known as Palo Muerto. He has designed a plant, with his team, where the fish coming from the community (and possibly other communities) can be cooled, smoked or frozen and then packed. In this way it can be maintained longer and also shipped and exported. With this plant, also an algae processing facility was considered. The initial plan was to make handcrafted soap and other products from the algae, but with the entering of ABAM and the insights in the market, this plan has changed. The process to be designed by ABAM will thus be operated by the plant at Palo Muerto. Also included in the design of the plant will be the new drying facility, as designed by Jorge Rivas and the student of the university. Since drying will evidently be a part of the process of processing the algae, it was decided to combine the two projects. This design project thus directly influences Mr. Zuñiga and he has a high interest in the project.

15.3.9 Fishermen community Palo Muerto, location of a new plant and provider of raw material

Palo Muerto is a fishermen community were a lot of algae and many fish are collected, which is chosen to be the location of the new production plant. The local fishermen are very pleased with the plans of a new plant in their area, since it will bring more jobs to the village, create more value of the collected fish, and make the collection and drying of algae more profitable and easy. In conclusion, Palo Muerto is very much interested and impacted by the different projects.

15.3.10 Fundaciónpara la Innovación Agraria (FIA), investor

The Fund for Agrarian Innovation (FIA in Spanish) is a fund for innovation initiatives, for which all projects described above are applying (more or less together). It can thus be regarded as a secondary stakeholder. When the fund is granted, more money will become available to execute the plans better and with more freedom and quality.

Table 14 - Stakeholder analysis overview

Stakeholder	Characteristics				
	Involvement in the issue	Interest in the issue	Influence/ power	Position	Impact of issue on actor
FEPACOR	Federation of fishermen communities, wants to add value to the algae they collect	High	Medium	Supportive	High
Universidad Austral de Chile (UACh)	University, provides students and knowledge to solve problems	Low	Medium	Supportive	Low
ABAM	Technological consultant, provides technical solutions to enrich algae	High	Medium	Involved	Medium -high
Algae processing companies	Process algae for profit, possible buyers	Low-medium	High	Marginal	Low-medium
Gelymar	Algae processing company that is investing in flour from algae	Medium	High	Supportive	Medium
Intermediaries	Buying algae from fishermen and selling to the processing companies	High	Medium-High	Opposed	High
Jorge Rivas	An involved intermediary, helps with developing a drying facility in Palo Muerto	High	Medium-high	Mixed	High
Nilo Zuñiga	A businessman who is developing a plant in Palo Muerto to freeze, smoke and pack fish, but also wants to include algae	High	Medium	Supportive	High
Fishermen community (Caleta) Palo Muerto	Community where a dryer and the plant will be located. Delivers a lot of algae during the season	High	Low	Supportive	High
Fundación Para la Innovación Agraria (FIA)	A fund for which can be applied by the project	Low	High	Unclear	Low

15.4 Caletas in FEPACOR

In descending order on algae collection:

1. Huape (including Palo Muerto)
2. Chaihuin
3. San Carlos
4. Huiro
5. Corral&Corral Bajo
6. Isla del Rey
7. Amargos
8. Valdivia
9. La Aguada
10. Lameguapi


CHAIHUIN
Chaihuín
Guapi
HUAPE
CORRAL BAJO
Corral
CORRAL
SAN CARLOS
AMARGOS
Niebla
EL PIOJO
NIEBLA
LA AGUADA
BAHIA SAN JUAN
MANCERA
ISLA DEL REY
SAN IGNACIO
LOS MOLINOS
T-352
T-350
Manzano
Romaza
Isla del Rey
VALDIVIA

