Creating, delivering, and capturing value through sustainability

- an exploratory study on the early development of commercial aquaponics in Sweden

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Uppsala Jan 2022

Rita Ndum and Fardosa Farah

Abstract

Aquaculture is one of the fastest-growing food sectors in the world, and the increasing world population is said to only increase the need for more seafood. However, the sustainability of the aquaculture has been questioned recently and measures have been taken to overcome and internalize the negative externalities. These externalities include eutrophication of water bodies, the various impact of wildlife, disease transfer, and water source pollution. With the rising concerns of the open cage aquacultural systems, there has been rising interest in the Recirculating aquaculture systems (RAS) which use a closely controlled environment to grow fish.

One example of this is aquaponics which is defined as an integrated system where two elements of recirculating aquaculture and hydroponics are combined. This system of integration allows some of the shortcomings of aquaculture and hydroponics to be addressed promising to be a sustainable food production method. However, research within the area of aquaponics is mostly focusing on technical perspectives such as the engineering aspect as well as the microbiology. There are few existing commercial aquaponics businesses known in Sweden and very little knowledge about how the aquaponic business model is developed in practice.

The aim of this research is therefore to explore the early development business model of aquaponics in Sweden and how it can be conceptualized as a sustainable business model. A qualitative method was chosen to collect the data where the unit of analysis is individual units. The people that are used as the unit of analysis are individuals with expertise in the field either from research or practice as well as policies that govern this area.

This explorative study of aquaponics found aquaponics to be a promising innovation for sustainable food production and a learning curve in the process of sustainability. However, its growth in Sweden is underdeveloped and a paradox. Understanding this weakness in the growth of aquaponics can help inform policymakers and contributes to the uptake of aquaponics in Sweden. Understanding the BMI of aquaponics has revealed economic viability as a central pillar in the development of innovations for sustainability and the foundation to the development of environmental and social sustainability. These finding questions the balance in importance shown in the literature of the three pillars of sustainability.

Keywords: Aquaponics, Business model, Business Model Innovation, Sustainability, Sustainable innovation, Sustainable Business Model Innovation, Aquaculture, Recirculating Aquaculture System

Table of contents

List of tables

List of figures

Abbreviations

BM	Business Model
BMI	Business Model Innovation
SBM	Sustainable Business Model
SBM	Sustainable Business Model Innovation
BMIS	Business Model Innovation for Sustainability
RAS	Recircling Aquaculture System
CSR	Corporate Social Responsibility
CSV	Creating Shared Value
PSS	Product Service System

1. Introduction

The world's population growth rate, which is projected by the UN to reach 9.8 billion by 2050 has caused quite a stir at national and international levels (UN 2017). There is an even greater need for sustainability in our production systems if we are to maintain or grow our current living standards to meet the needs of the growing population. This concern is even more crucial because of the evidence that most resources are finite and taking from nature at an unsustainable rate has global side effects like global warming, increased acidity, natural resource depletion, rising sea levels, and the destruction of our biodiversity and ecosystems amongst others (Whiteman et al. 2013).

An increased evidence-based consciousness of what our growth rate and increasing commercial activities are doing to our world has led to several NGOs, intergovernmental organisations and consumers calling for a change from business as usual (Claydon 2013; Doh & Guay 2004). The United Nations sustainable development goals set 17 benchmarks which 193 countries of the United Nations signed committing to taking actions towards a more sustainable future for the planet (UN 2015). Aware of the inherent conflicts between growth, development and sustainability, the world commission on environment and development, (1987) defines sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Following this definition there is still evidence in literature of a lack of scholarly consensus of what really defines sustainability especially in businesses (Brühl 2002; Freidberg 2014; Romer 2021; Segura Salazar & Tavares 2018). There is a common confusion between corporate sustainability, sustained business growth, CSR, shared value and

the triple bottom as theories and concepts aiming to define sustainability (Torelli, 2021; van Marrewijk, 2003).

The private sector particularly businesses are a huge part of our socio-ecological system and could be a solid contributor to changing the current degrading state of our environment (Dentoni et al. 2021). Multinational businesses lead national/ international value chains that either promote or curb impacts to our economic, social, or environmental systems. In innovating and adopting business processes and practices with a focus on environmental impacts businesses are argued to be central to effecting changes towards sustainability in our systems (Dentoni et al. 2021; Van Tulder et al. 2021; van Zanten & van Tulder 2018; Whiteman et al., 2013).

Businesses strive and distinguish themselves through their business models. “A business model describes the rationale of how an organisation creates, delivers, and captures value.” (Osterwalder & Pigneur 2010, p.14). With this understanding of a business model, it provides a framework where technological and intellectual inputs are converted to economic value and hence the basis of competitive advantage (Chesbrough & Rosenbloom 2002; Osterwalder & Pigneur 2010).

The traditional linear business model (BM) that focuses on the end of pipe value creation from farm to land field is under pressure to adapt to the changing waves of concurrent trends (Jurgilevich et al. 2016; Michelini et al. 2017). Three huge trends have been seen recently in all the business sectors, 1. The sustainability problem, 2. Changing preferences of the customers regarding sustainability and 3. Technological shift that promotes new opportunities (Jørgensen &Pedersen 2019). There is an uptrend in the demand for business to incorporate sustainability in their business model (Doh & Guay 2004; Fraser 2005).

The sustainable business model (SBM) and Business model innovation for sustainability (BMIS) has been proposed severally as valid ways to change existing systems towards sustainability (Boons & Lüdeke-Freund 2013; Evans et al. 2017; Ulvenblad et al. 2019). Bocken et al. (2014, p.44) defines BMIS as “Innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its

value network create, deliver value and capture value (i.e., create economic value) or change their value proposition." Geissdoerfer (2018, p.407) on the other hand defines sustainable business model innovation as "the conceptualisation and implementation of sustainable business models. This can consist of the development of entirely new business models, the diversification into additional business models, the acquisition of new business models, or the transformation from one business model to another".

Given that we are aiming at a world without poverty as one of the sustainable development goals, there is a need for a sustainable increase in food (protein) production that will meet the rising demand (Henchion et al. 2017). Particularly in Sweden, there is a healthy demand for seafood and fish because of its healthier nutritional benefits (Rickertsen et al. 2003). Also, Sweden is known to be a trailblazer in sustainability in Europe championing sustainability discourse (Krutmeijer 2019). Furthermore, The Swedish customer base have been said to be more conscious of sustainability than in most parts in Europe(ibid).

The constant demand for fish and the rising concern of the sustainability of the supply has sparked interest in a more sustainable way of producing fish (Henchion et al. 2017). Aquaponic is an agricultural system where fish and plants are farmed in a circular supportive manner where the waste from the fish feeds the plants and the plant in effect filters the biowaste of the fishing system. According to Wu et al. (2019, p.833), "Aquaponics presents an innovation in conventional aquaculture systems by combining aquaculture with hydroponic plant growth. In these systems fish grow in conjunction with plants using closed loop, typically recirculating, water systems and can potentially reduce the environmental concerns associated with both conventional aquaculture and agriculture"

Even though the idea of land-based fish farming has been done for hundreds of years, the innovative idea of merging aquaculture and hydroponics is a novelty in the cultivation of land-based fish. It is argued to be a more sustainable way of farming fish as it is said to have a triple dimension of value-added that is economically, socially, and environmentally viable (Blidariu & Grozea 2011; König et al. 2016).

This technology purportedly has the ability to support the sustainable production of organic fish and plants as it offers the possibility of farming indoors in a controlled environment in all seasons of the year hence offering the possibility to increase production with limited use of arable land and water (Bernstein 2011). Considering the concept of planetary boundaries and the fact that our global consumption exceeds the rate at which resources are being regenerated, aquaponics may well offer an opportunity to bridge the gap in production as these systems is argued to "be four to six times more productive and use 90% less water than normal gardens" (Bernstein 2011; Gregg et al. 2019).

1.1. Problem

There is a huge sustainability issue with our current food production and consumption habits that generate various environmental impacts, such as increased CO2 emissions and other externalities (Jurgilevich et al. 2016). The UN's Food and Agriculture Organization (FAO) emphasizes on the inefficiencies of the food economy globally which results losing productivity, energy, and natural resources (Gustavsson et al. 2011; Bennett et al. 2021; FAO 2021a).

One area that has had extensive expansion worldwide and has caused severe environmental damage to coastal ecosystems is the aquaculture (Folke & Kautsky 1992). Rapid growth in this sector has been associated with environmental problems such as eutrophication, oxygen depletion and pollution of the surrounding waters which in turn makes these waters and its ecosystem unsuitable for other purposes(ibid). It is, therefore, important that sustainable transition in both infrastructure and technology as well as business practices happen fast (ibid).

As described in the background, the complex issue of the incumbent agri-food sector requires novel and innovative solutions (Banbury & Mitchell 1995). Many studies have addressed some technical aspects of aquaponics and its potential sustainability (Tyson et al. 2011; Palm et al. 2014; Palm et al. 2015; Kloas et al. 2015). However, there has been limited attention paid on the development of the

BM of aquaponics, its practical adaptation and economic viability. Research conducted within the area of aquaponics mainly focuses on the technical aspects such as the integration of aquaculture and hydroponics, water quality, microbiology, and engineering and very little on the business model and its practices (Love et al. 2014; Van Woensel et al. 2015; Van der Goot et al. 2016).
Studies on the adoption of technology in agriculture reveals that there are usually unforeseen social/cultural, economic, environmental, and institutional/political factors constraining the uptake of agri-innovation (Feder et al. 1985; Feder & Umali 1993; Natcher et al. 2021). However, if agri-innovations are to provide a significant change in our food systems, there is a need for an in-depth understanding of the innovation at the development stage and an exploration of the potential factors that may limit its adoption and diffusion (ibid).

Most studies on aquaponics focus on the technique, the micro biological composition of the system, life cycle analyses and comparative techniques (Forchino et al. 2017; Chunjie Li et al. 2018; König et al. 2018; Lunda et al. 2019; Suhl et al. 2019). Research in Sweden on aquaponic on the other hand has mostly focus on the technique, and its potential contribution to the transition to circular systems (Gigliona 2015; Gregg et al. 2019; Körner et al. n.d.). There is a Gap in studies on the business model innovation of aquaponics, its conceptualization as a sustainable business model and the recent challenges to the uptake of this innovation in the context of Sweden. The lack of knowledge regarding the potential sustainability of the already existing business models in aquaponics has resulted in aquaponics conceptualised as business practices to be underdeveloped and this study is intended for contributing to the understanding of this gap through exploring the early development of commercial aquaponics in Sweden.

1.2. Aim

The aim of our study is to contribute to the understanding of the business model of integrated fish and vegetable farming in this case for aquaponics in Sweden and how that can be conceptualised as a sustainable business model.

1.3. Research Questions

To achieve the aim mentioned above the following research questions were conducted.

1. What is innovative about Aquaponics business models?
2. How can it be conceptualized as business model innovation for sustainable food production?
3. What are the challenges and opportunities for creating, capturing, and delivering sustainable values from aquaponic production systems?

1.4. Delimitations

Due to time constraints and resources, we were subjected to make some delimitations. This study mainly focuses on Sweden. More so, because of the method of data collection, we do not intend to make statistical generalizations on a broader scope about the relationship between the concepts and the cases that are specific to those practitioners and researchers that has been used as a unit of analysis. However, because the respondents are researcher in the field of aquaponics in Sweden, top practitioners of aquaponics BMs and policy advocators, the findings of this research will be relevant in the context of Sweden and could be used as foundation to similar studies conducted in similar environment.

1.5. Outline of this thesis

The disposition of our thesis is structures as the figure below where we start off with a background introduction chapter that gives an overview of the intended study. we continued with our conceptual framework chapter which gives the reader

how this study is conceptualized by using a conceptual model and then we discuss, in detail, the different concepts that are relevant to our research question.

Then, in chapter three we present our methodological point of departure and how we collected data as well as the strategy behind how we sampled our data, and how we analysed our data. In chapter four we presented our empirical data by organizing it thematically and described what our respondents had to say about each theme. In chapter five we discussed and analysed the data as well as synthesized it in to conceptualised tables and lastly, our conclusion follows where we state our general conclusions.

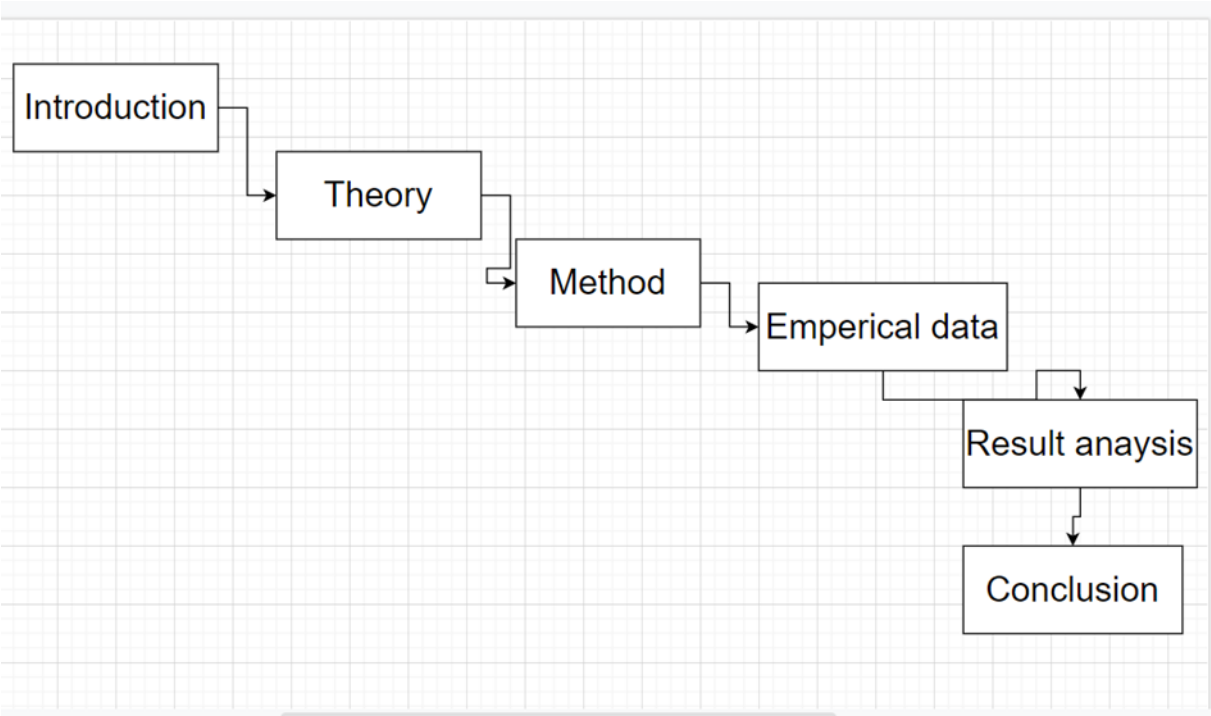

Figure 1 outline of the thesis

2. Conceptual Framework

In this section, the authors use concepts in literature, to frame this study and to act as a foundation for the analyses of our findings. Firstly, the authors explain the concepts of aquaculture, RAS and aquaponics to give the readers a deeper understanding of the subject matter of this thesis. Secondly, a brief historical background of the concept of SBM is given followed by an introduction to this paper's underlying concepts, which are BM, and BMI. We then critically evaluate the literature with a focus on, SBM and BMI for sustainability which will be used to analyse our finings.

2.1. Background introduction of aquaculture”

Aquaculture which is defined to be “the farming of aquatic animals and plants” is not a novel practice as it dates back to about 4000 years ago in China (Halvorson & Smolowitz 2009; Tidwell 2012). Discoveries in some Egyptian tombs dating back to about 2500bc shows that tilapia was being farmed in Egypt thousands of years ago(ibid). However, aquaculture is said to have evolved in Europe during the Middle Ages with the introduction of the cultivation of carp (ibid). Today the farming of seafood has expanded throughout the world with China being a leader in aquaculture production producing about 65.2 million tons of fish in 2015, 75 % of which was from aquaculture (FAO, 2021b).

There are different types of aquacultural systems open systems, semi closed, closed and hybrid systems (Tidwell 2012). Recently, the sustainability of the aquacultural sector and its effect on the environment has been put into question by many environmentalists. Areas of criticism include, the use of fish in fish feed (the use of captured fish to feed cultured fish), eutrophication of water bodies, various impact to wildlife, diseases transfer water source pollution that has been associated with the different forms of aquaculture (Halwart et al. 2007; Hasan et al. 2009; Tidwell 2012).

According to Jordbruksverket (2020) Swedish aquaculture produced 9900 tons of fish for consumption in 2020 worth 400 million sek and 3% higher than 2019 production indicating that there is much room for increasing production in this sector.

