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Creating the Triple Bottom Line in the Insect Rearing Industry: Current and Future Perspective

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Abstract

The insect industry is a nascent but emerging industry that poses many opportunities for creating a sustainable food system. But how does the insect industry contribute to the triple bottom line, and how will its sustainable impact improve if certain barriers are overcome? In this research, we take a look at the sustainable potential of insect rearing both now and in a future where barriers like feed policy and insect food acceptance are overcome. Through interviews with insect rearing experts we discover that currently the insect industry is not able to offer many economic, environmental or social values. But if barriers are overcome, significant value can be created for each three. This signifies the potential that insect rearing can have for the planet and its society. This research can thus be used as an argument to policymakers to support the industry, or even as a motivation for entrepreneurs seeking to start their own insect business.

INTRODUCTION

The food system is under enormous environmental and societal pressure. With a staggering 35% of all CO2 emissions being related to food production (Sawal, 2020), all the while issues like food security remain unsolved in large parts of the world (Prosekov & Ivanova, 2018). Moreover, as we live in a finite world with a growing population and thus a growing need for food, it requires a more efficient system for food production (Godfray et al., 2010). The food system is therefore in need of sustainable solutions that, as stated by the United Nations: "meet the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

One such possible solution is the rearing of insects, in which low value organic material can be turned into high value protein. In this process, insects, and especially the insect *Hermetia Illucens* otherwise known as the Black Soldier Fly (BSF), feed on organic material whereby they grow themselves exponentially in a short time, whereafter they are processed and turned into insect protein meal and other resources (Madau, Arru, Furesi, & Pulina, 2020). Insect rearing can greatly increase the efficiency of the food system, for example, in Europe alone there is already more than 100 million tons of food wasted every year, which these insects can feed upon (Timmermans, 2015). The aforementioned issues and possibilities, along with economic incentive, have given rise to the insect rearing industry (Fowles & Nansen, 2020).

The business model of insect rearing has high potential to become circular, as the resources used for its operations could potentially flow from cradle-to-cradle instead of the cradle-to-grave flow (Lazarevic & Valve, 2017). However, reaching full circular potential and maximizing its sustainable value creation through insect rearing has not yet been achieved in Europe. According to research, there are multiple barriers that the insect industry faces, including aspects of food safety, production processes, supply chain and more (Veldkamp et al., 2022). Yet, it can be concluded that there are two core barriers which need to be overcome in order to create larger sustainable value (Cadinu, Barra, Torre, Delogu, & Madau, 2020).

First, human insect consumption is still rare and usually unaccepted in the western diet (Van Huis, 2021; Rumpold & Schlüter, 2013). This means that the main consumers of insect derived products at this moment are livestock (IPIFF, 2021). If insects are used as feed for livestock, which are consecutively eaten by humans, it has a smaller environmental benefit. Conversely, if insects are consumed directly by humans, then this can displace previously consumed meat, in which case it would be more environmentally friendly (Van Huis & Oonincx, 2017). Therefore, an important distinction must be made between insects reared for indirect consumption, also known as feed (e.g. eaten by pigs, fish and poultry) and insects that are reared for direct consumption also known as food, (e.g. eaten by humans).

Second, under current EU policy, it is not allowed to use non-certified waste streams. To clarify, this means that materials such as organic household waste, manure and sewage sludge cannot be used to feed insects, even if it is for feed purposes (Regulation EC No. 1069/2009, 2020). Thus, at the moment insects are raised on side streams which are already efficiently being used by livestock (Smetana, Schmitt & Mathys, 2019). It is found that, outside reduced land- and water use, major environmental benefits are only created if insects are reared on waste that cannot be used as feed or food for other organisms (Bosch et al., 2019).

Even though the aforementioned barriers are still present today, there is progress being made on both of them. For instance, research on acceptance of insects as food is growing and lobbyists like the international platform of insect for food and feed (IPIFF) are pushing legislation (Hein, 2021; Mancini, Moruzzo, Riccioli, & Paci, 2019; Mancini, Sogari, Espinosa

Diaz, Menozzi, Paci, & Moruzzo, 2022). However, it is not clear how the insect industry would benefit when aforementioned barriers are overcome, thus missing out on the ability to communicate its potential sustainable benefits.