15.5 Stakeholder overview following to Donovan & Stoian (2012)

Table 15- Stakeholder overview, interactions and interventions

Stakeholder	Stakeholder type	Description of the stakeholder	Expected interactions	Expected interventions
Fishermen	Actor (households)	The people collecting algae (sometimes dry them) and selling them	- Sell (wet/dry) algae to buying actors in value chain	-
Intermediaries	Actor (small enterprises)	The people picking up and buying algae from different fishermen, (dry them if necessary) and sell them to big industrial buyers	- Pick up and buy algae from fishermen - Sell algae to industry	-
Algae industry companies (Gelymar amongst others)	Actor (big enterprises)	The big processing companies that produce products form algae and sell them to customers (food processing companies)	- Pick up and buy algae from actors in value chain - Set product standards - Sell algae-derived products	- Identify new product opportunities
Nilo Zuñiga	Actor (small enterprise)	Owner of a small enterprise setting up a plant which will include an algae drying &processing facility	- Buy algae from actors in value chain - Sell algae to industry	-
FEPACOR & Jorge Rivas	Service provider (association)	An association for fishermen communities who operates in their interest and unites them to create more leverage power	-	- Identify organizations who can do interventions to benefit fishermen
ABAM	Service provider (technology consultancy company)	An enterprise situated in the university of Valdivia, which has a high understanding of chemistry and its applications	-	- Provide technological solutions and possibilities to the value chain actors
Fundación para la Innovación Agraria (FIA)	NGO (governmental investment fund)	A fund that gives grants to innovative ideas in the agricultural sector in Chile	-	- Provide financial credit
Universidad Austral de Chile (UACh)	NGO (university)	University capable of providing several engineering and chemical knowledge	-	- Provide knowledge for solutions and possibilities

15.6 Assumptions in mapping the current value chain

Table 16- Assumptions current value chain

Part	Assumption	Explanation
Collection	Every man can collect 250 kg of wet algae in a day (if available)	Based on the opinion of various fishermen who collect algae
	The capacity of algae collection of each community differs and is the maximum of the harvest per type of 2014-2016 (see appendix 15.7).	From a meeting with the fishermen, it is known that there remain algae on the beach, uncollected since there is low demand for this type. By taking the maximum of each type, the maximal capacity is calculated of collection.
Drying (fishermen)	In the biggest community can dry 2000 kg wet algae (known from the people there), the other communities a number relative to their size compared with this number. This results in a capacity of 2993 kg wet algae per day.	The relation is created by relative amount of algae that are collected with respect to the biggest community (where the drying capacity is known). In this way it is proportionally with the algae collection.
	Drying on the rocks needs 5 people to perform in the biggest community and takes a full day for each batch (of 2000 kg thus).	This is an estimation off the people in charge there. Furthermore, the amount of people in other communities is proportionally to their drying capacity (as calculated above)
	A person drying on the rocks earns 40.000 Chilean pesos per day.	This relates approximately to the daily salary of an average algae collector.
Wet storage (fishermen & intermediary)	Wet storage does not preserve well, therefore it is assumed that per day 10% of the algae is lost.	This number comes from the fact that algae can only be stored a couple of days without drying, but the depreciation starts slowly and accelerates. Furthermore, at times it rains, which ruins the algae that are not sheltered.
Transport to intermediary	A van can transport 2000kg wet algae and 3000 kg dry algae	This is an estimation of the fishermen
	A van comes 3 times a day to collect the algae	This is an estimation of the fishermen
	The exact location of the intermediaries is unknown but estimated at 20 minutes' drive from each community. Once loaded, the truck directly drives back, another 20 minutes.	This is more or less in the middle of all communities, centered around the biggest ones. Also the fishermen indicated this location to be a good estimation.
	The buying, loading and unloading time is 10 minutes.	Based on an estimation of the fishermen.