2.2. Recirculating Aquaculture System (RAS)

With the rising concerns of the open cage aquacultural systems, there have been rising interest in the Recirculating aquaculture systems (RAS). The RAS system offers a novel way to farm fish in a controlled recirculating system with bio filters in indoor tanks (Halvorson & Smolowitz 2009). The RAS system is argued to be highly productive and eco-friendly, compared to open case aquaculture as it addresses some of the challenges in the open cage system like eutrophication, diseases transfer, parasite and the interruption with biodiversity (Ahmed & Turchini 2021). The RAS system is argued to be a newer system in the aquacultural sector. According to Saeki 1958; Halvorson & Smolowitz 2009; Murray et al. 2014, the RAS concept was developed about 65 years ago to address some of the uncontrollable and unsustainable aspects of open cage and marine aquaculture and over the years, different RAS systems with different techniques of system control has evolved.

RAS is a method of farming fish usually indoors in tanks with closed controlled systems with biofilters (biological Filters) and treatment methods which allows for the reuse of water in the system. The system is argued to have minimal water use as water in the system can be filtered with biochemical filters and reused within the system for continuous production. An RAS system is argued to be able to recirculate up to 90-99% of water used (Badiola et al. 2012; 2018; Dalsgaard et al. 2013; Ahmed & Turchini 2021).

2.3. Background introduction to aquaponics

Aquaponics is an integrated system where two elements of recirculating aquaculture and hydroponics are combined. This system uses fish tanks filled with water and the water in the tanks and the nutrients from the fish are used to enrich the plant growth (Rakocy 1989). The process uses fish waste and bacteria as a fertilizer for the crops, see figure 2. below. Because of the sustainability problems associated with both aquaculture and hydroponics, this system of integration allows some of their shortcomings to be addressed promising to be a sustainable food production method (Turcios 2014).

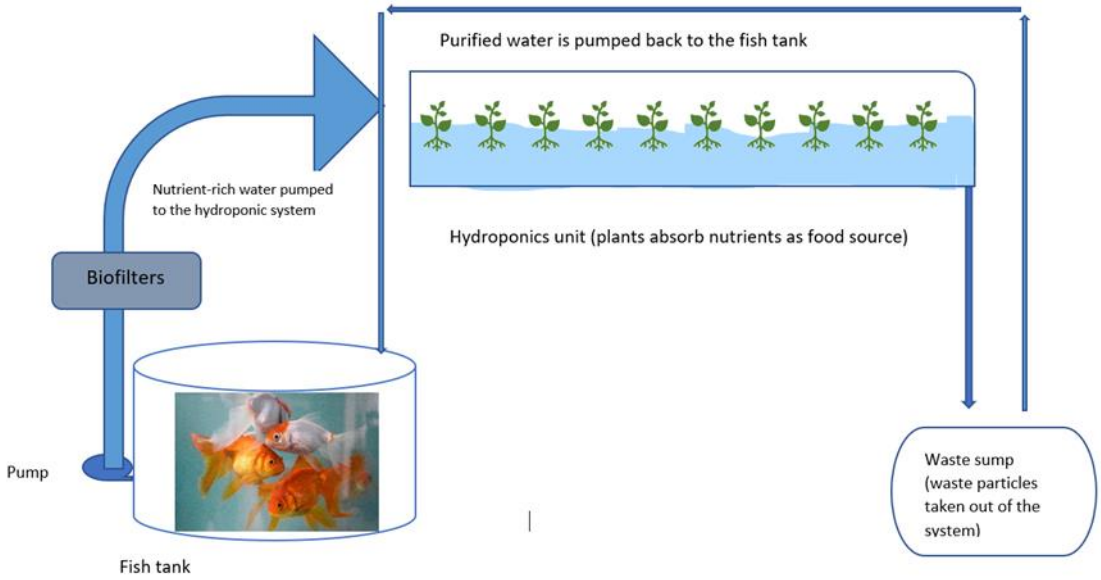

Figure 2 Authors visualisation of the aquaponics system inspired from (Goddek et al. 2015; Wu et al. 2019).

When it comes to whether aquaponics is considered a sustainable agricultural production or not, Lehman et al. (1993), defined sustainable agricultural process as a process that does not deplete any non-renewable resources are can be considered essential to agriculture in order to sustain the agricultural practices.

One of the properties of aquaponics is that it has mineral transfer with the two systems from the aquaculture to hydroponics allowing efficient nutrient recircling,

energy and water usage reduction (Turcios, 2014). In traditional hydroponics, the material used are finite resources and requires a considerable amount of macro- and micronutrients from industrial and mining origin, leading to high energy and other finite resource usage. The same goes for aquaculture where there is no recirculating properties resulting high usage of water as well as massive pollution to the surrounding water surfaces (Ragnarsdottir 2011).

Despite its synergistic interaction and promising methods of fish and plant farming that claims to contribute to both global and urban sustainable food production as well as reduces pollution, the practical application of aquaponics is yet to be proven to its potential (Rakocy 2012). Research has shown that developed aquaponics system components are not yet fully realised in terms of their cost effectiveness and their technical capabilities posing a challenge for its global application (Vermeulen 2013).

One of the things that pose a challenge to the technique is that its system design and application is a complex multidisciplinary approach that integrates environmental, mechanical, and civil engineering design concepts as well as aquatic and plant related biotechnology (Goddek et al, 2015). Manging the complexity of system requires in depth knowledge and expertise related to all the fields involved. Running this system requires skills in pH stabilization, nutrient balance, phosphorus, and pest management. Furthermore, when it is adopted as a business model in a commercial use, the need for expertise in economics, finance and marketing arises adding to its complexity affecting the efficiency factor of running this system(ibid).

Global agriculture is associated with high water usage around 70% of the available freshwater resources and even more water usage in arid climate zones(ibid). Unlike the conventional agriculture, aquaponics uses less than 10% of water and can reduce the problem associated with the shortage of fresh water and resource depletion while still allowing sustainable farming and food production (Bernstein 2011).

2.4. Business Model and its component

The term Business Model is very often used by managers, consultants, or scholars from different fields as well as the media. Since it is repeatedly used, it suggests that business models are significantly important (DaSilva & Trkman 2014). There are million dollars spent each year in funding of defected business models and understanding how business operate and how they create value is vital quest for management (Shafer et al., 2005).

There is lack of common definition of what business model is and it usually results misuse thus, when a business model stands on untested assumptions about the future, the firm is likely to get an uncertain outcome. A big step in the proliferation of the term's use was driven by the disruptive changes from new technology, such as ICT etc. The possibility that come with technical and organizational networking enabled a broad range of business networks and business strategies to emerge as well as faster adaptation of these strategies. (DaSilva & Trkman 2014).

Business model is defined as a " ..blueprint of how a company does business" (Osterwalder et al., 2005, p. 2). This definition is based on separating the words business and model. Where Business in its simplest form can be described as " .. the activity of providing goods and services involving financial, commercial, and industrial aspects" and a model is defined as " .. a simplified description and representation of a complex entity or process" (Osterwalder et al., 2005, p. 2). A more sophisticated definition of what a business model is that: " .. a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm" (Osterwalder et al., 2005, p. 3) and this way of defining business model is shared by other researchers (Bocken et al., 2014, p. 42; Morris et al., 2005; Timmers, 1998).

However, according to Teece (2010, p. 173) "a business model articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers" which aligns with the view of other researchers (Johnson et al., 2008; Magretta, 2002). Likewise, Zott and Amit (2008, p. 3) and Amit and Zott (2012, p. 42) propose along those same lines in defining business

models, as “system of interconnected and interdependent activities that determines the way the company “does business” with its customers, partners and vendors.” In contrast to that Boons and Lüdeke-Freund (2013, p. 10) define a business model differently even though they still have some commonalities. They argue that a business model is “a plan which specifies how a new venture can become profitable” this definition is founded in the old school way where the goal off business is to maximize shareholders value (Boons & Lüdeke-Freund, 2013, p. 10).

Based on the above definitions, Hedman & Kalling (2003) have proposed a generic business model with the components; (1) customers, (2) competitors (3) offering, (4) activities and organisation, (5) resources, and (6) supply of factor and production inputs as well as longitudinal process component, which covers the dynamics of the business model in terms of cognitive and cultural constraints that managers face. According to this model, there is an integration of firm’s internal aspects which transfer resources and activities within the firm to products and offerings to.

According to Osterwalder and Pigneur (2010) Business model canvas comprises of nine different components “value proposition, customer segments, customer relationships, channels, key partners, key activities, key resources, cost structure and revenue streams” that are linked with a firm to illustrate how value is created and utilized and to explain existing business models as well as innovative business models. Central to this concept is the value proposition and explains the value the company provides to its customers (Lewandowski 2017). Richardson (2008) also developed a widely used framework for business models, comprising of “value proposition (including the offering, the target customer and differentiation strategies); value creation and delivery (including resources and capabilities, organisation and position in the value network); and value capture (including revenue sources and the economics of the business)”.

The value proposition — is explained as the firms offering to the customers and it also explains why customers will be willing to pay for it as it shows firm’s basic approach to competitive advantage (Richardson 2008).

The value creation and delivery system — explains how the firm will provide and deliver that value they proposed to its customers, and it entails the basis of its competitive advantage. These are what the firm has in terms of "Resources and capabilities, the value chain, activity system, and business processes they operate in and the position they are in the value network in terms of links to suppliers, partners, and customers" (Richardson 2008).

Value capture — Explains ways in which the firm generates revenue and profit and the economics of the business. The aim is to increase value for both the customers and the firm through trade-offs to ensure value capture for the firm (Richardson 2008).

2.5. Business Model Innovation (BMI)

When it comes the concept of innovation, it is not just product, service or technological innovation and it even goes far beyond enhancement approaches or sales model (Lindgardt et al. 2009). According to Lindgardt et al. (2009) an innovation becomes BMI when two or more component of a business model is reinvented to provide value in a new way.

Schumpeterian theory of innovation holds that innovation as a novelty of economic value (McKelvey & Holmén, 2006). BMI is usually categorized as either product or service innovation where the product or the service is either new to the firm or significant improvements has been made to their characteristics or intended use (Björkdahl & Holmén 2013). The core definition of BMI is not to discover a new service or product but may redefine how an existing product or service is used, delivered to the customer, or may add to new value in terms of profits to the firm (Björkdahl, 2009b).

Since mid-1990s, research relating to business model innovation has increased (see e.g., Slywotzky, (1996); Slywotzky and Morrison, (1998); Amit and Zott, (2001); Chesbrough and Rosenbloom, (2002); Magretta, (2002); Björkdahl, (2007; 2009a); Zott et al., (2011). The increase in research in BMI is associated with the fact that many companies exert huge resources, effort and time on trying to launch new

business models. Because it represents an underutilized future, BMI is important to both managers, entrepreneurs as well academic researchers. BMI is also vital to these group because of the fact that it can be used as a competitive advantage and competitors might find it harder to replicate an entire activity or novel system than a single novel product or process (Amit & Zott 2012). They further argue that innovation that is at the level of BM can be transferred to sustainable performance and might be better that product or process innovation as they are easier to be undermined and eroded (Amit & Zott 2012). According to Lee et al., (2012), globalization of the business environment as well as the technological shift of business today are some of the known drivers of a companies need to innovate and reinvent their business models.

Despite the view many holds on BMI as either product or service innovation, some economics hold that there is also a specific type of BMI called process innovation. Process innovation focuses on internal organisation flow of information and is seen as an integral part of an organization (Swann, 2009). However, the key word here is "novelty that creates value" and it is the fundamental aspect of BMI, thus can entail process innovation, new revenue model or other types of innovation that create value for the firm. Thus, Björkdahl & Holmén (2013); Rowley et al. (2011), argue that business model innovation is a "new integrated logic of how the firm creates value for its customers (and users) and how it captures value". From this point of view, a business model innovation is not limited to just product or service innovation, nor is it a process innovation but rather new ways for the firm to create value and the way the firm creates new offerings (e.g., product or service innovations). According to them, it also includes the ways the firm positions itself and the new ways for the customers to view the firm's offers (positioning innovation), as well as the changes in activities and how the firm views it (paradigm innovation) and firm operations (process innovation). Thus, a business model innovation can be defined as Björkdahl & Holmén (2013) stated in the paragraph above in terms integrated logic of value creation and value capture whether new or old product or service.

There are difficulties when distinguishing between the different innovation aspects. When thinking in terms of product and service innovation the focus lies in creating, products that are new to the firm and can create a new offering for customers, on the other hand, process innovation, the focus lies in reducing cost of producing existing products or enabling ways to produce new products (Traill & Grunert 1997). They hold the idea that the distinction is not always clear cut and both product and process innovation go hand in hand. Process innovation is seen as a way the firm invests in improving skills, resources and competences which can result in cost saving changes in the production processes. It can also result in introducing new technology that can help the firm produce new rages of products or improve already existing products (bid).

2.6. Business model innovation for sustainability BMIS

The aim of re-strategizing and invention in businesses have originally been centred on profit maximisation for the shareholders with little consideration for the environment and society in which these businesses operate (Dodd 1931; Friedman 2007; Freeman et al. 2010). Later, the narrative shifted to the consideration of stakeholders with the advocacy of cooperate social responsibility (CSR) and creating shared value (CSV) as a better way (ibid). Today, the SBM is understood to embody characteristics of CSR, CSV, with more emphasis on the environment and longevity (Schaltegger et al. 2012, 2016). Given the growing market for sustainability, several businesses are rethinking their BMs to evaluate new ways of proposing and capturing sustainable value in an attempt to capitalise on this growing market. Stubbs & Cocklin (2008); Schaltegger et al. (2012); Bocken et al. (2014) however, propose that, for a business to be more sustainable there is a need for a transformation in the business model not just structural change. This kind of change may however be harder for already established businesses with lock in dependencies, but it is easier for business start-ups to take up innovations that embody sustainability (Stubbs & Cocklin 2008; Geissdoerfer et al. 2018). Stubbs & Cocklin (2008) however, in their case study of the SBMI of interface a multinational flooring company that transforms and innovated its entire business to

stand out as one of the most sustainable multinationals proves that the locked in dependencies can be overcome by mutual value supply chain/ environmental stewardship and innovation for circularity and waste reduction.

The concepts of Sustainable business model innovation (SBMI) and Business model innovation for sustainability (BMIS) are used interchangeably in Geissdoerfer et al. (2018). Looking at the definition we noticed some differences. The definition of the SBMI by Schaltegger et al. (2012); Boons & Lüdeke-Freund (2013); Geissdoerfer et al. (2016); Roome & Louche (2016) looks at the conceptualization and the transformation of the BM. BMIS on the other hand focuses on what characterises the innovation of the business model as sustainable as seen in the definition Bocken et al. (2014). To further highlight this difference for the purpose of a clear conceptualization of this thesis discussion, we use the definitions of Geissdoerfer et al. (2018) and Bocken et al. (2014). The definition of BMIS by Bocken et al. (2014) is chosen because of its simplicity and explicitness and this thesis focuses on understanding how the BMI of aquaponics can be understood as sustainable. However, the two definitions have many similarities that may cut across in our analysis. Table 1. shows the definition of SBMI and BMIS.

Table 1 SBMI and BMIS by Geissdoerfer et al. (2018) and Bocken et al. (2014)

(Geissdoerfer et al. 2018) SBMI	(Bocken et al. 2014) BMIS
"*… the conceptualization and implementation of sustainable business models. This can comprise the development of entirely new business models, the diversification into additional business models, the acquisition of new business models, or the transformation from one business model to another" page 407*	*"Innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its value-network create, deliver value and capture value (i.e., create economic value) or change their value propositions". Page 3*

Innovation is the successful marketing of an invention, so the BM is crucial for the market penetration of an invention for sustainability (Boons & Lüdeke-Freund

2013). But the question which still needs answering is what standards could be used to categorise an innovation as sustainable. Lüdeke-Freund (2009); Schaltegger et al. (2012) argues that there are no ideal standards for the categorization of an innovation as sustainable. This may be due to the nature of sustainability itself which is the base for the characterization of an innovation as sustainable. Lélé (1991) argues that sustainable development is a process where we continuously take actions to balance social, political and environmental factors in the process of development. Therefore, conceptualising sustainable innovation as a process make it easier to categories.

Bocken et al. (2014) categorization of the BMIS is very popular in literature as it has been cited according to web of science and google scholar by 1189 and 2996 articles respectively at the time of the writing of this thesis. It uses several literature reviews and real-life cases of innovation for sustainability to propose 8 categories (also called archetypes) for the evaluation and understanding of BMIS.

These categories are seen in the table 2. Below are 1. Maximise material and energy efficiency 2. Create value from 'waste' 3. Substitute with renewables and natural processes 4. Deliver functionality, rather than ownership 5. Adopt a stewardship role 6. Encourage sufficiency 7. Re-purpose the business for society/environment 8. Develop scale-up solutions. These have several sub categorizations under each category and can be used to evaluate, categorise, and understand BMIS (Bocken et al. 2014; Ulvenblad et al. 2019)Table Business model innovation for sustainability by Bocken et al. (2014).