In order to understand these potential benefits, first we must understand how the insect rearing industry creates sustainable value as of now, after which it can be investigated how this can potentially change when barriers are overcome. This can be done by researching how the insect industry is currently creating and potentially could create value for each pillar of the triple bottom line (TBL); People, Planet & Profit (Elkington, 1997). By using the TBL approach, a holistic understanding is created on how insect rearing creates societal, environmental and economic value. Which is important as current research into insect rearing takes a very siloed approach, addressing either its economic or environmental benefits, while mostly disregarding its societal benefits (Smetana, S., Spykman, & Heinz, 2021; Madau et al, 2020; Niyonsaba, Höhler, Kooistra, Van der Fels-Klerx, H J, & Meuwissen, 2021). Besides showcasing how insect rearing companies create value for each pillar of the TBL, it is also important to highlight how certain environmental or social benefits double as economic benefits. Thereby effectively creating a business case of sustainability, in which environmental and social benefits are not just an ad hoc measure but attribute to the economic prosperity and thus makes for a stronger sustainable business model (Schaltegger, Lüdeke-Freund, & Hansen, 2012)**.**

Thus, to shed light on how insect rearing companies address all three pillars of the TBL both with current barriers and without the current barriers, the following research question has been formulated: *How can insect rearing companies create environmental and social value alongside economic value, both now and in the future?.*

This can be an important guideline and motivation for entrepreneurs seeking to start an insect rearing business. But even more critical, it can be used to showcase the sustainable potential of this emerging sector and convince policymakers to support it. Finally, the knowledge gained in this research also attributes to the general progression of the insect industry as a whole.

As mentioned before, BSF are well suited as they can feed on a variety of organic waste, therefore this research will focus on the rearing of black soldier fly larvae (BSFL) within the context of the Netherlands. To answer the research question, a group of eight experts in the field of insect rearing are interviewed with regard to both current and future potential environmental and social benefits of insect rearing and how these affect financial performance. To facilitate this process, the triple layered business model canvas (TLBMC) is used. The TLBMC is a tool that visualizes how economic, environmental and societal values are created alongside each other and combines them in one framework (Joyce & Paquin, 2016).

The paper is structured as follows, in the theory section a general outline of current literature on insect rearing and the types of value that it creates are made, which is followed by the introduction of the TLBMC tool. Then, a qualitative case approach is argued as a method to fill in the TLBMC and answer the research question. Finally, the results are presented and their implications discussed, from this flows a short conclusion with the main theoretical and practical contributions.

THEORY

As noted in the introduction, first a general baseline of the current state of insect rearing research into each pillar of the TBL needs to be set. By doing so, it can be discovered what the known sustainable benefits are today, and also where research in insect rearing falls short. This baseline can later be used to verify information gained during the research and help fill in the TLBMC tool, which is introduced at the end. But first the TBL approach is introduced and argued.

Creation of triple bottom line in the insect industry

The TBL was first coined in the mid-1990's by business consultant John Elkington as an accounting framework for measuring not only financial performance, but also environmental and social performance (Slaper, 2011). Besides being an accounting framework however, it also suggests that companies should engage in value creation in all three pillars, People, Planet & profit, simultaneously (Elkington, 2018).

As mentioned before, most studies into the still quite nascent field of insect rearing have taken a rather siloed approach. For example, there have been a number of studies into the environmental aspect of insect rearing as well as few studies into the economic aspect of insect rearing (Smetana, Spykman, & Heinz, 2021; Madau et al, 2020; Niyonsaba et al, 2021). One exception to this is the article by Lange & Nakamura (2021), who take into account multiple aspects of the insect rearing industry. However, this is a very broad review article and does not involve perspectives from industry experts.

Keeping in mind the lack of research involving multiple aspects of insect rearing, taking a TBL approach would lend itself perfectly for creating a broader perspective. This being said, to get a perspective of what has been researched until now, a review of literature on each of the pillars of the TBL is done below.

People

Research on social value that insect rearing companies create is nearly non-existent, with only a few inferences that can be derived from literature. This is no surprise as companies usually first attain the double bottom line before engaging in the triple bottom line, so first focus on creating economic and environmental value before also creating social value (Belz and Binder, 2017). One inference that can be made is that insects provide great nutritional values, which can be a great asset in improving food security and health (Rumpold & Schlüter, 2013). However, currently only non-western countries consume insects on a regular basis, so this is applicable to only a part of the world (van Huis, 2021). But, if we consider other living organisms, like farm animals and pets to also benefit from insect nutrition, this could become another story. For example, it has already been proven that an insect based diet improves the gut health in fish (van Huis, 2021). A topic of debate in the insect industry is insect welfare, as it is still unknown if they experience emotions or not. What is generally accepted is that insects should be seen as sentient beings, meaning that, when farming them, steps to minimize pain should be adopted (Van Huis, 2019).

A different type of social value that is directly created by the insect industry is the creation of jobs. The mass production of insects in the EU is an emerging and rapidly growing industry which, according to the IPIFF, will have created 25000 jobs by the end of the decade (IPIFF, 2021).