	The average utilization of the truck is 50%	An estimation to keep the calculations conservative
	The efficiency of the van is 7km/L and petrol is 800 Chilean pesos/L	The efficiency is an estimation for an average van and the price is on own observations.
	The salary of the driver is 60000.	This number is a little higher than that of an algae collector and is an estimation.
Drying (intermediary)	Drying takes a day, but the capacity (and batch size) is 3000 kg wet material	There are 3 intermediaries working in the zone, 300 ton wet algae are gathered maximally in the area per month. This means 10000 per day. Three intermediaries and the drying facilities at the communities are just enough to serve this maximal demand.
	Drying costs 20$/kg plus the labor costs of one person ($60.000 per day)	This relates to approximately 0,15 kWh of electricity, which in combination with solar energy should be enough to evaporate 750 grams of water, which needs 0,52 kWh (Weiss & Buchinger, 2012).
Dry storage (intermediary)	To store, one person is assigned, earning 60.000 pesos per day (more than an algae collector). Furthermore, 1% of the stored material is lost per day. The amount that can be stored per day is depending on the frequency of transport	The person needed in a rough estimation, as is its wage. The amount that can be stored is calculated with the frequency of the truck that is coming and storage capacity (approx. 20000 kg dry at the intermediary and none at the communities since they do not store the algae for more than a day). This results in approximately the same capacity per day as the drying, which implies a balanced line and is thus found to be likely. The storage time is an average and is therefore the half of the pickup frequency.
General	To transfer from wet to dry material, a factor 4 is used.	Seaweed is usually dewatered from a moisture content of 80% to a moisture content of 20% (McHugh, 2003b; Reith et al., 2005). This results in a relational factor of 4.
	One US dollar is worth 630 Chilean pesos ($) and the euro 750 Chilean pesos.	Based on the current exchange rate.

15.7 Maximal algae collection per community per day

Max algae collection (kg wet algae per day)	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
AMARGOS	193,55	0,00	202,35	4,94	19,39	9,39	98,10	64,52	0,00	0,00	18,71	101,48
BAHIA SAN JUAN	493,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	410,52	0,00	0,00
CHAIHUIN	1708,16	1425,23	586,61	820,71	156,71	2,84	104,10	197,61	0,16	0,00	142,10	483,32
CORRAL	215,48	2447,52	1564,68	506,71	196,77	116,65	1,94	0,00	17,42	163,94	883,35	579,32
CORRAL BAJO	0,00	119,35	1,94	90,32	7,55	0,00	0,00	0,00	0,00	16,13	129,55	32,03
HUAPE	9618,55	9669,52	9703,81	5277,65	1160,81	920,94	1657,48	1861,29	245,81	345,00	2531,55	5037,39
HUIRO	378,13	767,74	266,13	732,87	67,74	0,58	38,71	59,68	0,00	0,00	0,00	393,81
LA AGUADA	161,32	63,10	1073,74	92,35	0,00	0,00	0,00	0,00	0,00	35,48	217,84	491,26
SAN CARLOS	1189,29	684,68	482,32	473,42	520,65	56,19	7,87	49,74	0,00	0,58	242,48	1077,65
Total	12717,71	12222,87	11822,48	7032,74	1610,84	977,06	1908,19	2215,26	261,48	755,68	3561,23	6464,19

15.8 The calculations of the added value of all processes in the current value chain

15.8.1 Drying by the fishermen

Table 17- Calculations current added value

Process	Value added per kg wet algae	Calculations
Algae collection	$150	Selling price to the intermediaries, set by monopoly position
Wet storage (fishermen)	-$10,00 (-$2,50 when sold wet)	Lead time x loss x lost revenue = 0,5 x -10% x $800/4 (0,5 x -10% x $150)
Drying (fishermen)	-$50	Selling price dry per kg wet – selling price wet – salary dryers = Price per kg dry x correction factor dry&wet – selling price wet – number of dryers x salary per day x lead time drying / capacity = 800/4 – 150 – 5 x 40000 x 1 / 2000
Total fishermen	$90,00	Sum of the above
Transport (dry)	-$9,23	Same as wet, but with capacity dry instead of capacity wet = (10000 x (0,4 + 0,167 + 0,167 + 0,167) + 800 x 1/7 x (2 x 15)) / (3000 x 50%)
Buying dry algae directly	$175,00	Selling price dry per kg wet – buying price dry per wet = Selling price per kg dry x correction factor dry&wet – buying price per kg dry x correction factor dry&wet = 1500/4 – 800/4
Dry storage (intermediary)	-$18,38	(Lead time x loss x lost revenue – number of workers x salary per day x / capacity per day) / correction factor dry&wet = (3,5 x -1% x 1500 – 1 x 60000 / 2857,14)/4
Total Intermediary (buying dry)	$147,39	Transport (dry) + buying dry algae directly + dry storage = -9,23 +175,00 – 18,38