Table 2 Business model innovation for sustainability by Bocken et al. (2014)

Bochen et al. (2014) BMIS Archetypes	Value proposition	Value Creation and delivery	Vale capture and economic viability
Maximise material and energy efficiency	Propose products or services that will use less resources, produce less waste and pollution compared to competing products or services	Carry out business activities, process partnerships in innovative ways that generate less waste, emissions, and pollution. Partnerships for waste reduction and supply chain emission. Product, process, and manufacturing innovation	Minimises cost by efficient use of material inputs and waste reduction, therefore, optimising profits leading to competitive advantage. Value to environment by minimising environmental footprint
Create Value for waste	Convert waste streams Into useful resource for other production	Engage into activities process, and/or partnerships to eliminate life cycle waste, close loops and optimise underutilised capacity	Minimising and using material and turning waste into value leads to minimal economic and environmental cost, reduced footprint and reducing strain on natural capital and also minimising the cost of production.
Substitute with renewable and natural resource	Propose innovative solutions addressing resource constrain associated with natural capital. Solutions that reduce impacts to the environment and increase business resilience	Innovate products and processes, for renewable resources and energy use. Create solutions that mimic nature. Create value networks and partnerships for renewable material and energy supply and systems.	Revenue streams to the organisation from new products and services from renewable ventures. Environmental value captured by; reduced use of non-renewable resources, Emission reduction through minimising the use of fossil fuel and limited waste to Lindfield.
Deliver functionality rather than ownership	Propose products or services that better align manufacturer and consumer's interests. Satisfy the need of customers without them having to own physical products.	Create and Deliver product/service offerings that are more durable repairable and upgradable. Enable direct customer contact and customer education to facilitate a shift from ownership to function delivery.	Reduces cost of ownership attracting low-income customers. Revenue stream to the company through the expansion of customer segments. The environmental value gained from efficient use of material, product longevity and potential reuse of material.
Adopt stewardship role	Propose products with broader benefits to stakeholders' health and wellbeing. Engaged with stakeholders to ensure understanding of value proposition.	Firms lead internal activities, supply chain, and partnerships with suppliers to ensure that all stakeholders' health and well-being are prioritised and the environment.	Steward strategy generates brand value and engenders premium pricing. Healthier and happier customers and workers ensure longevity for the organisation. Better environment
Encourage Sufficiency	Propose innovative products or services that will reduce consumption, demand, and hence increase production of Durable products.	Innovate and redesign the products and services for durability, reducing waste and ensuring the material's longevity. Lead supply chain and customers for less consumption	Profitability to the company through premium pricing, competitive market advantage from providing a better product. Value captures to the environment by less use of resource and less waste
Repurpose the business for society	Prioritise delivery of service or products over making economic profits. Prioritise stakeholders value.	Focus on creation and delivery of products and services with benefits to all stakeholders, including society. Creation of non-traditional partnerships and supply chains to achieve this goal.	Be a meaningful enterprise that provides products and services at a low environmental cost, value wellbeing of the community. This will in turn generate support from the community for the business

Develop scale-up solutions	Propose scalable solutions for maximum benefits to society and the environment.	Ensure that SBM solutions can achieve scale by partnering with government and other agencies to facilitate infrastructural change that enables scalability	Enable franchising and licensing and other mutual benefit scaling up solutions. Value captured to the organisation from fees paid for these solutions and value captured to the environment by larger scale of environmentally friendly solutions

2.7. Sustainable Business Model (SBM)

There has been an upsurge in literature and research on SBM as there is a general advocacy for the incorporation of sustainability in all operating systems and practises (Stubbs & Cocklin 2008; Bocken et al. 2013; Boons & Lüdeke-Freund 2013). Many works of literature have conceptualised SBM as a tool for analysing, evaluating and implementing sustainability in the business model (Stubbs & Cocklin 2008; Boons & Lüdeke-Freund 2013; Evans et al. 2017; Geissdoerfer et al. 2018).

Sustainability has been a controversial concept in literature as scholars continuously search for a generally acceptable and sufficient construct of sustainability (Leist & Holland 2000; Moore et al. 2017). This question of what suffices as a SBM is yet to be answered in scholarly literature (Boons & Lüdeke-Freund 2013; Evans et al. 2017; Geissdoerfer et al. 2018). For our analyses in this thesis, we conceptualize the SBM by analysing 3 papers that proposed constructs of the SBM. We aim to deduct crosscutting concepts which we will used as a base for exploring aquaponics in this paper.

Table 3 Cross cutting synthesis of the sustainable business model from Stubbs & Cocklin (2008); Boons & Lüdeke-Freund (2013); Evans et al. (2017)

(Boons & Lüdeke-Freund 2013, p.13)	(Stubbs & Cocklin 2008, p.121-122)	(Evans et al. 2017, p.605)
-Value proposition – consider ecological and social and economic factors in concert -Supply chain – Responsible action by all stakeholders in the supply chain from the suppler to the focal firm to the customer. Collaboration for circularity and waste reduction -Customer interface- Responsible customers that take responsibility for all stakeholders including the environment and firm customer relationship of mutuality and reciprocity without pacing the incident of to each other -Financial model. An inclusive financial model that accounts for the distribution of economics cost and benefits for all involved in the model and considers the organization's social and environmental impact".	-A SBM Draws on Economic, Environmental and Social Aspects of Sustainability in Defining an Organization's Purpose - A SBM Uses a TBL Approach in Measuring Performance - A SBM Considers the Needs of all Stakeholders Rather Than Giving Priority to Shareholders' Expectations. - A SBM Treats Nature as a Stakeholder and Promotes Environmental Stewardship - Sustainability Leaders, or Champions, Drive the Cultural and Structural Changes Necessary to Implement Sustainability -An SBM Encompasses the Systems Perspective as Well as the Firm-Level Perspective	P1- Sustainable value incorporates economic, social, and environmental benefits conceptualized as value forms. P2 -SBMs require a system of sustainable value flows among multiple stakeholders including the natural environment and society as primary stakeholders. P3- SBMs require a value network with a new purpose, design, and governance. P4 -SBMs require a systemic consideration of stakeholder interests and responsibilities for mutual value creation. P5 -Internalizing externalities through Product service systems (PSS) enables innovation towards SB

2.8. Cross cutting conceptualization of the sustainable business model

From the analyses of the characteristic of SBM from Stubbs & Cocklin (2008) Boons & Lüdeke-Freund (2013), Evans et al. (2017) in table 3. We develop a synthesis of SBM that cuts across all the authors to use for our analysis

1) The 3 pillars of sustainability, the social economic and environmental consideration is at the core of a SBM value proposition, and is central in the process of creation, delivery and capturing value.

2) A SBM requires a system approach of sustainable value flow, collaboration for waste reduction, circularity, and environmental/ societal stewardship by all stakeholders in the value chain with the consideration of the natural environment and society as primary stakeholders

3) A SBM requires redesigning and repurposing value networks, governance, culture, and drive. Considering all stakeholders interest with a system of responsibility, accountability, and reciprocity for mutual value creation.

4) The SBM develop innovative systems to internalise externalities Product service systems (PSS) and has an inclusive financial model that is considerate of social and environmental impacts and distributes economic cost and benefits to all stakeholders with the environment and society as primary stakeholders.

2.9. Mapping the BM

To further understand sustainability in a business model, Bocken et al. (2013) suggest a business model mapping tool aimed at supporting companies to create and capture more sustainable value (see table 4.). Whereby, businesses can reinvent

themselves towards more sustainable practises by identifying the value destroyed and value missed in the value creation process and transforming that into an opportunity to create more sustainable value. Value destroyed is defined by Bocken et al. (2013) as the environmental and social cost involved in creating an economic added value, also known as the negative externalities. Value missed is the value that the current business model does not capture, constituting waste to the operating system. If identified, this value could be maximised to yield more utility for the organisation and its stakeholders. An example of missed value is underutilised capacity and waste which the authors attribute to the poor BM design that allows for wasteful and uncaptured value (ibid).

Table 4 Mapping of the business model by Bocken et al, (2013)

VALUE DESTROYED	*VALUE MISSED*	*VALUE OPPORTUNITY*
The environmental and social cost involved in the creation of an economic added value also known as negative externalities	The value that the current business model does not capture, constituting waste in the operating system of the BM	The optimization of value is missed by creating other forms of value for the organization and its stakeholders from the missed value in the current business model.

2.10. synthesis of the theoretical framework

Figure 3 below shows a synthesis of the theoretical framework of this thesis demonstrating how the authors frame this research in agreement with Lélé (1991) proposition that sustainability is a process and not a destination. Here the authors use different tools in literature to explore how novelty in proposing, creating, and capturing value can be interpreted as sustainable and how this contributes to the sustainability process.

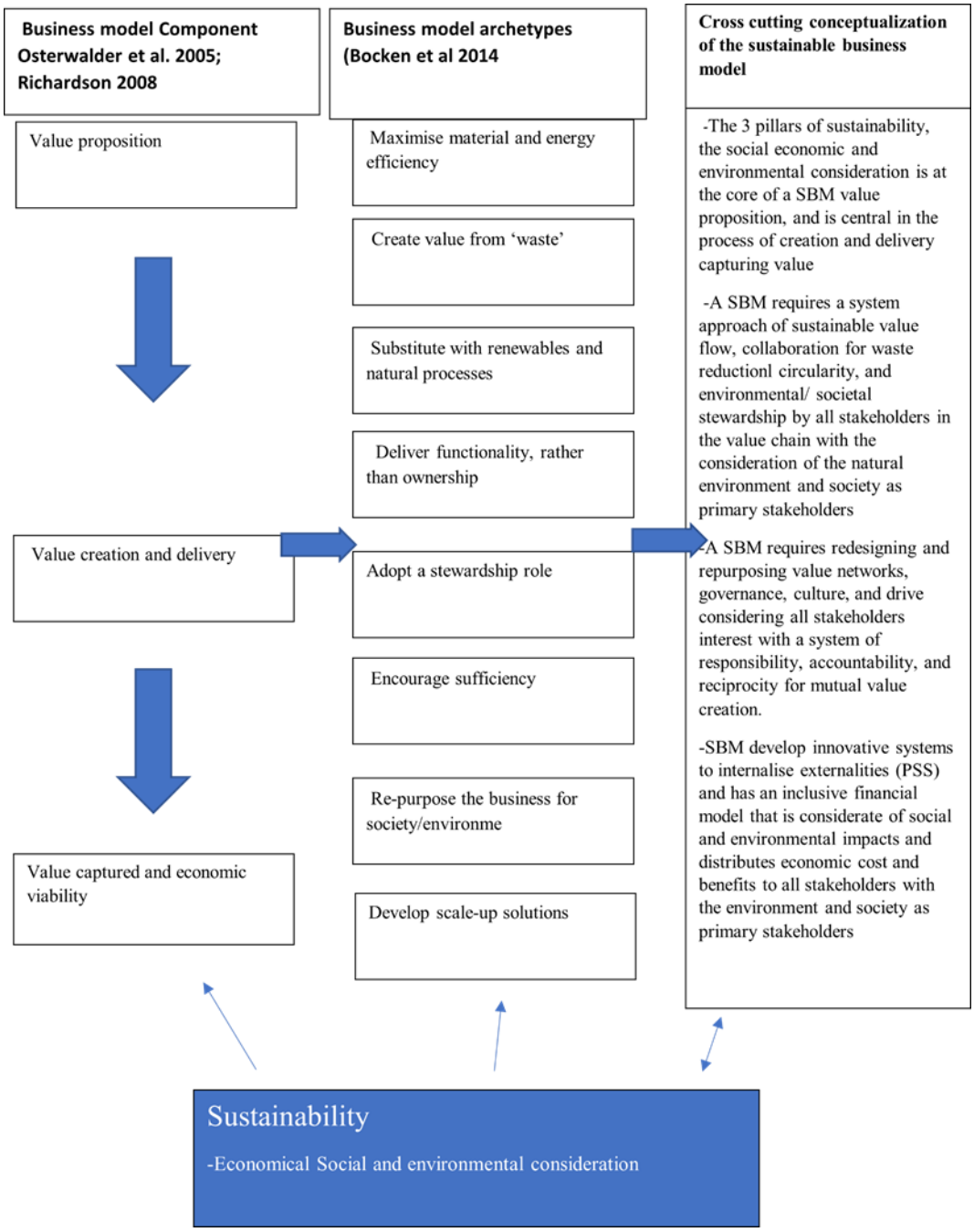

Figure 3 Synthesis of the conceptual framework

Thinking sustainably at each stage improves the process. As shown in figure 3 above, we Build-up from the (Osterwalder et al 2005; Richardson 2008) business model elements as a conceptual tool that expresses a business idea and follow up with Bocken et al. (2014) BMIS archetypes which are classic exemples or patterns

proposed by Bocken et al. (2014) for the understanding, evaluation, and interpretation of innovation in business that produces sustainability. We further explore the sustainable business model and its components as proposed by Stubbs & Cocklin (2008); Boons & Lüdeke-Freund (2013); Evans et al. (2017) which is an important milestone in the sustainability process. This frame will be used in chapter 5 to explore the business model of aquaponics in Sweden with the aim to understand the novelty in the business model of aquaponics in Sweden and how it can be interpreted as a business model innovation for sustainability.

3. Method

In this section we cover the method selected and description of the data collection process. The purpose of this chapter is to describe methodological choices authors decided to make and justify our research strategy.

3.1. Research design

According to Buckley and Chiang research methodology is defined as "a strategy or architectural design by which the researcher maps out an approach to problem-finding or problem-solving." Crotty (1998) concurs with that, describing research methodology as a comprehensive strategy that explains the choices of the author in regard to specific methods and the anticipated outcomes of these choices. Thus, the choice of research method is dependent on the type and features of the research problem being studied. For this research, the phenomenon the authors are interested in is aquaponics and the interest lies in understanding it thoroughly. Therefore, qualitative research is deemed to be applicable since it generates insightful data that has deeper meanings. The authors conducted both primary research which is done through qualitative interviews, collecting data through webinar and literature review which is the foundation for understanding the background of the study.

3.2. Qualitative Research

When conducting basic qualitative research, the goal is to discover and understand a phenomenon, process, and perspectives of individuals involved in that phenomenon (Sharan,2002). Qualitative data is collected through interviews

observations or document analysis. Qualitative research is also used to explore and provide deeper insights into real-world problems. Unlike quantitative research which deals with numerical data points, qualitative research helps the author to create hypotheses on situations(ibid). The authors conducted explorative qualitative research because aquaponics is not a well-studied phenomenon and its uptake as a sustainable business model is not fully understood. When exploring a phenomenon, it is that there is little or no scientific knowledge about the group, process, activity, or situation they want to examine but have a motivation to believe it is worth discovering (Stebbins 2001). Stebbins (2001) also added that in order to explore effectively in a given phenomenon, there should be must flexibility in looking for data and open-mindedness about where to find them. Thus, gathering insightful data and perceptions will allow the authors to understand the conceptualization of aquaponics as a sustainable business model.

3.3. Literature review

In order for the authors to be well informed and to fully understand the background of the problem in focus, a literature review has been done. According to Bryman, (2012) a literature review has the purpose to show existing research of the topic as well as how a study contributes to existing research and fills knowledge gaps. In this study, the authors reviewed literature on sustainability, innovation, business model, business model innovation, sustainable business model innovation. Specifically on aquaculture, hydroponics, and aquaponics from both scientific articles as well as renowned organisations and institutes to get state-of-the-art knowledge, these are presented in the literature review above.

3.4. Data Collection

When conducting qualitative research, it requires the use of several techniques in collecting data that includes interviews, document analysis, focus groups, and observation. To get a good in-depth knowledge of the topic mixing these methods can be beneficial ((Eisenhardt 1989). However, due to the fact that the focus of this study is business models in aquaponics which did not have enough data documented other than the technical aspect, the authors found interviewees to be a suitable method. The authors also used webinar that had researchers of the topic in panel discussion to collect data. Furthermore, Interviews may be structured, unstructured or semi structured, with open-ended questions on a topic where the interviewer adapts to the responses (Sargeant, 2012.) For this study a semi-structured interview is deemed to be suitable since it allows more room for discussion of the topic.

3.5. Sampling and unit of analysis

In research, especially in qualitative research, sample selection has a huge impact on the ultimate quality of the research (Coyne 1997). In the early stages of the study, researchers look for groups which they believe will maximise their chances of obtaining the data required for answering the research questions (Glaser, 1978). In this study, the authors used a purposive sampling strategy to select the sample for this research. The key to purposive sampling is getting access to key informants in the field from sources who know the subject well and can help in providing information-rich answers. For this research, the authors have selected individuals that are presumed to possess the knowledge in the aquaponics field by either direct involvement or indirect involvement.

These individuals include entrepreneurs who practice aquaponics, researchers who study the phenomenon, policy advocators, who work in the course of the aquaponics and what it can do for the world etc. These people were selected on the criteria that they contain knowledge on the subject and will provide insightful answers. These are the units of analysis for this study. Unit of analysis can be said

to be “the entity that is being analysed in a research” or what is being looked at in a study (Dolma, 2010). The level of analysis for this study is individual level as we interviewed 7 individuals who have insights about aquaponics and contributed to answer the research questions.