Planet

Literature on the environmental value that insect rearing companies create is relatively abundant. Environmental impact comes in two ways according to Van Huis & Oonincx (2017), namely direct and indirect. Direct impact refers to the greenhouse gas (GHG) emissions that are created by the insects themselves, which are much less than conventional livestock produces (Oonincx, Van Itterbeeck, Heetkamp, Van Den Brand, Van Loon, & Van Huis, 2010). Indirect impact refers to the GHG emissions that are created throughout the entire supply chain. Life cycle assessments (LCA) have been used for multiple insect species to quantify the indirect impact that insect rearing brings. In general, the LCA's point out that insect rearing requires large amounts of energy for heating, this is because insects are poikilothermic, meaning that their body temperature depends on the ambient heat. However, this also means that insects can convert feed far more efficiently than conventional livestock, as they don't waste any energy on maintaining their body temperatures (Van Huis & Oonincx, 2017).

Finally, it is also found that insects use less water and most evidently reduce land-use in comparison to other types of feed (Van Huis & Oonincx, 2017, Smetana et al, 2019). For example, in an LCA on BSFL, it was found that land-use for producing 1 kg of BSFL protein is only a fraction of that needed for growing 1 kg of soybean protein (Salomone, Saija, Mondello, Giannetto, Fasulo, & Savastano, 2017). The reduction of land-use is important, as it is one of the planetary boundaries that is nearly transgressed (Steffen et al., 2015). However, a key fact to remember is that land-use is not the only factor in climate change that needs to be addressed (Smetana et al, 2019).

Profit

Literature on the profitability of insect rearing companies seems to be scarce, one article only infers that it has a high return on investment and low starting costs (Madau et al., 2020). Another article goes a step further by calculating the margins that could be earned while producing several kinds of insects. For example, for BSFL these margins are between -798 to 15,576 euro per tonne (Niyonsaba et al, 2021). However, this article is limited as the data used was incomplete. Finally, according to the IPIFF, the turnover of insect rearing companies is likely to exceed 3 billion euros annually by the end of this decade (IPIFF, 2021).

An economic challenge that insect rearing companies face, is the price competitiveness of their insect products. The price for insect products are still very high due to the mostly small scale of production and high feed costs (Sogari, Amato, Biasato, Chiesa, & Gasco, 2019; Madau et al, 2020).

Triple layered business model canvas

The TLBMC was modeled after the original business model canvas (BMC) which was introduced by Osterwalder and Pigneur (2010). The original BMC is a tool consisting of 9 building blocks that define how the business operates, what it offers, its activities, and the cost and income structure. The BMC focuses on the economic part of the business and disregards the environmental and social aspects of it. In response to this, Joyce and Paquin (2016) introduced the TLBMC, which adds two layers to the original BMC, namely environmental and social. Accordingly, the TLBMC is a tool to help visualize how organizations create environmental and social value alongside economic value, which can then be used to communicate the business' sustainable value creation and discover potential gaps and opportunities (Joyce & Paquin, 2016).

The environmental layer is based on the LCA of a product and is used to show how an organization creates environmental value and limits its carbon footprint. The environmental layer is built up of 9 sections just like the economic layer, these are: functional value, materials, supplies and outsourcing, production, distribution, use-phase, end-of-life environmental impacts and environmental benefits.

The social layer takes a stakeholder perspective and captures how social value is created, stakeholders can include employee's, customers, shareholders, suppliers etc. The social layer is also built up of 9 sections, these are: social value, employees, governance, communities, societal culture, scale of outreach, end-users, social impact and social benefits. The social layer is particularly hard to fill in, as there are no guidelines provided by the authors on how to do so. Instead, Joyce and Paquin (2016) refer that the social layer of the TLBMC is intendedly broad and flexible in use.

The TLBMC has three main purposes, which are: 1. Providing a visual representation of the organization's sustainable business model, 2. A tool to create new business models, and 3. To validate new business models. Thus, it lends itself as a proper tool for analyzing how a business can create sustainable value but also how in the future a new sustainable business model might look (Joyce & Paquin, 2016). For example, in a similar type of research within a manufacturing company, environmental benefits were discovered that also doubled as economic benefits, this shows that the TLBMC can sometimes highlight unseen benefits within a company (García-Muiña, Medina-Salgado, Ferrari, & Cucchi, 2020).

METHODS

Research design & method

As can be denoted from the small amount of literature available, the insect rearing industry is quite nascent. As such, in line with the paper about methodological fit from Edmonson and McManus (2007), a qualitative case-study approach is taken. According to the definition of a case study approach by Creswell et al (2007): “a case study is an approach where the researcher explores one or multiple cases over time through detailed, in-depth data collection from multiple sources (e.g. interviews, documents and reports)”. As such, this approach allows the researcher to explore and gain deeper insights into why and how different types of value are or can be created and is thus well suited for this research (Bell, Bryman, & Bill, 2019). The BSFL rearing industry in the Netherlands is taken as the case. This is as it was questionable if one firm could offer all the information needed to do a reliable research, furthermore it is also deemed more interesting to explore where the whole industry is going and what its capabilities are.