15.8.2 Drying by the intermediary

Process	Value added per kg wet algae	Calculations
Algae collection	$150	Selling price to the intermediaries, set by monopoly position
Wet storage (fishermen)	-$10,00 (-$2,50 when sold wet)	Lead time x loss x lost revenue = 0,5 x -10% x $800/4 (0,5 x -10% x $150)
Total fishermen	$147,50	Sum of the above minus the drying and less wet storage
Transport (wet)	-$13,85	(Salary driver + petrol costs) / (truckload capacity wet x utilization) = (hourly wages x (two times the distance + load time + unload time + time to buy algae) + petrol price x efficiency van x (2 x distance)) / (truckload capacity wet x utilization) = (10000* x (0,4** + 0,167*** + 0,167*** + 0,167***) + 800 x 1/7 x (2 x 15)) / (2000 x 50%) *Hourly wage based on 6 hours per day **two times the distances 20 minutes ***10 minutes expressed in hours
Wet storage (intermediary)	-$12,38	Lead time x loss x lost revenue = 0,33 x -10% x $1500/4
Drying (intermediary)	$185,00	Selling price dry per kg wet – buying price wet – salary dryer – drying costs = Price per kg dry x correction factor dry&wet – buying price wet – number of dryers x salary per day x lead time drying / capacity – drying costs = 1500/4 – 150 – 1 x 60000 x 1 / 3000 - 20
Dry storage (intermediary)	-$18,38	(Lead time x loss x lost revenue – number of workers x salary per day x / capacity per day) / correction factor dry&wet = (3,5 x -1% x 1500 – 1 x 60000 / 2857,14)/4
Total Intermediary	$140,39	Transport (wet) + wet storage + drying + dry storage = -13,85 – 12,38 + 185,00 – 18,38

15.9 Assumptions new carrageenan value chain

Table 18- Assumptions new carrageenan value chain

Part	Assumption	Explanation
Collection	Algae collectors earn a salary of $40.000 per day.	This is a reasonable wage and based on a average to good salary in the current situation.
Drying (fishermen)	The same as in the current value chain	-
Wet storage (fishermen & intermediary)	This is not needed anymore, only when the form of drying is chosen to be on the rocks by the fishermen. In that case the selling price of the current situation is used as cost reference.	Because of the close distance to the drying facility, the transport can be performed more or less continuously, thus eliminating the need for wet storage.
Transport to plant	A van can transport 2000kg wet algae and 3000 kg dry algae	This is the same as in the current situation
	The location is so close that it is considered as at zero distance. Only the loading, unloading and buying time are still considered (making the driver more an algae mover).	The planned location of the plant is just higher up the beach. The loading and unloading time will be used as a buffer to include a little transportation time.
	The average utilization of the truck is 50%	This estimation is kept the same, because of the location which is so close by the collection site. Also algae can just be transported by hand, wagon or any other transportation vehicle at hand, thus justifying the use of a 50% utilization.
	The salary of the driver is 60000.	This number is the same as in the current situation.
Drying (plant)	Drying takes 0,25 day and the capacity is 4000 kg wet material. The process is continuous	The capacity (throughput) is 4000 kg per day, and the Work In Process (WIP) is 1000 kg that can be processed at the same time (not in batches but continuously, by the use of a conveyor belt). Little´s law proves that the lead time is thus 0,25 day.

	Drying costs 20$/kg on electricity and other materials plus the labor costs of one person ($60.000 per day)	This is the same as in the current value chain.
Dry storage (plant)	To store, one person is assigned, earning 60000 pesos per day (more than an algae collector). Furthermore, 1% of the stored material is lost per day. The amount that can be stored per day is depending on the frequency of transport	This is the same as in the current value chain.
Sales	The sale is not included in the value chain, but can be seen as the former role of the intermediary. This costs approximately $8 per kg wet algae with a capacity of 5000 kg dry.	Selling can go in large bulk, thus the price per kg is very low. The price is built up out of partially salary and partially costs such as calls and the use of computers.
General	To transfer from wet to dry material, a factor 4 is used.	This is the same as in the current value chain.
	One US dollar is worth 630 Chilean pesos ($) and the euro 750 Chilean pesos.	This is the same as in the current value chain.
	Workers are flexible: when a capacity is not used completely, the worker has to be paid the percentage of the used capacity.	The tasks are not difficult and can thus be performed by the same person without the need for extra education. The person can be used for more processes in order to make the job fulltime.