3.6. Semi Structured Interviews

For this research the authors conducted semi-structured interviews with 7 individual that comprise of researchers, practitioners/entrepreneurs as well as policy advocators in the business of aquaponics and SBMs. The authors prepared a set of questions as well as an interview guide for the informants, but also give the liberty to the interviewees so that they can speak their mind and develop their perspective if they need to. These means that the questions were open-ended questions, even though they had a set of structure to follow, we encouraged their discussions based on their views.

3.7. Introduction of the key respondents

The departing for this study was that one of the authors got internship last spring in a company that deals with RAS technology and has aquaponics related farming method. This company is formally called Nära &Naturlig and today is called Cresponix. The author was exposed to the idea there and to make case study on that company was first chosen. However, after consultation we realized that it will be too narrow since the company is fairly new and has not had any commercial business yet. We then searched information online and got to know 3 other companies that do aquaponics related business. Later, we attended a webinar and workshop on integrated fish and plant production organised by SLU aquaculture and SLU partnership Alnarp on the 27th of October with the aim being, “To present current knowledge and discuss what is needed to strengthen integrated fish and plant production in Sweden” (SLU 2021). The webinar had in attendance entrepreneurs, researchers and policy advocators for integrated fish and plant farming. At the webinar, some key respondents for this thesis were identified and

contacted. Other respondents were contacted using a snowballing technique based on the recommendations of the key respondents. Since the focus was innovative sustainable business models in regard to aquaponics, and there are not many studies done in this topic. Doing explorative study where we do individual analysis instead of case study was deemed suitable. In that case we could include researchers and policy advocators as they also take part in the uptake of this innovative system. Therefore, we selected seven individuals that were consisted of four entrepreneurs that run business in aquaponics or related system, two researchers, and two policy advocators (with one entrepreneur doubling as a policy advocator). The following individuals were the key informants for this study. We conducted interviews through zoom and google meet. The length of the interview took between 60 to 90 minutes. The interview guide is in the appendix.

Matthias: Works as CEO in Nära & Naturligt now called Crexponics. His company deals with tropical farming of fish in land-based system involving tanks by using RAS system and biofloc system. His company grows giant shrimp and Tilapia fish. There are no commercial success story for the company yet and they are working with pilot study in Södermanland near Eskilstuna. Mattias has been involved in this technology nearly two years now.

Håkan: Has worked in different roles with question of Sustainable agricultural systems in Sweden for more than 35 years. To name a few, he has worked with the Swedish board of agriculture for more than 5 years, has worked as a representative for Swedish horticultural industry, worked as a project leader with "Expansion horticulture" for more than 6 years. He is currently holding a position as a program leader at SSE-C Swedish Surplus Energy – Collaboration. He has worked with questions on integrated fish and plant production in Sweden for a big part of his career. He is now also a consultant with the municipality of Bjuvs on a pilot project with his company. His pilot concept is called Food Parks. Food parks has some similarities with aquaponics, the difference is that in aquaponics the fish and the vegetables are grown in the same house in what he terms "a more linear system" while in his, pilot concept, the fish and the vegetables are farmed in different houses to increase scale and reuse of resources.

Sammar: Is a researcher at SLU university in the department of biosystems and technologies. Her research includes “Cultivation in aquaponic systems regarding product quality, cultivation in low air and water temperatures” she has been a great help in establishing the definition of aquaponics and the difference between these systems.

Annie: Is a PhD student in Horticultural Science especially Business Administration at the Swedish University of Agricultural Sciences, the Department of Biosystems and Technology in Alnarp, Sweden. Her research includes adoption of knowledge and innovations in sustainable horticultural production systems. She was a great help in defining innovation and how that can be used in aquaponics.

Lisa: Works in a company called Joanna's Stadsodling that designs and operates circular food production in aquaponic. The company is a start-up and is based in Vallentuna near Stockholm. She was a former student of SLU, did her internship in this company and is a business developer.

Daniel: Is a cofounder and head of sales at Agtira. Agtita is the largest aquaponics operating business in Sweden, and it is listed in the stock market. The company is located in Härnösand Municipality in Västernorrland County and was founded in 1996. Agtira recently changed its value proposition from selling tomatoes and cucumbers grown from aquaponics systems to being a system developer. The company sells, service and operate aquaponics systems to supermarkets for them to grow fresh vegetables at their stores. Agtira has recently signed a contract and a letter of intent respectively with ICA Skelleftea and ICA Haninge (the largest ICA in Sweden) for these supermarkets to operate aquaponics at their stores.

Bengt: Is the Business coordinator in the municipality of Bjuvs and have been in that position for more than 10years. Bjuvs is a municipality with a long history of food production and agricultural businesses. He also doubles as the managing director of Swedish Surplus Energy Collaboration (SSEC). He has been working with questions on aquaponics, integrated fish and plant fishing and sustainable food production for about 8year both in Sweden and internationally

Below table shows the length of the interview as well as the date and the channel used to conduct the interview.

Table 5 Table of respondents

Respondent	Matthias	Håkan	Sammar	Annie	Lisa	Daniel	Bengt
Date	2021-12-08	2021-12-16	2021-11-19	2021-11-11	2021-11-30	2021-12-08	2021-12-14
Length/min	90	90	70	60	60	80	80
Channel	Google meet	Zoom	Zoom	Zoom	Zoom	Zoom	Zoom

3.8. Data analysis

The purpose of qualitative data analysis is to make sense of the data and the result, to facilitate understanding of the phenomenon being studied (Sargeant, 2012). After data collection, qualitative research could result in a large amount of data that is hard to understand. Therefore, it requires the data to be organized in a structured manner through transcriptions which may then be coded manually or with the use of Computer applications. After the data is coded, the result is synthesised and interpreted in terms of themes, theory or model development.

For this research, the authors collected data, transcribed it in English, since the interviews were conducted in English. We manually coded the data using repeated phrases, similarities and differences in the interviewees' response. We then use thematic analysis in interpretation and analysation. Thematic analysis contains patterns within data that is used for identifying, analysing, and reporting to make

sense of the data. (Braun & Clarke 2006). The themes have different headings, and the data has been organised according to similarities and differences as well as the patterns that were repeated in the interview.

3.9. Quality assurance

After data collection and analysis within qualitative research, quality assurance should be provided for the data collected. To promote rigor and quality of the research two things should be considered 1.) ensuring the quality or "authenticity" of the data collection and the quality or "trustworthiness" of the analysis (Sargeant, 2012). Unlike quantitative research which uses validity and reliability to ensure quality, qualitative research uses Credibility, Transferability, Dependability and Confirmability to ensure quality and rigor (Shenton 2004).

3.9.1. Credibility

One of the key criteria of a good research is that of internal validity, in which the author seek to ensure that the study measures or tests what is actually intended to measure. The equivalent concept of internal validity in qualitative research is credibility which deals with the question, "How congruent are the findings with reality?" (Shenton 2004). One way the authors ensured credibility in this study is to employ procedures that align the study with the line of questioning pursued in the data gathering sessions and the methods of data analysis. The questions were asked in easy and understandable English, there were enough time provided for the interviewees to answer questions and they were ensured anonymity if anyone would like that, however, all the respondents were comfortable in been used for their first names and were okey with being identified.

Triangulation is also another way to ensure credibility as it involves the use of different methods for data collection (Shenton 2004). Triangulation is implemented in this study by choosing different sources in collecting the data, with practitioner who have practical knowledge in the field, researchers who are passionate about

the topic and policy advocators who are working with questions that govern aquaponics. The authors also attended a Webinar about integrated fish and plant farming that was held in Zoom 27/10/2021 organised by SLU aquaculture were key actors in aquaponics in Sweden were in attendance. This webinar allowed the authors to attain information as well as key people to contact to collect background information of the different components in the field of aquaponics. We also used literature review and many articles in the field of aquaponics, BM, BMI, BMIS and SBM were read, analysed and synthesised to give the readers an understanding of the topic.

3.9.2. Transferability

When it comes to external validity of the research the concern lies to the extent to which the findings of one study can be applied to other studies. Generally, the findings of a qualitative project are case specific and apply to a small number of environments and individuals, thus it will be impossible to demonstrate that the findings and conclusions are applicable to other cases and populations (Shenton, 2004). Therefore, the authors in this study do not intend to generalize the data to other populations other than that the study concerns. The study concerns aquaponics in Sweden and the cases drawn here are individual cases that cannot be used to generalize a larger population.

However, transferability in a population with similar characteristic as Sweden may be possible. Also, BM, BMI and SBM concepts are general concepts in business. Meaning, this research on how innovation in the business model of aquaponics can be understood as a SBM and can contribute to sustainable food production may act as a learning curve in exploring other innovations in the aquaculture and agricultural sectors.

3.9.3. Dependability

When addressing the issue of reliability in a research, the authors employ measures to show that, if the work were to be done again, provided that same context, same methods and the same participants were applied similar results would be collected (Shenton, 2004). The authors applied dependability by carefully designing the research and its implementation and by thoroughly describing what was planned as well as how it was executed and if that aligns with the study. The operationalization of the study was made clear to the reader throughout the introduction, conceptual framework and the method.

3.9.4. Confirmability

When discussing confirmability in qualitative study, it is the qualitative investigator's concern to state objectivity if the authors were free from their subjective views (Shenton, 2004). For this study, the authors hold an objective view throughout the study by taking steps such as interview guides, transcriptions for the interviews to help ensure as far as possible that the findings are the result of informants' experience, rather than the characteristics and views of the authors.

4. Empirical Findings

In this section, the authors combine and present the empirical data that have been acquired from the interviewees. We explore the business models of aquaponics by interviewing researchers, practitioners, and municipality official (policy advocators). The compiled results are divided into themes that were developed from the transcripts concerning similarities/differences and patterns that were noticed between the interviewees. These themes are

- *value proposition and innovation*
- *value captured and economic viability*
- *Sustainability in aquaponics*
- *Challenges and opportunities*

4.1. value proposition and innovation

In this theme, the interviewees were asked about what is innovative about aquaponics and what is the value proposition of aquaponics. Interviewee Håkan was asked about what is innovative about aquaponics and his answer highlighted the circularity of the system as quite innovative stating that "*it is a huge and important step towards a circular production that means that you are connecting one type of production with another production…use waste streams for things that you cannot use otherwise".* He, however, highlighted that ". *aquaponics is one step in the right direction but it is not the complete system*". Interviewee Sammar furthered elaborated on the innovation of aquaponics by saying, "*Yea I mean aquaponics is an innovative system. When we close the systems, we reduce the environmental impact that is associated with aquaculture and hydroponics system on one part, another part is that, it can be used in different scales both as*

commercial production and local production and has the potential to enhance food production since we are cultivating two different kinds of food production, fish and vegetables". Interviewee Bengt added that *"the technique of producing fish in closed systems has been around for more than 1000 years. Today, we have a very good technique with how to take care of waste streams in closed systems, how to make use of residual water, how to make use of by-Products from the fish, how to produce new things out of the uh, what was, yesterday's waste".*

Interviewee Matthias, however, indicated that aquaponics is a technology that produces more vegetables than fish stating that, "*aquaponics systems have maybe a 1:5 to 1:10 ratio of fish to plants making it more productive for plants than fish"*. He adds that, however, aquaponics can be good in a market with a high demand of plants or to produce a unique plant that will be competitive in the market. When it comes to producing the products that are already competitive in a market aquaponics is not yet competitive.

Interviewee Matthias further explains the RAS technology and the place his technology and aquaponics fit in it. He also introduces his technology called Biofloc technology *"RAS technology is a recirculating aquaculture system; it is a word for every land-based fish farming that has the goal to use as less water as possible*. He introduces his pilot system with added features to RAS and aquaponics stating that, *there are different leading technology like aquaponics in the market. Ours is the biofloc technology. In RAS technology you have different biofilters that clean the water. In Biofloc technology we have biological filters; microbes and algae that eat up the residual product in the fish farm the cleaning system"* Matthias further explains the difference between the value proposition of his system to aquaponics stating that, *"Aquaponics is good it reuses a lot of organic waste,* He added that the limitation of aquaponics is that the fish feed that dives the system is unsustainable as it is gotten from the sea. He introduces his technology called the biofloc system that is a system with biological filters and microbes and algae that food on the waste in the system then the fish intern feed eats the algae reducing fish feed added to up to 30%. (*see Q1 in appendix).*

Interviewee Håkan also identifies some lapses in the value of aquaponics' value proposition and introduces a novel technique which he is leading to further innovate the aquaponic system and make it more circular called food packs. He explained that "*aquaponic is still a linear system. In aquaponics you have fish and plant production system in one building and the waste, organic materials and wastewater in the system is carried away in cars to get rid of or put in sewage system or destroyed. This is a linear system this is not circular this is the kind of system we have all over in our society today*". Food parks on the other had according to interviewee Håkan offers a better way of closing the loops. He explains the system to be a system that fish, and plant are cultivated in different houses with a maximum reuse of waste. The fish will be produced in one house, the organic materials from fish skin will be reused as leather and the wastewater from the system will be transferred using pipes to waste-water magazines to be used to water plants in the field or in green houses. Thereby, using the waste in one system in another system in a more circular way. Optimizing the economic value of waste. However, Interviewee Håkan admits that the food parks idea is a concept that is still being developed with already tested techniques in aquaponics, but it is not a functional concept yet. Interviewee Håkan further explains that *"…. this is a new concept as I told you and the technique that we involve is very well known to us so we don't hesitate to say that it will work*….".

Interviewee Sammar however clarifies that even though there are many types of RAS systems what qualifies as aquaponics is a RAS System where nutrients are shared between plants and fish in a recirculating manner "*Because a principle of the aquaponics is the recirculating between the two systems so that the nutrients move around… you need to have the recirculating streams between the hydroponics systems and the aquaculture…. to have an integrated system for aquaponics you need to have nutrients circulated all the time between the fish tanks the RAS system and the hydroponics. You have the biofilters that you can reduce the amount of nitrogen or ammonia in the system and enhance the nitrogen to be turned over to nitrates that can be taken up by plants that is the principle of aquaponics*". Also , interviewee Sammar talking on how aquaculture can benefit from aquaponics said that "*aquaculture system can benefit from the aquaponics through the reuse of the*

*nutrient because when we are recirculating the nutrient in RAS system can be reused and utilized by the plants…we can benefit other kind of microbes that helps reduce fish disease, because there are some studies that show integrating these two systems can have an effect to reduce fish pathogens in the system, but it is not yet proved and more research is neede*d".

We also asked interviewee Sammar about the ease in the uptake of aquaponic as a Business model in the Swedish market and her response was "*Easy it is not since it is not been applied on a large scale, we have to solve many factors that bring complexity to the system, the nutrients part is one aspect to solve, the microbes and the pathogens are also another aspects so there are different aspect to be solved before it is applied*" interviewee Samar, however, stated that there is a need for better collaboration between research, policy and practice engender the growth of this sector.

Sustainability and sustainable food production were highlighted by all interviewees as the main value proposition of aquaponics. When interviewee Lisa and Daniel was asked about the value proposition of their organization, they had this to say; Interviewee Lisa answered saying "*the founders, they wanted to do something for sustainable food production so that is the core idea .. sustainable food production and resilience food production that can handle climate change*". About their unique selling point, respondent Lisa made a comparison to green houses and hydroponics saying compared to the greenhouses of growing in soil, their aquaponic systems have high water reuses, zero nutrient leakage to the surrounding environment and lower or equal electricity cost. Compared to hydroponics the nutrients are usually mineral sourced or chemically created nitrogen with a high climate impact whereas their systems offers a nutrient loop ecosystem so "*comparing we think that from sustainability and efficiency perspective it's way better".(see Q2in appendix)*.

Interviewee Lisa also highlighted the shorter chains as a major part of their value proposition *" big part of it is that we want to be close to the customers and have as short transport chains….we don't really see if we are making the case that something that has been in a truck from Spain for three days is inferior then we can't really do that ourselves and put it in a truck for three days ….wherever there*

is people that will be a demand for food So what we do need is really good source of electricity and good water and if we had that then we could place it anywhere.

When Interviewee Lisa was further asked about their target market, she answered saying she said their target market at the moment is high earn restaurants as they demand sustainable and fresh products later, they intend to target supermarkets and private customers later. Lisa added that main value proposition is sustainable, no pesticides fresh product *(see Q3in appendix).*

Lisa said they are planning to scale and use automated systems *"the big plant that we are planning for now should we say the first full scale that would be producing 50,000 plants a week and two and a half million plants per year*".