15.10 Assumptions new pre-product for flour value chain

Table 19- Assumptions new pre-product for flour value chain

Part	Assumption	Explanation
Collection	Algae collectors earn a salary of $40.000 per day.	This is a reasonable wage and based on a average to good salary in the current situation.
Washing (fishermen)	The washing improves the quality of the algae and is performed by the fishermen with either fresh or salt water. It will costs $20 per kg on water and electricity and one person will be assigned to perform the task with a capacity of 5000 per day. 10 kg of wet algae can be washed at the same time.	Calculating the lead time with Little´s law gives us a lead time of 0,002 days (10/5000). The capacity follows from an informant in the fishermen community which stated this as an appropriate amount to be processed in any way per day. 10 kg at the same time comes from the fact that algae can be washed at the same time, but not too many since the washing then will be less effective.
Drying (fishermen)	The same as in the current value chain &the new carrageenan value chain	-
Wet storage (fishermen & intermediary)	Same as in the new carrageenan value chain.	-
Transport to plant	Same as in the new carrageenan value chain.	-
Drying (plant)	Same as in the new carrageenan value chain.	-
Production process (plant)	The production process consists of 6 steps, each of which will have a worker assigned to it and a total WIP of 1000 kg dry algae and a capacity of 5000 kg dry per day. Each process costs $20 per kg dry material on energy to process	The production process consist of: Chop, Bleach, Remove Smell, Pulverize, Pack, and Sell to customer. Therefore, six people are needed. Each process has the capacity of 5000 kg dry algae per day, based on the informant at the fishermen community. The costs per kg to process are based on the estimation from Seghetta et al.(2017), who estimated chopping on 0,07 kWh per kg and less with other operations. These are then doubled to be conservative to 0,15 kWh per kg The lead time in calculated by Little´s law and is 0,2 days per kg.
Dry storage (plant)	Same as in the new carrageenan value chain.	-
Sales	Same as in the new carrageenan value chain.	-
General	To transfer from wet to dry material, a factor 4 is used.	This is the same as in the current value chain &the new carrageenan value chain.
	One US dollar is worth 630 Chilean pesos ($) and the euro 750 Chilean pesos.	This is the same as in the current value chain &the new carrageenan value chain.
	Workers are flexible: when a capacity is not used completely, the worker has to be paid the percentage of the used capacity.	The tasks are not difficult and can thus be performed by the same person without the need for extra education. The person can be used for more processes in order to make the job fulltime.

15.11 Calculations of the costs of the operations in the proposed value chains

Table 20- Calculations added value proposed upgraded value chains

Process	Costs per kg wet algae	Calculations
Algae collection	$160	Wages in $ per day / productivity in kg wet per day = $40.000 / 250
Wet storage (fishermen)	$10,00	Lead time x loss x lost revenue = 0,5 x -10% x $800/4
Drying (fishermen)	$100	Number of dryers x salary per day x lead time drying / capacity = 5 x $40000 x 1 / 2000
Transport (wet)	$3,75	(Salary driver + petrol costs) / (truckload capacity wet x utilization) = (hourly wages x (two times the distance + load time + unload time + time to buy algae) + petrol price x efficiency van x (2 x distance)) / (truckload capacity wet x utilization) = (10000* x (0** + 0,167*** + 0,167*** + 0,167***) + 800 x 1/7 x (2 x 0)) / (2000 x 50%) *Hourly wage based on 6 hours per day **two times the distances 0 minutes ***10 minutes expressed in hours
Transport (dry)	$2,50	Same as wet, but with capacity dry instead of capacity wet = (10000 x (0 + 0,167 + 0,167 + 0,167) + 800 x 1/7 x (2 x 0)) / (3000 x 50%)
Drying (plant)	$35	salary dryer + drying costs = number of dryers x salary per day x lead time drying / capacity – drying costs = 1 x 60000 x 1 / 3000 - 20
Production processes (plant): Chop, Bleach, Remove Smell, Pulverize, Pack	$40	Number of processes x wage per kg wet + electricity costs per kg wet = 5 x (wage per day / capacity dry per day + $20) correction factor dry&wet = 5 x ($60000 / 5000 +$ 20) / 4
Dry storage (intermediary)	$22,75	(Lead time x loss x lost revenue + number of workers x salary per day x / capacity per day) x correction factor dry&wet = (3,5 x 1% x 2000 + 1 x 60000 / 2857,14)/4
Sales	$8	Wages per kg wet + material costs per kg wet = (Wage/capacity per kg dry + $20) x correction factor dry&wet) = ($60000/5000 + $20) / 4

15.12 Discussion on other performance indicators

15.12.1 Investments needed and Return on Investments

Initially there will be an investment needed to, primarily, construct the drying and storage facility. This is estimated at $200.000.000. With the costs of equipment, a transportation vehicle, machines to perform the operations and offices for the employees, included, the total investments are estimated at $218.500.000 for the new carrageenan value chain and $225.000.000 for the new flour value chain. The added value in the value chain can be used to give a return on these investments, shown in Table 21. In this calculation all of the added value is used for this and the maximal capacity is used every week. The maximal capacity is limited by the capacity of the plant (4000 kg wet per day) or 30% of the maximal limit of available algae (as resented in appendix 15.7), since this is a likely amount of algae that can be reserved for a new value chain due to politics in the fishermen community.

Table 21- Return on Investments

Value chain	Investments needed	Added value	Return on Investments (years)
Carrageenan value chain (scenario 1 & 3)	$218.500.000	$149,87	2,5
Flour value chain (scenario 2)	$225.000.000	$198,50	2,0

These are very good ROI rates and therefor it is estimated that part of the added value can also be used to increase the wages of the fishermen. Furthermore, after these year only depreciation of the machines and buildings have to be paid, all the other added value can go directly to the involved employees.

15.12.2 Employment

Aside from added value to the products, the new value chains also bring new employment to the area. These employments are already subtracted from the added value and therefore have to be calculated separately. These wages can be compared with the added value as presented in the current value chain.

The total wages can be expressed in number of people needed fulltime per day, with the assumptions of capacity and employment needed per operation as presented and calculated in appendices 15.9, 15.10 and 15.11. When this number is known the salary can be compared with the salary in the current value (as if the new employees were fishermen at this moment with a salary of the current added value). The difference can be seen as an improvement in the new value chain. This is shown in Table 22.

Table 22- New employment in new value chains

Value chain	People working location	Wages	Former wage	Number of employees	Total extra money in the value chain per day
New carrageenan value chain (scenario 1 & 3)	Fishermen	$40.000	$36.875	16	$50.000
	Plant	$60.000	$36.875	1,88	$43.475
New flour value chain (scenario 2)	Fishermen	$40.000	$36.875	16	$50.000
	Plant	$60.000	$36.875	5,35	$123.718,75

These values are calculated per day. They can however also be seen as an employment per year. When changing to an employment per year, again the maximal capacity is limited by the maximal capacity in the value chain and the available algae in the area (as was with the calculation of the return on investment). These calculations result in a fulltime year employment of 7,0 persons in the new carrageenan value chain and 8,37 persons in the new flour value chain.

15.12.3 Robustness of the value chains

In assessing the robustness of the value chain, three factors can be marked as most important: 1) the sureness of the supply of raw material, 2) the knowledge of the production process, and 3) the sureness to be able to sell the product.

The flour value chain (scenario 2) performs well on the robustness on the supply side. This is due to the fact that for the production of flour from algae, the type of algae to be used is currently no sold for any product or for an even lower price than calculated in the current value chain. Because of this, the supply will always be available, only being constraint by the amount of algae the total number of fishermen can collect during the summer months.

The carrageenan value chain (scenario 1 & 3) performs less on the robustness of supply. The current supply chain is already in place and functioning, using the same supply as the new carrageenan value chain, since the eventual buyer is the same (the algae processing industry). This means it has to compete with the current value chain and the supply will thus be less sure.

The addition of the paper product to scenario 1 (resulting in scenario 3) has a very robust supply. The algae processing company will keep processing and there are several algae processing companies available with residues.