About innovative ways of using waste interviewee Lisa also mentioned that *"concerning waste yes we as I said investigating the possibility of using green waste to raise insects …. research indicates that is very possible to use it as fish feed"* she said the system will always have a level of waste, but they are looking at west to maximise the waste use. Also, she mentioned a pilot project to add blue mussels from the biotic sea into fish feed *(see Q4 in appendix).*

Interviewee Daniel also explained their value proposition indicating that they have changed their value proposition from last year to producing and selling the products from their aquaponics systems to being system providers and operators from 2020. Daniel talks about their company and how it has changed, *"The old BM is that we are selling to this market tomatoes and cucumbers from our own farm in greenhouse".* He said the new BM of Agtira is to sell stems for supermarkets to farm their own vegetables in their packing garage and sell services to operate these systems for the supermarkets at their store, so they are a system developer and systems operator *(See Q5 in appendix).* He also mentioned fresh sustainable products as their unique selling point. He said farming at the parking lot of the super market is an innovation to the BM that has not been done before and Swedish customers are supportive to product "farmed in Sweden" *(see Q6 in appendix).*

Interviewee Sammar also mention something important about the ease of diffusion of aquaponics innovation into the Swedish market, Interviewee Sammar said that it is not easy given the complexity in the system, the pathogens and nutrients are an important part to solve and needs more research for easy uptake. (see Q7 in appendix).

4.2. value captured and economic viability

In this theme the interviewees were asked the value captured and economic viability of aquaponics in Sweden. All interviewees agreed that in Sweden right now, aquaponics is not economically viable, but it has promising returns in the future. All respondants agreed that economics is an important part that needs to be highlighted in an aquaponics BM. Interviewee Håkan stated that *"…. it's not easy to find good examples of aquaponic companies that is really working as a business model with a viable economy*". Interviewee Mathias had similar views saying, "*As of today, i dont know of any aquaponics business that is successful in the EU. For example, one of the early developers in Sweden, because of the high cost, they have changed their BM to a technology developer because of the cost of production and it is hard to compete with higher cost*. Interviewee Annie added that the entrepreneurs are positive but the business model itself is not yet viable *", but I think it's also a bit difficult because when you talk to these new firms, they are really positive and say we make so much money. But then you check the record and there you see…they don't earn anything…. entrepreneurs they are really positive, and they think everything is going so well… I mean they are Selling their ideas and there is potential for the future".* Interviewee Sammar agrees by saying that "*I think the economical part needs to be highlighted, it is an important aspect because you need a profitable business and that aspect to be shown as a good system because environmentally there are some works that has been done*".

On economic viability, interviewee, Daniel and Lisa were asked about the economic viability of their business model and they had this to say; When Interviewee Daniel was asked if they are breaking even he said "*We are not*

breaking even. But we are pouring so much into development, so, I mean, it's like Tesla they started breaking even about a year ago, and not all their cars are presently breaking even ..they pour a lot of money into development and that's what we are doing so no, we are not there yet". Interviewee Lisa answered the same question stating that "*We do not break even at the moment the pilot was never really designed to be profitable anyway but rather to gain early traction and financing"*.

Interviewee Håkan expands on economic viability by stating that independent systems of fish and plants optimized have better economic viability than combined in aquaponic as of today he says, Fish and plants produced separately and optimised using fertilizers etc is more productive and viable compared to aquaponics today *(see Q8 in appendix).* "Håkan and Bengt further highlights that the scale in aquaponics is an important factor in the economic viability. Interviewee Bengt stated that "*There, there are a proven to work techniques stand alone and we try to put them together and, uh, as I said in small scale it works and we need to scale it up*". He adds the businesses need to scale to gain economics of large scale and attract investors. Also, customers may want sustainable products but can't afford the premium price. *(See appendix Q9).*

Interviewee Håkan illustrates the scale advantage by giving his projections and also highlights the week point of the production cost as feed (*see Q10 in appendix for cost projections).* Håkan also mentioned that even though the scale is important the production in Sweden is there yet *"and even if there is some return on investment, we are looking at good margins, it would take time to get there as it requires scaling up"*.

Respondents Håkan, Bengt, Lisa and Matthias (both the practitioners and the policy advocators) mentioned permits a major concern in scaling up aquaponics as it takes about 5-10years to get permits for large scale aquaponics from 5 different agencies as there is no one agency that handles aquaponics questions. Interviewee Håkan and Bengt said with they discuss these questions with the authorities and government they tell them these things and they agree there is a problem but because of the scale of aquaponics, the lack of understanding of the aquaponics by the authorities and

lack of a central department for aquaponics, the legislations to promote growth in the sector is weak and unfavourable. *(See Q11and Q12 in appendix).*

When asked how they capture their value, Interviewee Daniel and Lisa had this to say; Interviewee Daniel stated that the have increase their value captured by taking out the middleman and building plants directly at the super markets *" Yeah, because if you have this cost on the product but then you take away all the other costs of the chain , you will still have the same product or a much better product at the same price and you think OK…Because the product is so good you think it will cost more no it will cost more than the import yes, but it will not cost more than organic or it will be affordable for customer and still a good business for the supermarkets"* Interviewee Lisa`s answer to the same question of value capture was *"that "High-quality products with environmental values gives good willingness to pay and satisfied customers"*.

Interviewee Matthias answered the same question about the value-added stating value captured in aquaponics favours plants than fish. "*You need maybe 1:5 to 1:10 in hectare farming for fish to vegetables so the fish won't matter anymore and slowly turn into vegetable producer, I would say that today aquaponics is a vegetable farming technology" (see Q13 appendix).*

About financing the interviewees Daniel and Lisa (the practitioners) had this to say; Interviewee Daniel stated that they are on the stock market and did not mention any financing problem even though he mentioned that they are now investing in development. Interviewee Lisa, on the other hand, stated that Sweden is supportive to start ups but, investors are not use to food tech, so the financing is slow. She mentioned that the length of time it takes to get permits is too long, a limiting factor and demotivates investors. *(See appendix Q14).*

4.3. Sustainability in aquaponics

In this theme, the interviewees were asked a set of questions that have the concept of sustainability in their framing to find out what their perspective is when it comes to sustainability in aquaponics. The first questions asked in regard to this theme is

their perspective on sustainability in aquaponics and if that influenced any changes to their business model as well as how aquaponics is perceived today. According to the respondents, sustainability has indeed influenced how business in general is operated today and the whole technology of aquaponics is founded in the idea of creating efficiency and making the product unit more useful and sustainable. When asked interviewee Matthias about his company's stand he said *that "We see as both personal and company goal to be a big enough player of the food sector worldwide so we can have influence towards creating sustainable food alternatives. Not every food producer has sustainability as their agenda but so far, we put the sustainability impact as our number one goal, and we will continue to do that"* Interviewee Håkan holds the view that it is a step towards right direction.

However, 2 interviewees, despite the fact that they think it is a step in the right direction, still have concerns on the extent it is sustainable. For example, interviewee Sammar, a researcher on the topic still believes that there is some more research needed in that area to prove the changes in the business model is indeed sustainable. Another interviewee , Interviewee Bengt agrees to that fact and thinks that it is fairly sustainable but to fully say it as a sustainable business model a more collaborations are needed in both research and practitioners so the technique can work *"As I said before, Agriculture and horticulture today can be a fairly sustainable, but can be more sustainable, and if they collaborate and take use of each other, To take one step further and be even more sustainable if they go fully aquaponics and close all the loop but As it is of today, it's still an immature business and the techniques aren't that that good as it is now".*

Following that, since they mentioned the circularity of the technology and the system of using and reusing, the interviewees were asked if they substitute production processes with renewable and natural materials that has less effect on the animal and plants as well as maximize material and efficiency in the production processes. Interviewee Lisa thinks the concept of aquaponics is based on maximising both material and efficiency. In that regard she said that *"the water is looping, the nutrients are looping an I mean I think that just the whole point of aquaponics is to do this so I mean and that is way different from if you're looking*

at typical aquaculture 1K feed yields 1kilo fish and a lot of environmental pollution whereas we instead of environmental pollution gets 10 kilos of vegetables I think that is efficient comparatively to not let those nutrients go to waste but to use them as a value instead of pollution". She even added that the electricity for the farm is all from a renewable source and the only thing that isn't is the emergency back up, and it is never used unless it is necessary. Interviewee Matthias also mentioned that the feed they are giving to the fish is renewable and helps them reduce buying unsustainable feed from the open sea for the fish. When explaining how they reuse the feed interviewee Matthias said that *"30% of the feed of the fish is bacteria and algae from the residual product which humans cannot eat and the goal of the company is to further develop and add insect farm so 100% of the feed given to the fish farm is produced from the bacteria and insects produced from the residual product and that will make our system circular"* He further explained that for them to manage and reuse the resource they have, they create a biological trap, where they have the total energy and nutrients in a feed eaten by the fish and that recirculates by going through the fish, then the fish faeces is eaten by the microbes and algae inside the water and the fish will eat the microbe again, creating a biological loop. He said, "we reuse the feed and the energy the same amount of energy can go through the digestive track of the fish many more times than any other fish production methods and that is why we reduce 30% feed use in our system, because we utilize 30% better of the energy and water".

The interviewees were also asked about environmental sustainability and if there are gaps in their value creation process and their current business model that are maybe destructive to the environment as well as how they handle waste from their value creation. The interviewees pointed out that sustainability has three aspects and each one of them is equally important when it comes to value creation. Interviewee Sammar, mentioned that environmental sustainability has been highlighted far more than the other aspects when it comes to aquaponics and the technology is based on that dimension, and even though there are some studies that show there is an efficient use of nutrients and waste management in aquaponics when it comes to clear evidence to say aquaponics is better than aquaculture in all aspects of sustainability, she still thinks that more research is needed in that.

Interviewee Matthias however, discussed the general problem faced by aquaculture today he said *"There is a big sustainability problem in the aquaculture especially in developing nation, the fish and the shrimp farmed 50% of it dies and with this process we can get almost 100% clean fish and shrimp. Fish and shrimp markets are growing super-fast and we cannot increase fishing from the ocean because the last 30 years the same amount of fish has been farmed from the sea and the whole world is screaming for solution which we can provide"* Interviewee Matthias also added that despite the fact that there are some solution they can provide, there are still some issues relating to waste management in their systems. He said that *"the feed still has some waste that we did not manage yet and there is co2 that is still leaking even if it is much less than the other animal farming. Feed will always have some residual waste and that is why we want to do 100% feed that is produced from residual product, the higher the nutrition we want the feed the higher waste and the quality will be higher, and the environmental impact will be higher, and the question can humans eat the feed, that is a sustainability issue too because we want a feed that humans cannot eat".*

Interviewee Lisa also agreed to that notion that even though they do have some waste management skims and they collaborate with other companies in managing waste, there will still be some waste that will be released from their value creation.

4.4. Challenges and opportunities

In this theme, the interviewees were asked a set of questions regarding the challenges and opportunities they face in their current business model and in aquaponics in general. The first question asked in that regard is what they see as the barriers that didn't allow for the adaption of the business model in many places as well barriers in scaling up. A universal response among all the respondents is that a broad range of knowledge is required to understand and implement the multidisciplinary concept of aquaponics. To fully comprehend the concept of aquaponics covering all interrelating issues, and to apply it on large scale, they need support from all institution that are concerned with this.

Interviewee Sammar also added to that and mentioned that aquaponics is a complex system to be applied in large scale as there are optimized requirement for the fish and the plant and other components like the bacteria and all the nutrients that need to be balanced. She said that *"I think it is a complex system. And we are talking about production system, we are talking about products with higher quality and that is sustainable and has a high competitiveness potential. For example, if you want to produce tomato, this tomato has to compete with existing tomatoes and should be better than those tomatoes in some way or another".*

Interviewee Håkan also concurs that when it comes to scaling up, it is one of the weaknesses in the system because the feed is costly and unsustainable. While showing the projection in their company he said *" that if you look at the projection actually (showing a picture of a projection a salmon production using DNS (dynification system) 10 tons of fish every year in a house the cost is estimated to be 50 kr , to produce 1K of salmon requires 11,mil feed that is 32% of the total cost of the fish and that is the weak point of this system in cost-wise and because the feed is not sustainable and it is a lot and it comes it from the open sea, to make more circular we have to replace it and make something else, it also requires a lot of electricity, and energy prices are rising".* However, he mentioned that when it comes to the projection in large scale it actually reduces the cost but still unsustainable. *"But if you scale it up the cost decreases so this kind of production system it is much easier to calculate and control the cost and impact on nature when it is a large scale, and we think about not just as aquaponics but multi-use and reuse of waste streams and this is the idea we work with*". He added to that the other main challenge they faced is also to make the market understand what they are really doing and trying to make the market understand the kind of product they are offering which he thinks is preventing them to scale it up.

Interview Matthias when discussing the challenges mentioned that there two problems in aquaculture when it is land based, the feed and health of the fish, and that is not solid in aquaponics yet. "there is still big risk for health as bacteria can easy filtrate the fish and kill and the feed that you give to the fish is not sustainable today " However, he also mentioned that they are working with an alternative

technology that can reduce the risks called " Crexponics" a further developed RAS technology. *"that is what our research does, with our technology we can get sustainable feed with superior health of fish as they are together with algae that can naturally boost their immune system. So, it decreases the sustainability issue of farming shrimp and fish as well as the feed consumption by 30% because they eat the microbes from the residual, and it also leads to less economic cost from the feed and there is a quality benefit as they eat vegetables and you are what you eat".*

Following with that the interviewees were asked challenges regarding the surrounding environments for example when financial systems like banks. Interviewee Lisa stated that they do get some support from some instutiions like that they have been in contact with STING incubator for start-ups in Sweden and that they have been part of their incubator which helped partly with investors. *"Our CEO spends a lot of time looking for investors, so I would say that there a lot of organisations that supports us in Sweden, the only thing I would say is that agrotech or food tech which ever category we are put is sort of new to Swedish market whether large investors or venture capitals because in Sweden innovation is more of software apps, digital services and so for them to see us we want to build something and we want to borrow investment so I would say Sweden does support startups but Swedish investors are not use this kind of innovation that we are dealing with and that can be a challenge*".

The same challenge was also mentioned by interviewee Matthias agreeing to the fact that it could be challenging to get investors on board on something that you don't have a successful story yet. *"we wanted to do a license model, but it is hard to do a license model without having a successfully running business to prove it. The IP was also an issue, should the IP be owned by the company, a separate company or the investors. We wanted to do license because of the need of the world for this technology, and through license it go faster and far places with mega impact, the scalability is great with license.*

The other question we asked the interviewees in regard to the challenges is if the policies in the Swedish market can also pose limitations. All the respondents agreed to the fact that there is limitation when it comes to the policies with in the Swedish

government. Interviewee Håkan claimed that the government does not show interest and does not support this technique as they should as there is no enough support when it comes to allowances and licences for the small companies that want to develop this technique. *"They don't promote, and it is more so in the company we are involved, it can take many years to get permissions and that is inefficient and there are two that are responsible, "länsstryelsen and kommunen". We have many companies that were trying to get their permissions but still didn't get it. They can spend millions but still may not get the permission, there are no banks that want to spend money without permission and that is a huge difficult".*

Interviewee Matthias also agreed to that notion mentioning that the government is not updated and doesn't differentiate their technology from the old aquaculture. *"it takes 1.5 years for anyone to get a go head to start a fish farm and RAS approved, they evaluate the sustainability by the amount of feed and they don't look at the data of residual reuse and what comes out of the feed is being used. So they cant see a different between us and other methods and that is a challenge"* Interviewee Lisa also added to that and mentioned that Swedish policy is super complicated generally very slow to change and not very supportive of innovations of this type *"so for example even though we have essentially zero pollution we're still categorised as environmentally dangerous activity because within fish farming there is no specific category for land based closed loop systems, so for the authorities not that when we talk to them they do think like that but in like what check boxes do we fall int, we fall into the same category as those who have fish in the open sea and the fish just pollutes right into the into the lakes and the oceans and that is just like crazy that we would be put in the same categories".* She also added that permit, especially environmental permits are complicated and take a long time to get. *"There are like other similar systems that have been waiting 8 years to get their permits when you know we couldn't wait years that's not going to happen we then the company is not going to exist anywhere because we have to get started*".

Interview Bengt also agreed to that mentioning the legislation needs to be updated to the techniques that are available today. He added that the legislations used today were written long before this was known as a technique. He mentioned that the

technique is known to the people, and everyone is talking about it as well as writing about it. *"I would say there isn't a municipality or region that hasn't written in their visions or policies that you should be, supportive of the sustainable production models, and then they talk about innovative aquaculture. They talk about the need to rise our self-sufficiency in the food sector. And then there is a lot of money going to research. But what's lacking still, is the legislation is still working against this development or transition***".**

The interviewees also discussed the opportunities they associate with aquaponics today and the future. Interviewee Sammar stated that she sees aquaponics today as a way the aquaculture system can benefit from through the reuse of the nutrient because when recirculating the nutrients in RAS, it can be reused and utilized by the plant, reducing electrification and she added the *" they can benefit also through the other microbes that helps reduce fish disease, because there are some studies that show integrating these two systems can have an effect to reduce fish pathogens in the system, but it is not yet proved and more research is needed".*

Interviewee Håkan also mentioned that the scale question could be used as an opportunity as well. *"The world needs a big scale, and that can be done in different ways like if there are many small scale companies that are all producing it will mean big scale production in total".* He added that for instance, in Thailand, there are many people living in the countryside and there are a lot of many small scale farmers producing fish, that means thousands of farmers are producing in small scale, this means there will be substantial produce of fish in total. *"If we only rely on big scale production, there is no back up if something goes wrong. If one big ship is destroyed in transportation, there will be a food shortage. So small scale producers are the backbone of the food supply even if we need big scale for our economy so we need both so we cannot expect one big aquaponics to cover it all".*

When discussing the opportunities, interviewee Matthias mentioned that he sees benefit of farming shrimp and fish per hectare than growing vegetable in the future as growing vegetables take so much space and resource. *He said that "You need maybe 1 to 10 in hectare farming so the fish won't matter anymore and slowly turn into vegetable producer, I would say that today aquaponics is a vegetable farming*

technology, you apply it if you have a market for veggies. In this other system we use we could divide by using 1 hectare for vegetable and another for bioreactor and so we could produce both vegetable and feed for the fish and it will balance".

Interviewee Lisa sees an opportunity specially for her company when it comes to Sweden as the Swedish/Stockholm (local market) consumers are generally conscious about sustainability issues which is a good starting market for them.

5. Analysis and Discussion

In this section, the empirical data is thoroughly analysed and discussed based on the theoretical framework to get insights and answer the research questions this study seeks to understand

5.1. Understanding aquaponics as an innovative business model

5.1.1. Innovation

Innovation is the successful marketing of an invention according to (Boons & Lüdeke-Freund (2013), therefore, aquaponics is no doubt an innovation but to answer the question of how innovative the aquaponics business model is it is necessary to look at the types of innovations proposed by different authors and where aquaponics fits. Björkdahl & Holmén (2013); Rowley et al. (2011) discusses four types of innovation, positioning innovation, the paradigm innovation, product, and process innovation. According to Damanpour (1987) discussing innovation and its different forms is essential to the development of theories of innovation in business.

Positioning innovation is positioning a business in a new way in the market to attract customer attention or reconstruct customers perceptions (Björkdahl & Holmén 2013). Aquaponics could be seen as a position innovation because of the new values proposition it offers. Drawing from the interviews all interviewees agreed that aquaponics is an innovation for sustainability, so aquaponics is positioned in the Swedish market as a novel system that engenders sustainable production, shared nutrient streams, less water consumption, and less waste to the environment. As stated by interviewee Håkan "*it is a huge and important step*

towards a circular production that means that you are connecting one type of production with another production…use waste streams for things that you cannot use otherwise". Sammar agrees saying that aquaponics is an innovative system that closed the system, reduces environmental impacts, can be applied in different scale commercially and locally, can be used to produce both fish and plants increasing sustainable production of both plants and fish. Aquaponics has positioned itself in the market as an innovation for sustainability by capturing the value missed or destroyed as prescribed by Bochen et al. (2013) of both hydroponics and the aquaculture BMs. Positioning itself as an innovation for sustainability. However, there is still room for improvement of the aquaponics business model as it is augured by respondent Håkan to still embody elements of linearity. All respondents agreed to the need for more research in aquaponics.

As a product innovation, the BM of aquaponics is seen to have improved product characteristics by combining hydroponics and aquaculture to produce a hybrid model maximizing the value missed in both systems. According to Björkdahl & Holmén (2013); Rowley et al. (2011) product innovations are new to the firm providing new offering or products with new characteristics or services to the customer. All respondents agreed that aquaponics offers a dual product of fish and vegetables that individual systems do not. Also, Sammar mentioned that aquaponics systems are sold at both commercial and local /home scales offering the opportunity to have freshly farmed products at both levels. Aquaponics offers fresh products with no fertilizer farmed using nutrients from the residuals of the fish, shorter supply chains and thus fresher product (respondents, Lisa, Sammar & Daniel). The enhanced characteristics of aquaponics systems that recirculates water offers a production system with more efficient water use. Nonetheless, the system is argued to be technical and complex to operate as the microbes and the pathogens managements in the systems may be complex and underdeveloped with more research being needed in those area *(*respondent Sammar).

Aquaponics is seen to be a process innovation by adapting the processes from the two systems of aquaculture and hydroponics as discussed above and corroborated

by all respondents. According to Swann (2009), process innovation focuses on the internal flow of information. According to Traill & Grunert (1997); Rowley et al. (2011) process innovation is an innovation to improve competencies and operations aimed at reducing cost. The aim of process innovation as discussed by the authors is the adoption of new technology usually to improve competitiveness of an organisation (ibid). The combination of the processes of hydroponics and aquaculture into one hybrid system that is aquaponics reveals aquaponics as a process innovation. All respondents agree that the aquaponics is a novelty in the combination of the process of aquaponics and aquaculture. Lisa stated that compared to greenhouses aquaponics uses less or equal energy in a dual system and compared to farming in soils aquaponics uses less water as water is recirculated in the system. Also, the use of external plant growth enhancers is minimised as aquaponics uses the nutrients of the fish system. This is also corroborated by all respondents. However, taking Traill & Grunert (1997) discussion of process innovation into consideration the enhance processes are cost saving in water and nutrients but expensive in technology and needs to scale to attain economic viability (all respondents).

Aquaponics is seen to be a paradigm innovation, as it makes provision for the use of waste streams in ways that were not possible before the innovation. It is true that fish farming is a process that has existed for thousands of years, but aquaponics is revolutionary and has shifted the paradigm of waste in aquaculture. There are growing and evolving ways of making use of waste in aquaponics systems. This is corroborated by all the interviewees. Björkdahl & Holmén (2013) argue that business model innovation is a "new integrated logic" of how the firm creates and capture value. He contends that BMI is not just limited to the types of innovation but revisiting the process of proposing, creation and capturing of value by the firm. Aquaponics is seen to not just be limited to an innovation category but a complete shift and restructuring of a new BMs based on solving the limitations of the BMs of aquaculture and hydroponics.

5.2. How can aquaponics be understood as a business model innovation for sustainability?

All Respondents agreed that the aquaponics value proposition offers a more sustainable use of resources and nutrients in closed recirculating systems where the waste the fish production is used as nutrients for plants. Bocken et al. (2014, p.44) defines BMIS as "Innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its value network create, deliver value and capture value (i.e., create economic value) or change their value proposition. The BM of aquaponics has the potential to significantly great positive value in sustainable food production if scaled up (all respondents). However, aquaponics is seen to have several areas that can be improved on as seen in the analyses in table 7 (see table 7 in appendix 2.) Aquaponics also reveals characteristics of SBMI by Geissdoerfer et al. (2018, p.407), as aquaponics is seen to prompt the development of what may be conceptualised as an entirely new BM having characteristics of both the hydroponic and aquaculture business model. The table 7 in the appendix discusses aquaponics value proposition, creation /delivery, value captured and economic viability using the data gathered from the interviews and Bocken et al (2014) archetype as a road map to further understand the BMI of aquaponics and its conceptualisation as a BMIS.

5.2.1. Value Destroyed value missed and value opportunity of aquaponics

Some interviewees however mentioned some value missed and value destroyed in the aquaponics system. Bocken et al., (2013) suggest that value destroyed, or value missed could be converted to value opportunity for a sustainable business model. Interviewee Håkan stated that "aquaponics, as it is today, is a linear model and not a circular model" and the waste of the system still needs to be carried away by cars and dumped. This indicates there is still room to take advantage of the value missed in the BM value proposition of aquaponics to make it even more sustainable.

Respondent Daniel explains his company`s experience of optimizing value missed in their value proposition in bypassing the wholesaler and selling directly to the supermarket. Consequently, taking advantage of the value missed in their original business model providing fresher products at better prices.

Besides the individual BMs, aquaponics as a production system has some value missed in its value proposition that is being taken advantage of by other systems as shown in table 6. For instance, the systems presented by interviewees Matthias and Håkan that are a form of hybrid of the aquaponics and RAS where the limitations of the two systems are further explored and optimised. Interviewee Mathias`s pilot system called cresponix is a biofloc technology with a RAS system were instead of vegetables being grown in the system, microbes and algae are grown in the system as biological filters, these biofilters eat up the residual product in the system cleaning it for the fish. The fish then eats the algae, reducing the amount of fish feed the system needs to almost 30% and therefore, contributing to solving the problem of fish feed (fish as fish meal). Interview Håkan also talked of the Food parks system explaining it to be a system whereby the fish and plant farming is not done in one house as in the case of aquaponics, but the two systems are operated differently with connecting pipes to optimise the productivity and scalability of the systems.

Table 6 Mapping aquaponics business model using Bocken et al (2013)

Aquaponics value destroyed	*Aquaponics value missed*	*Aquaponics value opportunity*
-Sludge which is the waste particles drained from aquaponics still constitutes an externality to the environment. -The fish meal in aquaponics systems (feeding fish to fish) constitute a value destroyed as this fish is taken from the oceans to support the aquaponics system. - The energy used for the heating of the aquaponics systems is high especially in cold weather.	-Sludge constitutes waste in aquaponics systems and can be used in a more optimal way -Aquaponics is observed to have elements of linearity that could be optimized as proposed by interviewees Håkan and Mathias. The fish waste is still carried out into the environment and the sludge is not optimally used. - Aquaponics is seen to be more productive for vegetables than fish with a ratio of fish to plant being between 1:4 to 1:10 in some systems.	-The value missed from aquaponics from the value opportunity for the optimization of aquaponics system or a learning curve for other systems. - Waste from fish processing could be used to farm insects for fish feed. Interviewee Lisa mentioned a pilot program in this area. - Interviewees Mathias and Håkan identifies the opportunity in aquaponics and propose pilot innovations of food parks and Cresponics. These are both systems with value propositions to optimize the waste stream in RAS and aquaponics

Table 6 uses the value mapping tool of Bocken et al. (2013) to discuss the value destroyed, value missed and value opportunity in the aquaponics BM.

5.3. Discussing economic viability and value capture in aquaponic (a paradox)

The economic viability of any business is essential to its survival. All respondents agreed that the economic viability of aquaponics is usually not highlighted in literature. Interviewee Håkan stated that *"…. it's not easy to find good examples of aquaponic companies that is really working as a business model with a viable economy*". Interviewee Mathias had similar views saying, "*As of today, i don't know of any aquaponics business that is successful in the EU for example one of the early developers in Sweden, because of the high cost they have changed their BM.* This is an interesting finding given that with the effective use of waste and less use of water one would expect a translation to low cost of production. But the two

functional aquaponics businesses that were interviewed admitted not to be making profits yet.

Scaling up was highlighted by all respondents as an important factor to gaining economics of scale, lowering the cost of production, and breaking even. Interviewee Bengt stated that hydroponics and aquaculture are proven to work concepts standalone but when combined, it is necessary to scale it up to get more productivity. Both interviewees Bengt and Håkan stated that individual systems of aquaculture and hydroponics are more productive and economically viable right now in Sweden compared to aquaponics. This is mostly because of the small scale of the aquaponics systems.

However, difficulties in getting the permits from the government for large scale production is also discussed by respondants Håkan, Bengt, Matthias and Lisa as a limiting factor to scaling up aquaponics BM. Interviewee Håkan, Bengt, stipulated that it takes about 5 -10 years to get a permit for large scale aquaponics from about 5 different government agencies as there is no one center agency that handles these questions and Permits may cost about 10 million Kr. This was corroborated by the practitioner's respondent Lisa and Mathias stating that this is limiting and may demotivate certain investors. Interviewee Håkan explains that aquaponics is not consideredd the most interesting topic at the governmental and the EU level because it does not really have the scale to impact sustainable food production. So at the current scale it does not generate enough support to change policy to ease or favor its growth scalability.

There may be a paradox (contradiction) here (see fig4) as it is seen that the EU and government is not supportive of the aquaponics systems because it is still small scales to impact sustainable food production, and aquaponics needs better policies and supportive systems to scale to a level of impacting food production. So, aquaponics seems to be in a trap (vicious cycle) because it is not big enough to make an impact in sustainable food production therefore not interesting enough to draw attention for policy change to engender the development of the sector. This makes it less lucrative to investors, demotivating investment to scale it up to more

significance. Consequently, limiting the economic viability, growth, and sustainability of the BMI of aquaponics.

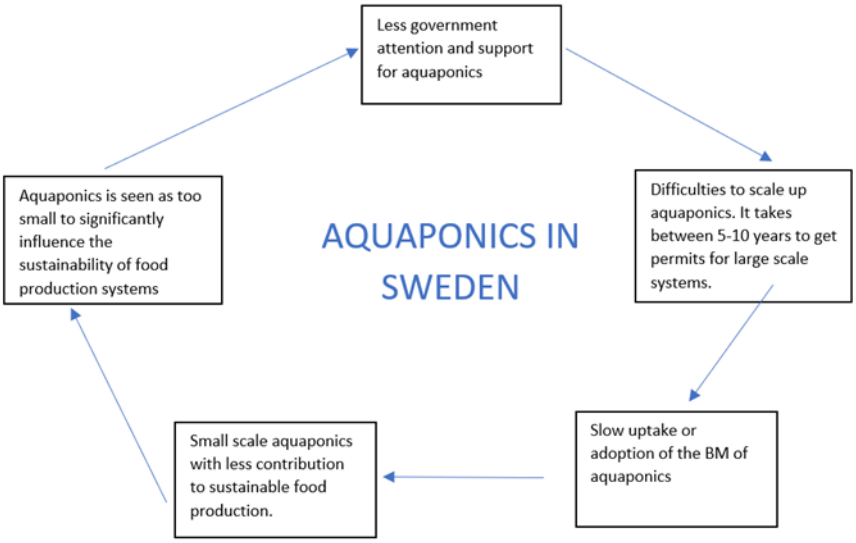

Figure 4 The paradox of the growth of aquaponics in the Swedish market.

From the Fig 4. above we see that the economic viability is a weak link in the BM as the business model of aquaponics is not yet economically viable in the Swedish market.

5.4. Can aquaponics be viewed as a SBM

There is no consensus in literature of what exactly constitutes a sustainable business model (Lüdeke-Freund 2009; Schaltegger et al. 2012). In this thesis, the authors use a deductive understanding of the SBM the synthesis in table 3. Of the compositions of the SBM defined by Stubbs & Cocklin (2008) Boons & Lüdeke-Freund (2013), Evans et al. (2017).

According to the findings, aquaponics today is founded in the idea of creating efficiency and making the plant and fish industry more sustainable. The findings

also show the companies practicing aquaponics in Sweden have sustainability as their main value proposition.

Studies by Stubbs & Cocklin (2008); Schaltegger et al. (2012); Bocken et al. (2014) supports BMI as a valid way to transform unsustainable business practices to become more sustainable. Our analyse of the aquaponics business model innovation in tables 6 and 7 using the concepts grounded in the literature of Bocken et al. (2013; 2014) explicates aquaponics as a BMIS. However, can aquaponics be defined as a SBM? In Fig 5 we explore aquaponics as a SBM using the synthesis from Stubbs & Cocklin (2008); Boons & Lüdeke-Freund (2013); Evans et al. (2017).

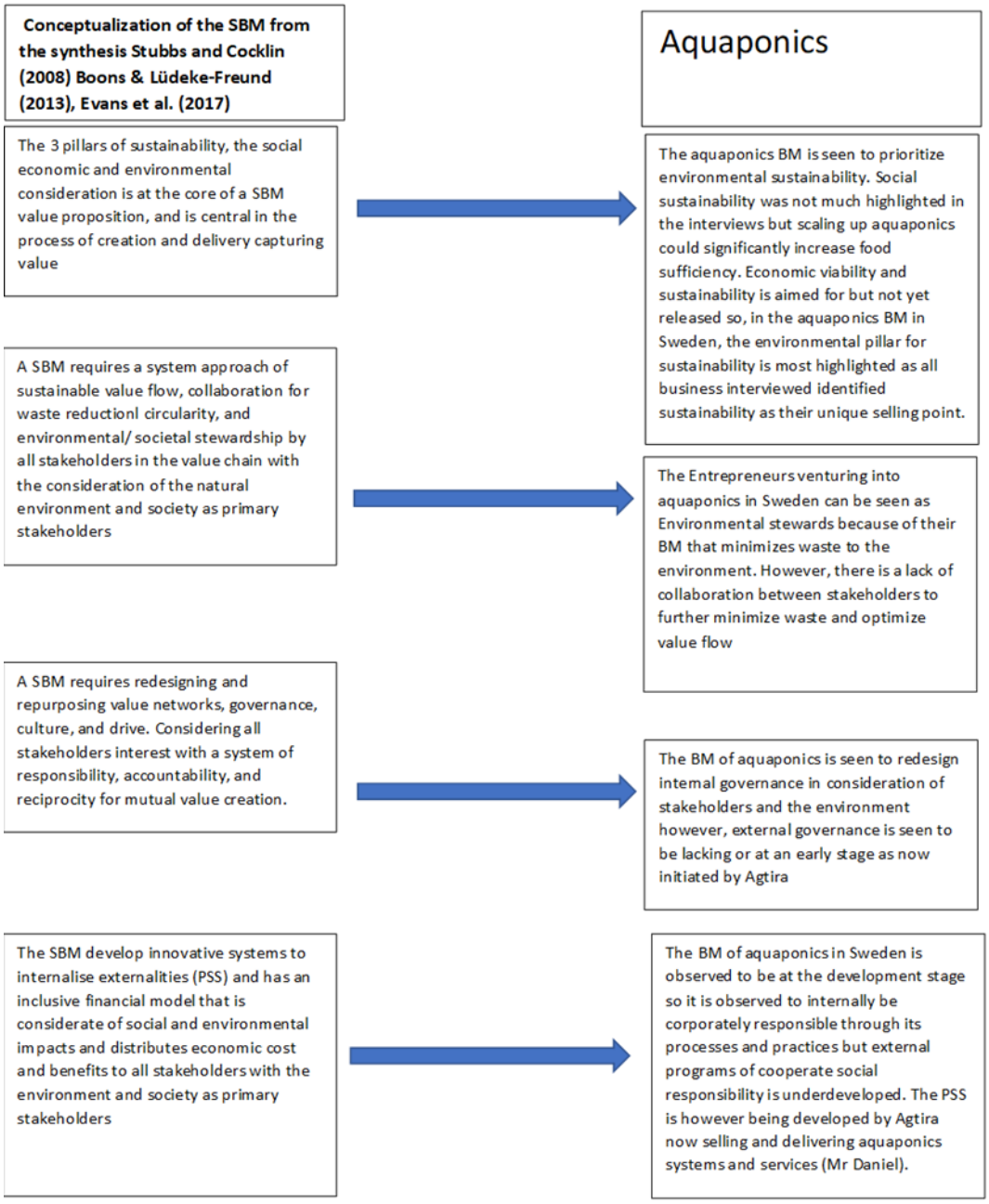

Figure 5 Conceptualization of the SBM from the synthesis Stubbs& Cocklin, (2008), Boons & Lüdeke-Freund (2013), Evans et al. (2017 in regards to aquaponics.