The new value chain of flour (scenario 2) has no sureness on the buyer side. The flour product is completely new and it can well be that the product will eventually have no financial profitability and the production will thus be stopped. All the investments will in this case be invested in equipment for this product and will thus not be used to its full potential. This is a risk that has to be taken into account.

Also, in the flour value chain there is low knowledge of the production process. The flour product is still being developed and the standards and demands for the pre-product are still unknown.

Therefore, the exact production process is still uncertain. This means that the exact layout of the value chain cannot yet be known and the implementation has to be delayed.

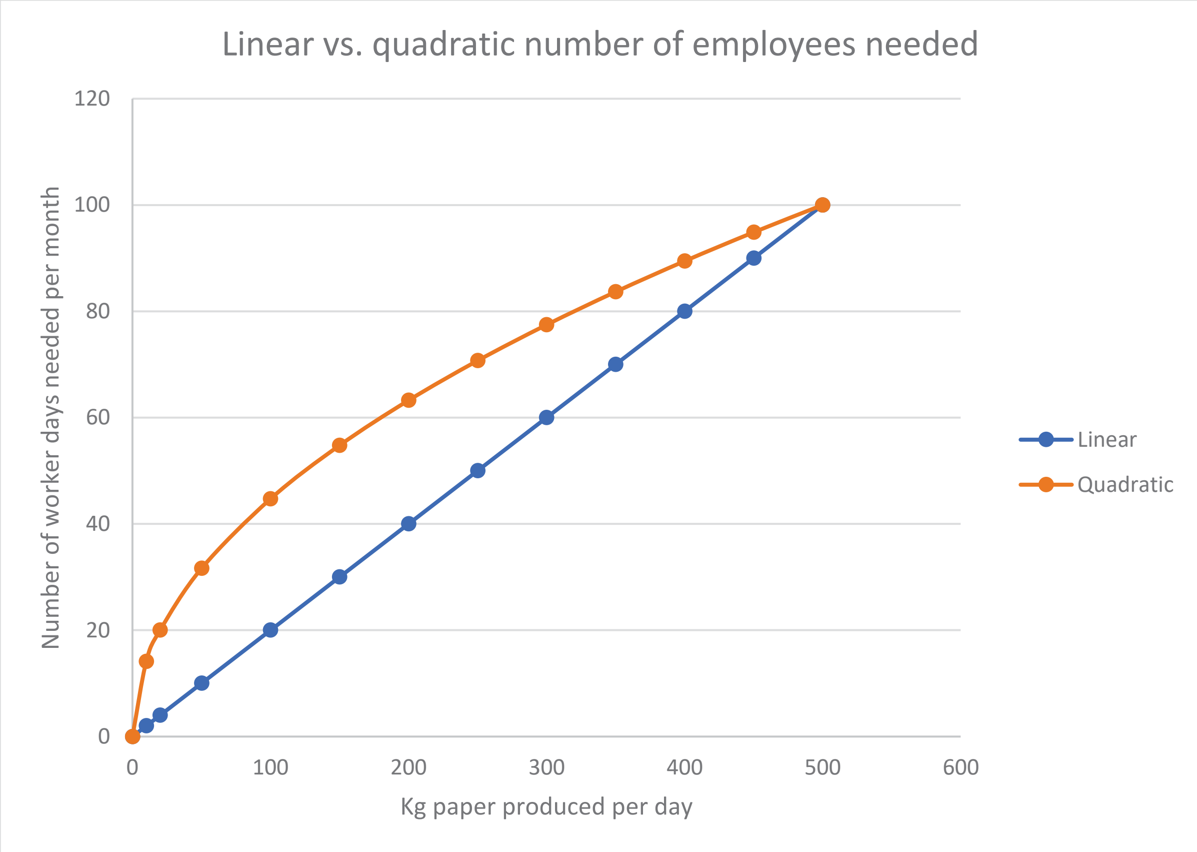
On the other hand, the demand for the product from the new carrageenan value chain (scenario 1 & 3) will be stable and sure. This is because it is already an existing product and the demand has been stable over several years. Furthermore, the production process is known and stable. These are advantages of this new value chain.