From our analyses of the aquaponics BM in fig 5. We observe that the characteristics of the SBM though formed with a certain level of abstraction in

literature, still presents themselves in the BM of aquaponics as sustainability is seen as the unique selling point of the BM of aquaponics by all the interviewees.

However, the were three notable weaknesses. The economic pillar of sustainability is seen to be the weakest link as these businesses even through the offer environmental and social benefits they however are not financially viablee. Also, fish feed that drives the system is seen to be unsustainable as it is made from fish. Thirdly, partnerships for scale up the contribution of this BM to sustainable food production is underdeveloped as there is insufficient collaboration between research policy and practitioners to scale up this is also corroborated by (SLU 2021). According to Lélé (1991), sustainable development is a process where we continuously take actions to balance social, political, and environmental factors in the process of development. Therefore, even though aquaponics is seen to be lacking in some elements of the SBM. These findings reveal aquaponics to be a significant milestone in the process of attaining sustainability in our food systems.

5.5. What are the barriers and opportunities in creating value through aquaponics business model?

Through the discussion the interviewees, a lot of challenges have been identified from both angles. To start with, aquaponics is an integrated technology and is seen as quite a complex system to deal with in its entirety. There are similarities and differences noticed from the practitioners and the researchers during the interview. When it comes to the similarities, they all pointed that the system is complex, and a broad knowledge is required to understand and implement the multidisciplinary concept of aquaponics. The finding shows that, to fully comprehend the concept and for it to work, there should be a support from all the stakeholders and institution that surround aquaponics.

This also aligns with the views of Rakocy, (1989) describing aquaponics as an integrated system where two elements of recirculating aquaculture and hydroponics

are combined resulting two separate system with different properties to be managed as one successful system. Also, Turcios, (2014) agreed to that notion of complexity in terms the sustainability problems associated with both aquaculture and hydroponics, and how this system of integration allows some of their shortcomings to be addressed promising to be a sustainable food production method.). Goddek et al. (2015) also stated one of the reasons why there can be a challenge to the technique describing its system design and application as a complex multidisciplinary approach that integrates environmental, mechanical, and civil engineering design concepts as well as aquatic and plant related biotechnology as well as requires knowledge on all these aspects.

Discussing further the challenges, Interviewees talked about two problems in aquaculture when it is land based, the feed and health of the fish, and they added that they can achieve large scale production that will allow them both reduction in cost and also improvement in the sustainability only if they have one successful story. Vermeulen, (2013) agrees to this notion in the aquaponics system a challenge is pest and disease management because the breeding of the fish and the biofiltration process occur in the same water loop increasing risk for contamination.

Practitioners and researchers both believe that controlling the cost is a big step in improving the use of this technology as both the production capacity and the practical application of it depends on it. The challenges relating to this, is that without a successful story no investors are willing to take a risk on this system and it makes hard for entrepreneurs to innovate if their chances of survival are very limited. This aligns to the fact that aquaponics today is not applied beyond small scale pilot projects despite its synergistic interaction and promising methods of fish and plant farming. There are claims it contribute to both global and urban sustainable food production as well reduces pollution however, due to the afore mentioned challenges, the practical application of aquaponics is yet to be proven to its potential (Rakocy, 2012).

Another challenge that came up during the discussion is that of the policies being a hindering factor to the adaption of large-scale aquaponics. In Sweden, where this study is conducted, there are no specific rules that govern production methods like

aquaponics. They still fall into the category of traditional aquaculture and hydroponic. This means that despite its promising properties of reducing unsustainability in the fishing industry, aquaponics is not classified as a sustainable production method. Lehman et al (1993), defined sustainable agricultural process as a process that does not deplete any non-renewable resources are can be considered essential to agriculture in order to sustain the agricultural practices. The practitioners hold the view that aquaponics indeed falls into this category. Discussing this they stated that they decrease the sustainability issue of farming fish and vegetable as well as the feed consumption by 30% because of the recirculating aspect and that the microbe from the residual is reused as a feed resulting both less economic cost from the feed and quality benefit.

The policies that are in place today do not favour aquaponics and because it is hard to get licences and certifications for labelling their products, it is also difficult to make the market understand what they are really doing. The market needs evidence that they are organic and are offering a better-quality fish than the open sea however, trying to make the market understand the kind of product they are offering is hard without the support of the policies. They believe that Swedish policy is super complicated generally very slow to change and not very supportive of innovations of this type. During this discussion it was evident that these start-ups are indeed in need of the support of the government and the policies to be adjusted as that is a limiting factor of what they can do with this system.

However, despite the challenges mentioned above, the opportunities mentioned were very little. Aquaponics is seen to be a sustainable solution to the food problem existing globally. From both the practitioners and the researchers, they hold the view that there is a potential and opportunities in this system, and it can fight environmental as well as social sustainability reducing both food insecurity and pollution. They hold the view aquaponics today could be an opportunity for aquaculture system as they can benefit from the reuse of the nutrient because when recirculating the nutrients in RAS, it can be reused and utilized by the plant, reducing electrification. This aligns with Turcios, (2014) where he stated one of

What was interesting to see is that all the interviewees have mentioned fish and vegetable quality to be a way for them to differentiate themselves from the conventional fish farmers. The data showed that fish farmed on land through these methods has more quality in terms taste and durability. Even when it came to the discussion on economic viability, the recurring answer was that if these methods are applied in large scale, there will overtake the traditional fish farming that exists today, and the market will be open to this. This is because of the quality it has and the sustainable methods it has been used to produce and if that information is transmitted to the consumers there will be a huge acceptance for this kind of fish farming methods in commercial large scale.

6. Conclusions and Recommendations

6.1. Conclusions

When we started this study, we had three research questions in mind

1) What is innovative about Aquaponics business models?
2) How can it be conceptualized as business model innovation for sustainable food production?
3) What are the challenges and opportunities to creating, capturing, and delivering sustainable values from aquaponic production systems?

In the framing of this thesis, the authors highlighted the need for sustainability in our current systems as a motivation for many businesses to innovate and transform their current unsustainable practices to tap into the growing market for sustainability while contributing to a sustainable future for the planet. Sustainability is challenging today's business processes and is becoming a reason for the shift in innovation where the core foundation of the business models is value creation through sustainability.

In the conceptual framework, the authors explained the concepts of aquaculture, RAS, aquaponics, BM, BMI, BMIS and the SBM as underlying concepts of this thesis to give the readers a better understanding of the topic being discussed. In the Empirical findings and analyses the authors report the findings and used tables and figures to analyse the finding based on the conceptual framing.

From our findings, Sustainability is highlighted as the unique selling point of the aquaponics BM by the researchers the practitioners and the policy advocate of aquaponics. The BM of aquaponics is rooted in the idea of optimising the limitations and unsustainable practices of hydroponics and aquaculture as it is a

joined system of aquaculture and hydroponics in a RAS system where nutrients from the fish feed the plant and the plants in turn take up what have been otherwise seen as waste making the water more conducive for the fish.

In our analysis of the data we found that the BM of aquaponics cuts across all concepts of innovation in literature. The BMI of aquaponics is not just a process, product, or position innovation but a paradigm shift in methods of food production as the system is designed to make use of aspects of the production process that were foreign concepts before.

In analysing aquaponics as a BMIS and a SBM, we found the aquaponics BM underpins all elements of the BMIS backed in literature by several authors. We however found economic viability to be the weakest link and a paradox in the BMI of aquaponics as there was found to be no economically profitable BM of aquaponics in Sweden at the time of the writing of this thesis. Scale was found to be an important factor to economic viability however, scalability seems to be in a trap as aquaponics is considered too small to significantly influence policy to promote scale and scale is required for aquaponics to grow into significance. Also, collaborations between practitioners researcher and policy makers to amplify the contribution of aquaponics to sustainable food production was found lacking.

Operationally, we found that aquaponics as a BM had several values missed and value destroyed that could be converted to value opportunity for optimal contribution of the BM to sustainability. We also found two pilot business models Cresponics and Food parks with value propositions that optimises the limitations of aquaponics.

These explorative studies of aquaponics found aquaponics to be a promising innovation in sustainable food production and a learning curve in the process to sustainability. However, its growth in Sweden is underdeveloped and a paradox. Understanding this weakness in the growth of aquaponics can help inform policy makers and contributes to the uptake of aquaponics in Sweden. Understanding the BMI of aquaponics has revealed economic viability as a central pillar in the development of innovations for sustainability and the foundation to the

development of environmental and social sustainability. These finding questions the balance in importance shown in literature of the three pillars of sustainability.

6.2. Recommendations

For future research we recommend that a study should be done where the focus lies the economic viability of this system. A quantitative study where the cost and benefit of this business model is analysed would be interesting to see.

Also, we recommend research study on the balance (weight) of importance between social, economic and environmental factors in the construction of BMIS. it will be interesting to conceptualise this balance evidence in other cases.

Lastly, we recommend an investigation into adaptive management of other innovations for sustainability in the aquaculture and agriculture sector. The collaborations that engender the adoption, diffusion and transferability of BMIS.

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Appendix 1

Hi,

We are two students who study “Agricultural Economics and Management” at SLU, and we would like to thank you for your time for this interview. The program is in English so the formalities and the interview is in English unless you have other preferences such as if you feel more comfortable in Swedish, we could arrange the interview in that direction. This study is for educational purposes that is meant for the attainment of a master's degree. Our study is within the scope of sustainability and business models with special focus on aquaponics conceptualized as a business model innovation that is likely be part of the transition to more sustainable food production in Sweden.

The following aim and research question is the foundation for the research.

Aim of the study

The aim of our study is to understand aquaponics conceptualized as business model innovation for more sustainable food system.

Research questions

What is innovative about aquaponics business models**?**

How can aquaponics be interpreted as business model innovation for more sustainable food system?

We will go from the following themes and each theme has a few sub-questions.

Theme A: background question

Theme B: value proposition

Theme C: Value creation

Theme D: value delivery

Theme E: value captured and Sustainability

Finally, we would like to let you know the following points

1)We apply a non-disclosure agreement (NDA) that all of our participants and any information related to any companies mentioned for the purpose of this interview will remain confidential throughout our research unless the participant requests otherwise.

2) We have prepared a list of predetermined questions but are very flexible and open for discussion that will allow any additional information that is relevant to the research.
3)We estimate that this interview will last between 1hour -1:30 mins and can be broken into two sessions if you would prefer.
4) If you feel that you do not want to answer a specific question, please just say that you have "no comment".
5. Finally, would like to ask for your consent to record this conversation for transcription purposes.
Kind regards,
Fardosa, and Rita

The interview questions broken into themes

Theme A: background question

- What does your company do?
- What is your role?
- How long have you been working there?
- What do you/your company consider a business model to be?
- Can you describe your company's business model?

Theme B: value proposition

- How do you create value and for whom? (What services/products for what customer group?
- How will you describe the product / service you provide? What is the unique selling point of your business? Will you say the value you propose is innovative?
- What is different and innovative about the value (Product / services) that your company is proposing to the Swedish market and what element of the product/ service you are offering would you say is your unique selling point?

Theme C: Value creation

- How do you maximise material and efficiency in your processes comparatively, how different do you think your method is? What is innovative about your methods?
- How do you create value for waste? Do you have partnerships to create value for waste? Are there still some under-utilised capacities that you are looking to explore how to create more value for in the future? (Concepts of closed looped systems, cradle to cradle and cradle to grave)
- Are you involved in any value core creation scheme with your partners, customers or suppliers by waste absorption, recycling and reproducing or reusing materials from each other?
- How do you substitute your production processes with renewable and natural materials?
- Would you say you co-create value with your stakeholders? How do you do that?

- Are there some social values you create for your employees that are different from other businesses?
- How is your company involved with the local community? Is the local community considered in the business model?
- How does your company think about the environment?
- What would you say are the gaps in your value creating process that you are exploring ways to enhance? will you say there are some parts of your current business model that are destructive to the environment? How do you Handel your waste for instance do you have a good waste management skim or are there the gaps for improvement?

Theme D: value delivery

- What distribution channels do you use to deliver your products? What is novel or unique about your distribution channels?
- Do your business propose any new form of delivery added value to its stakeholders (customers, suppliers, partners and society and environment)
- Do the way you do business influence the way your partners and distributors do business? If yes, in what way would you say that is? Do you have some standards you expect your partner and suppliers and distributors to align to and what are those standards?
- Would you say your business prioritises the delivery of social and environmental value over economic value? If yes, can you please explain?

Theme E: value captured and Sustainability

- How is value captured? (costs/revenue streams or customer satisfaction)
- How do you measure value captured do you measure it in economics terms or would you say you measure it both economic and social terms and do the environment you operate in support that measurement (Given you have some new ways of measuring value captured not just in economic terms)
- Have sustainability influenced any changes to your business model?
- How has the business model changed over time?
- What actions do you do in order to help the environment?
- What groups do you think about most when innovating (changing/updating) your business model?
- What are the trade-offs you would say your organisation has had to make to survive in the market in contrast with what was the initial plan of the organisation?
- How would you describe your corporate social responsibility in your business model?

- Do you believe your business model has that potential of being scaled up and what are the barriers and opportunities you see in the scaling up of your business?

Quote continuation.

Matthias (Q1 comparing aquaponics with Bioflocs systems) *"Aquaponics is good it reuses a lot of organic waste, but the problem is still that, what you add to in through the fish, you get a nutrition for the vegetable but the feed we give to the fish that drives the whole system is not sustainable today. Our technology can make that feed sustainable because when we make microbes and bacteria algae as a feed alternative to the fish, we can take away Fish meal, fish oil or other soy protein from our system. The algae and microbes eat up and cleans the waste in the system and the fish eats up the algae reducing fish feed added to the system to up to 30%. So, the Bio floc system presents improvement in the technology of aquaponics. The is a pilot project to make the feed 100% more sustainable.*

Lisa(Q2 comparing aquaponics to hydroponics and greenhouses) "*I mean we're comparing aquaponics to either more conventional greenhouse growing in soil or an in that case we have an extremely high water re usage so in the end of low total water usage compared to greenhouse is essentially zero nutrient leakage to surrounding environment and also typically, actually lower electricity or power costs or lower or equal because when you have a greenhouse and it's in a cold country you have to heat it since we're doing indoors, that is not as much of a problem because greenhouse are so very inefficient we do indoors. Compared to hydroponics, hydroponics the nutrient are typically mineral sourced or chemically created nitrogen which has a very high climate impact whereas we have the nutrient loops in ecosystem really so those are what we are comparing we think that from sustainability and efficiency perspective it's way better".*

Lisa (Q3 on target market) -*" ....our first target customers which is high end restaurants or restaurants hotels conference centres our first target group their customers demand sustainable foods so they demand sustainable food….had had restaurant really high end restaurants saying that this is not only you know they look good they taste good but they also have a better shelf life and they are willing to pay for it so I would say our seriously early adopters that would be targeting restaurants of the upper bracket price bench…..they can be trend-setting for other restaurants and in the end after restaurants then private consumers looking to buy in the supermarket" she adds that ".... so we do the value proposition is at the base level is sustainability but, also local no shipping no pesticides and in the end actually a very high quality product….is what makes them interested is sustainability what really makes them buy more is that it's a high quality product*. "Lisa adds that "…*we want to work local the farm placed in Stockholm is not*

supposed to ship to London so if we want to sell in London we build in London. because you know when you have an import that is like spinach coming from Italy and it's been in a bag for two days that's a short shelf life….we want to work local the farm placed in Stockholm is not supposed to ship to London so if we want to sell in London we build in London".