The addition of the paper product to scenario 1 (scenario 3) has a promising but not yet secure demand. Also the process has been developed, but lacks small scale and industrial scale trials.

15.13 Example output financial business model coaster company

Inputs		**Outputs**	
Ingresos			
Precio por posavasos sin imprimir	$54,75	Precio por posavasos	$69,75
Precio imprimir	$15,00	Total kilos procesado al mes	166,75
Gramos posavasos	5		
Gramos basura	1,67	Ingreso por kilo	$ 10.457,54
Cantidad posavasos por mes	25.000	Sin imprimir	$ 8.208,66
Días en un mes	20		
		Total costos por kilo	$ 10.457,54
Proceso		Sin imprimir	$ 8.208,66
Gastos máquina (kW)	10	Sin inversiones	$ 4.460,54
Gastos secar (kW)	10	Sin retorno de inversiones	$ 6.459,54
Horas por día	8		
Precio kWh	$ 133,00	Ganancia por kilo	-$ 0,00
Capacidad kg papel al día	500	Sin inversiones	$ 5.997,00
		Sin retorno de inversiones	$ 3.998,00
Materia prima			
Precio/kg pulpa papel (incluido transporte)	$ 300,00	Total ingreso	$1.743.794,38
Precio/kg pulpa algas	$ 100,00	Sin imprimir	$1.368.794,38
Transporte pulpa algas	$ 100,00		
% papel	70%	Total costos al mes	$1.743.794,38
% algas	30%	Sin imprimir	$1.368.794,38
		Sin inversiones	$743.794,38
Sueldos		Sin retorno de inversiones	$1.077.127,71
# personas para máquina	2		
# personas para resto	2	Total ganancia	-$ 0,00
Sueldo al día de trabajadores	$ 60.000,00	Sin inversiones	$1.000.000
# personas para vender	1	Sin retorno de inversiones	$ 666.666,67
Sueldo al día de vendedor	$ 60.000,00		
		Días*personas al mes	12,91317157
Inversiones		Personas necesario al mes	0,645658579
Máquina papel	$20.000.000		
Otros máquinas	$20.000.000	Capacidad usada	1,668%
% interés al año	10%		
Número de años para recuperar inversiones	5		
General			
Usa distribución cuadratica de employees	TRUE		

15.14 Employees needed in coaster company: linear vs. quadratic



15.15 Other small improvements available in the value chain

15.15.1 Dryer using rest-heat

The design of the dryer should be chosen in a way that it will still be effective in the humid area of Valdivia. To do this, the rest-heat of the freezer of fish and shellfish, which will also be incorporated in the new production plant at the fishermen community, can be used to increase the efficiency of the dryer (or lower the energy consumption needed). Furthermore, in the handbook of Weiss & Buchinger (2012) all possible (solar)dryers are discussed.

15.15.2 Dry the paper in the same dryer as the algae

Paper needs also drying and by including this in the same dryer as the algae, more economies of scale can be obtained.

15.15.3 Pickup dry algae and drop off algae residues

At this moment, the dry algae are picked up by an empty truck from the algae processing company, which makes a round along several fishermen communities. When this trucks travels to the community with the algae processing plant (to make paper), it can directly bring the algae waste stream residues. In this way transport costs are minimized.

15.15.4 Use infrastructure of fish/shellfish value chain

Since the plant is also going to process fish and shellfish, the infrastructure and processes needed for this could also be used by the algae processing part of the plant, to enhance economies of scale. For example, the computers, sales office, financial management, but also the collection and transportation of the raw material and the use of personnel, can be shared.

15.15.5 Increase capacity dryer by using local dryers

Since the dryer will probably be the bottleneck of the value chain (also since it will be used twice in the chain), increasing the capacity will greatly influence the profitability of the value chain. This could be done by implementing small, cheap local dryers on the beaches. Also the currently not working dryer in Palo Muerto could be restored and add to the capacity of drying locally at the fishermen communities. How these dryers should be constructed and how the current dryer at Palo Muerto could be altered to become functional can all be found in the extensive handbook on solar dryers of Weiss & Buchinger (2012).