Lisa (Q4 innovative ways of using waste) "concerning waste yes we as I said investigating the possibility of using green waste to raise insects .... research indicates that is very possible to use it as fish feed" she said the system will always have a level of waste, but they are looking at west to maximise the waste use. Also she mention a pilot project to add blue mussels from the biotic seas in to fish feed….well so there is always going to be some percentage of the of the production that is not sellable and doesn't get sold .... also, their roots from our system is always going to be a waste…. something we are very much interested in raising insects…" She also mentioned an innovative way of using nutrients from the Baltic *"we are also looking at taking blue mussels grown in the Baltic Sea using that to put in the fish feed and so Baltic Sea mussels they produce eutrophication of the water because they don't make the water more nutrient rich they make it less nutrient rich and the Baltic Sea is just so full of nutrients that is real problem so then we could actually have a farming system that makes the Baltic Sea more healthy by including blue mussels in the feed"*

Daniel (Q 5 on Agtira`s systems and changes BM) *"The old BM is that we are selling to this market tomatoes and cucumbers from our own farm in greenhouses. That's the old business model. And our new business model is to only sell the system for the supermarket to farm by themselves and then provide the service that we are operating the greenhouse with the supermarket that we have sold to the supermarket. So, we go from being a farmer to being a system deliverer…we do both things we sell the system and operate them at the supermarket. So, we help out at the supermarket to sell food, so that's the main thing. That is what we are going to, uh, earn money from, both selling and providing services to the supermarket*"

Daniel (Q6 on the innovation of farming at the supermarket parking lot) *,"We don't know so many who farm at the parking lot of their supermarket, And if you then connected with Aquaponics, it's I mean it's a good farming system that you Can put in the parking lot. It's really high in that way. It's really unique and it's really nobody else doing it. And you look at work people in Sweden eat a lot, We eat lots of tomatoes, we eat a lot of cucumbers and for creating that you don't need to transport long coming to the Customer. The customer goes and buys meals and can buy this on the way up. So it's really the way the customer goes through this*

greenhouse and cucumbers hanging there and gets this feeling of good food and really happy and sees the cucumbers and so on. So it's really this,. This is really strong and when I speak with supermarkets saying this is oh, we want to do this. So that's really the big and important thing I need to lift up when I speak with them"

Sammar (Q7 in the ease of taking up the innovation) " *Easy it is not since it is not been applied on a large scale, we have to solve many factors that bring complexity to the system, the nutrients part is one aspect to solve, the microbes and the pathogens are also another aspects so there are the different aspects to be solved before it is applied….Yea there is a big interest but there should be clear baselines of how it works. So now it is mostly at the research stage and maybe if more research is done maybe more companies would find it interesting? Yea I think so*"
Håkan (Q8 on the productiveness of individual systems optimised compared to the productiveness of aquaponics today) "*if you produced fish isolated from the plants and only use fertilizers that you can buy on the market and produce it in a greenhouse or in the open field you can optimise it much more easy then compared to if you combine fish and plant. With fish only as a fish production you can optimise it compared to if you produce fish and plants. When you combine it you lose a lot of production compared with if you produce food and plants separately*
Bengt(Q9 on the necessity for competitive prices for aquaponics product) *" Of course, the price sensitive, uh, so it's this kind of of production and as everything it needs to be Economical compatible and that's why the business models needs to be in place Otherwise it's it's not going to be economically competitive of 'cause the large masses of the population or they aren't, uh can't afford, uh, uh, what's produced in this kind of of production model models if the price is too high, there is i cant say where, but there is of course a tipping point where Sustainability, even if you think It's important when it's when the price is too high, you can't afford to be sustainable or viable to actually want to buy for a conscience or or what you feel"*

Håkan (Q10 projections about economic viability and scale) "…. *a projection of salmon production using DnS (dynification system) 10000 tons of fish every year in a house the cost is estimated to be 50 kr per kg , to produce 1K of salmon requires 11,mil feed that is 31% of the total cost of the fish and that is the weak point of this system cost wise ….sensitivity study of this kind of investment shows if you produce 8000 tonnes you have a self-cost price of almost 60kr if you we produce 14000tones the cost price per Kg will go down to 45/46k"* Håkan also mentioned that even though the scale is important and the production in Sweden is there yet *" and even if there is some return on investment we are looking at good margins, it would take time to get there as it requires scaling up.*

Hakan (Q11 on the process difficulties in establishing large scale aquaponics systems) "*We are talking about 5 to 10 years of waiting for some companies and it is unacceptable because we lose finance. Investors fear in cases where the permission process is too slow. The municipality is the one that gives the permission and maybe in small companies it takes less time but for big companies that are building big things they are troublesome they need something called bygglov and you should have a good contact with them, when it comes to aquaponics the problem is not in municipality, generally they are supportive but in big scales they are problems".* About the scale problem he said *"There is always a scale, aquaponics as it is, is not seen as something that can cause massive increase in food production, it is not seen as something that can change the supply of feed food in big scale. And that is where we feel that there is not enough support from the EU policies. But this not the case we can add to the increase of food production in Sweden for example if we produce 50000 tons of fish in a year that almost half of the consumption of the Swedish people and that is fresh fish that people eat. But the quantities produced today is very small and not interesting for the government or the EU policies. So the interesting question is scale, the world needs a big scale,*

Bengt (Q12 on legislation to support aquaponics*)*
"I have myself in the network. I I'm running. We have been to the government and we have spoken to a lot of governmental individuals persons. Uh, in a dialogue way and we all agree, uh, but that that is not the same as the legislation actually is being reform. Uh, and and changing. Uh, regulations is of course a time consuming process. Uh, so it takes time. Uh, it takes time to change legislations. And as I said, it takes even more, uh, time when it is different departments. Uh, that needs to see and, uh, understand the same thing in the same way and aim at the same goal. That is, that takes time. Maybe too long. cause we have already seen today many investments. Uh passing by Sweden? OK.

Bengt also added that*" I would say there isn't a municipality or region that hasn't written in their visions or policies that you you should be, Uh, supportive of the sustainable production models, and then they talk about They talk about uh, innovative aquaculture. They talk about the we need to rise our self-sufficiency. The food sector. And then there is a lot of money going to to research. In this field and. What what I what But what's lacking is still, uh, what we had talked about before, the legislation Is still working against this development or transition, so we need to get the legislation up to speed*

Bengt also added that *"The technique is in place. The financing is in place, but the legislation is holding it back. Could be up and running, running for it could have been for two or three years ago, but it takes up to maybe seven years to get the*

legislations. And you don't even know if you get all the permits needed because.Because, uh, policies and legislations and permits they aren't written for this kind of of production models and techniques.So it's it's very difficult and challenging for a business or investor to get involved in this kind of business. Holding it back"

On permits Bengt said *"You need to to apply six or seven different permits. For doing the one business and that that is not, uh. How should it work? We need to to get one department or a uh, who has their responsibility, uh, for For these kind of Permits. And they need of course to to collaborate"*

Mathias (Q13 on the economic viability of aquaponics compared to his production innovation) *"You need maybe between 1:5 to 1:10 in hectare farming for fish to vegetables so the fish wont matter anymore and slowly turn into vegetable producer, I would say that today aquponics is a vegetable farming technology, you apply it if you have a market for veggies if you have a market for fish you do not buy an aquaponics system you buy a RAS system. In our system we could divide by using some of the waste for vegetables we can make one-hectare fish farming one-hectare vegetable farming and 1 hectare microbes farming and we could produce vegetables and feed for the fish and it will be balanced. ……, the fish feaces is eaten by the microbes and algae inside the water and the fish will eat the microbe again, so we create a biological loop where we reuse the feed and the energy, the same amount of energy can go through the digestive tract of the fish many more times than any other fish production methods and that is why we reduce 30% feed use in our system because we utilize 30% better of the energy and water. that is the big thing in our technology we can really reuse 100% of the farming water there are some evaporation … and some of the water that gets into the fish and shrimps when it grows but otherwise we reuse all of the water in 10 years the system has used the same water while the RAS have to take out 5 % of the water every day and traditional shrimps farming needs to take out the total volume of their farm every third day….there is "*

Lisa (Q14 on finance and support) *" so we have been in contact with STING incubator accelerator for start-ups , we have been part of their incubator which helped partly with investors our CEO spends a lot of time looking for investors, so I would say that there a lot of organisations that supports us in Sweden, the only thing I would say is that aggrotech or foodtech which ever category we are put is sort of new to Swedish large investors venture capitalists. Because, in Swedish innovation is more of software apps digital services and so for them to see us we want to build something, and we want to borrow investment…. so I would say*

Sweden does support startups but Swedish investors are not use this kind of innovation",

Appendix 2

Table 7 Discusses aquaponics based on the framing provided by Bocken et al. (2014)

Aquaponics as a BMIS (Bocken et al. 2014)	Aquaponics value proposition	Aquaponics value Creation and delivery	Aquaponics value captured and economics viability
Maximize material and Energy efficiency	The aquaponics value proposition with RAS and hydroponics is seen to allow for the sharing of nutrients that will otherwise be wasted in individual systems of open cage aquaculture or hydroponics. These benefits of aquaponics is corroborated by all interviewees. However, there is room for better collaborations for the optimization of waste in the system.	Aquaponics internal operations allow for the use of waste between two systems Hydroponics and aquaculture. However, aquaponics BM does not eliminate waste in the system. The partnership for the use and optimization of waste still being produced by the system is underdeveloped	Waste is minimized but not optimally enough to make a profit. The sizes of aquaponics firms in Sweden does not allow for the capturing of the economy of large-scale production. However, value is captured to the environment by minimal water used and less waste to land fields. Increase scale needed for profitability
Create value e for waste	Valuable nutrients from fish waste that would have caused water pollution or eutrophication in a stand-alone system of aquaculture is converted by biofilters into nutrients to be taken up by plants. Plants then clean the water by using this waste and oxygenating the water for fish.	Create value for fish waste which will have otherwise be seen as waste or pollution to water bodies and the environment. Deliver this value to customers by fresh produced plant and vegetable "farmed in Sweden". However, partnerships to optimize waste use is underdeveloped as sludge that is filtered out from the water is not optimally used.	Minimizing waste leads to minimized material and environmental costs. Nonetheless, due to the small scale, the cost of production is high in observed aquaponics systems. Therefore the BM of aquaponics is not yet economically viable in the Swedish market.
Substitute with renewable and natural resource	Aquaponics addresses the resource constrain associated with natural capital. More so for fish than plants due to 1:10 production ratio of fish to plants in productive aquaponics systems. The substitution rate of captured fish for farmed fish is not quite high in aquaponics systems due to the ratio of plants to fish.	Aquaponics create solutions that mimic nature as the biofilters and helpful bacterial in an aquaponics system naturally convert ammonia to nitrites and later to nitrates enabling the nitrates to be taken up by plants and oxygenating the water for fish. However, partnerships for material and energy supply is underdeveloped.	The revenue stream from this innovation seems to come from plants more than fish. The firms interviewed focused mostly on plant production because the fish produced in these systems seems very small to add significant value to their BM. However, value is captured by the environment as less water is used and less waste to environment.

Delivers function rather than ownership	The value proposition of the BM of food can hardly align with this archetype due to the nature of food as a consumable. The BMI of Agtira that Sells aquaponics systems to supermarkets and helps operate these systems at the supermarkets ensuring that they are productive and efficient in producing fresh products at the supermarket comes quits close to focusing on providing functional needs of customers than customers owning the products.	Creation of functional, durable, and reparable products is seen in the BMI of Agtira. The aquaponics system in this case is designed to function as a productive system of fresh vegetables at these supper markets. The staff of Agtira ensures the functionality, durability, and reparability of these Systems but the focus is providing fresh “farmed in Sweden” vegetables at the supermarkets. There is direct contact with the retailer bypassing the whole seller to deliver fresh value (freshly farmed product) to customers.	Value Captured to the aquaponics BM by Agtira by increase customer segment, reduction in delivery cost, branded for delivery of fresher products farmed in Sweden. Even though this identified aquaponics BMI of Agtira is not yet economically viable it is still at the development stage with promising returns. Value captured by the society and the environment as the customers benefit from freshly farmed products at the supermarket. Also, environmental carbon emissions from transportations are reduced. There is a promising future return for reduced import of fresh vegetables upon adoption of this technology by other supermarkets which will result in a higher level of emission reduction by reducing import.
Adopt a stewardship role	Aquaponics in Sweden proposes a broader scope of benefits to society and the environment compared to individual systems of hydroponics and aquaculture. There is recirculation of water reducing water to up to about 90-99% in productive systems. Again, there is waste being converted to nutrients in the systems for further production. Less carbon escapes to the environment by locating aquaponics systems directly at supermarkets. Also locating aquaponics systems at supermarkets facilitates direct exchange with customers enabling a better understanding of the system and may lead to the diffusion and adoption of the technology at a broader scale.	Aquaponics as a closed RAS system is seen to have fewer activities with its supply chain as nutrients mostly recirculate and are shared within the system in a particular location. Partnerships for superior value creation are seen to be underdeveloped. However, Aquaponics creates and delivers value in consideration of the health and wellbeing of the environment and society by offering fresher products compared to imports, better use of waste as nutrients, and less carbon escape to the environment. There is seen to be a need for better collaborations and partnerships for the BM environmental problem-solving ability to significantly contribute to sustainable food production.	Aquaponics brand value is seen to be at the development stage in Sweden as the companies operating aquaponics are at the early development stage. Brand loyalty which engenders higher value captured to aquaponics companies is not yet developed. Still, the business model innovation of Agtira is seen to have promising results with potentials for increasing brand loyalty and higher value captured to both society and the environment if scaled up and adopted at a brother scope.
Encourage sufficiency	Proposing products that will reduce consumption may be a hard objective to attain in the provision of consumables. Still, aquaponic systems that are durable and innovative to safe energy and material may reduce the use of resources in the production of food. Also, nutrients is shared in between systems, external material used is reduced in aquaponics systems, Meaning that even though aquaponics does not exactly reduce food consumption it proposes a more sustainable food production system.	Aquaponics designs creates value for waste as agreed by all interviewees. There is nutrients used between systems and less waste to the environment. However, there is a need for more collaborations for the optimal use of the waste still being produced by the system. Also, there is a need for better collaborations in the supply chain. The Fish as feed to fish problem in the aquaculture system is not yet soled in the aquaponics system. Collaborations like the insects for fish feed mentioned by Interviewees	Aquaponics produced products are seen to attract Swedish customers that value farmed in Swede, fresh and sustainable products. Still the aquaponics produced products still need to offer competitive prices because customers may want more sustainable products ´but may not be able to pay the premium for aquaponics products therefore will go for more competitive alternative farmed in Sweden organics products. Aquaponics may improve on its value captured by scaling up and making their products more competitive to customers. That way, value is captured by both the environment the company as more environmentally friendly products are produced and marketed

		Lisa and Mathias offers innovative solutions to the fish feed problem and collaborations to in this direction will make aquaponics systems even more sustainable	
Repurpose the Business for the society	The value proposition of aquaponics is seen to priorities environmental value. Still the business rolling out these business models need economic viability to survive in the market and continuously propose sustainable products to the market.	Aquaponics is seen to create value for all stakeholders, even though the social value created by aquaponics was not quite highlighted in the interviews and the economic value created to the company is still underdeveloped. Nonetheless, the environmental value of water recirculation, nutrient reuse and waste reduction is very much developed in aquaponics systems although the is still room for improvement	Aquaponics in Sweden at the early development stage is seen to have more value captured to the environment than captured value to the entrepreneurs as there is no economic viable aquaponics system in Sweden as of the date of the writing of this thesis. This implies that even though aquaponics proposes creates and deliver sustainable environmental value as agreed by all interviewees the business that proposes this environmentally sustainable value do not mage to capture enough economic value to be financially viable.
Propose scalable solutions for maximum benefit to society and the environment	Aquaponics proposes a business model which is seen to have great benefits to the environment as supported by all interviewees. It also has the potential to be scaled up with larger aquaponics systems. Still, the is room for improvement as stated by my interviewee Håkan and Mathias with their pilot solutions to improve the productions of both fish and vegetables simultaneously called food parks and Cresponixs respectively	Aquaponics is seen to have the potential to create scalable solutions as corroborated by interviewees Håkan, Bengt, Daniel, Lisa, Sammar and Mathias. However, there is a need for partnership between government, businesses, and research to facilitate the development of this BM into larger scales that will significantly influence sustainable food production.	Aquaponics business model supports scaling up through other means of licensing and franchising. This is seen in the BM of Agtira as corroborated by Interviewee Daniel. Agtira is seen to have changed its business model to be a system developer that supplies aquaponics systems to supermarkets and operates these systems at the supermarket thereby capturing value both as the sales of the system and cost of operation. Also, value is captured to the environment is called up when different supermarkets in different cities in Sweden buy aquaponics systems to produce their own vegetables at their supermarket reducing carbon emission in transportation and importation and therefore influencing food production at a larger scale