The case study approach has several limitations, most notably it is criticized for its inability to obtain generalizable findings due to differences in context or time (Harrison, Birks, Franklin & Mills, 2017). However, the objective of this study was not to generalize findings, but explore and visualize a broader perspective of the potential of the insect industry which could serve as theoretical generalization (Yin, 2009; Bell et al, 2019). Finally, as European policy on this subject is standardized it does pose a perspective for the industry within the European Union (Gomm, Hammersley, & Foster, 2000).

Respondent#	Profession	Background	Date	Duration
R1	Researcher	Life cycle assessments, knowledge on the environmental impact of insect rearing.	25/4/2022	37:08
R2	Consultant	Has owned an insect farm and helped multiple insect start-ups.	26/4/2022	53:16
R3	Founder	Founder of an insect start-up.	3/5/2022	47:07
R4	Consultant	Consultant at an insect consulting firm and has owned an insect company.	3/5/2022	44:30
R5	Founder	Founder of an insect company and has academic background in the insect rearing field.	3/5/2022	35:23
R6	Consultant	Consultant in the insect industry.	4/5/2022	52:17
R7	Researcher	Life cycle assessment, knowledge on the environmental impact of insect rearing.	9/5/2022	52:05
R8	R&D	Research and development at an insect rearing company.	9/5/2022	Done in conjunction with R7

Table 3.1, Respondent list.

Data collection

Seven semi-structured interviews with eight respondents in total were held to gather information on how insect rearing companies create sustainable value (see table 3.1 for respondent list). Semi-structured interviews are chosen as it allows for a certain degree of freedom while still keeping the focus on the subject flexibility in the interview while maintaining a focus on the subject at hand (Bell et al, 2019). Three interviews were partly held in conjunction with another student as the first questions were similar, and one interview was held with two respondents at the same time. A set of eleven open-ended questions with eight more sub-questions made up the core of the interview guide which can be found in appendix A. To assess the face-validity of the questions, they have been discussed with the supervising professor (Bell et al, 2019). Interviews were held through an online connection using Google meet. Five interviews were held in Dutch as it was the native language of those respondents and usually makes them more comfortable (Keats, 2000). The other two interviews were done in English. Finally, before each interview, respondents were asked to sign a consent form that allows the researcher to audio record the interview and use the data for the research (see consent form in appendix B). The same consent form also notes that respondent data is anonymized, this is to guarantee confidentiality and reduce social desirability bias (Bell et al., 2019).

As the purpose of the interviews is to gather information on how insect companies operate and create sustainable value alongside economic value, it is required that the respondents have some prior knowledge about the business model of insect rearing (preferably about the BSF) and about sustainability. With the help of the company supervisor and extensive LinkedIn research, a list of relevant stakeholders in the insect rearing industry was made. This list consists of entrepreneurs, consultants and researchers that are all active in the field of insect rearing. After the list was created, each person was contacted via LinkedIn. This type of sampling was used as the insect rearing field is a quite nascent field with few experts and the subject was quite specific (Robinson, 2014).

The interview is structured as follows, first the research aim will be introduced after which the respondent will be asked to explain his/her position and expertise. Afterwards, the core of the interview takes place, in which 11 open-ended questions regarding sustainable value creation and sections of the TLBMC are asked.

Data analysis

Data analysis started with transcribing the interviews, after which the data was coded in two separate coding cycle's using the coding software Atlas.ti. For the whole process, a combination of open coding with some pre-selected codes was used. In the first cycle, an open mind is kept to discover different practices used to create value and the values themselves that are created through it. Through the use of descriptive coding both the practices and the created values themselves are described in short nouns (Saldaña, 2021). For example, the code "odors" emerged when respondents talked about how BSFL rearing creates a lot of smelly odors.

The second cycle aims to categorize the codes created in the first cycle into the sections of the TLBMC framework. Besides this however, it was also open to new categories to arise. For example, the code "odors" was put into the section of "social impact" as according to the respondents it could affect people living around the insect farm.

To clarify the approach taken for filling in the environmental and social layers of the TLBMC, a short explanation is now given as to how the data was analyzed in regard to these sections. As noted in the literature, the environmental layer of the TLBMC is primarily built on the logic of LCA's which are very heavy on metrics (Joyce & Paquin, 2016). However, the aim of this study is not to measure the environmental impact or benefits, but rather to see how they are created and what they are. Therefore, the LCA research on the BSFL rearing by Smetana et al (2019) is used only to verify data from the interviews when needed. This research was chosen as it is very thorough and the most recent one accessible to the researcher .

Analyzing the data for what is and what is not social value is quite difficult, this is because there are different views as to what counts as social value. For this research however, social value is based on the definition by Ebrahim & Rangan (2014), who state that it should constitute long-lasting change in the lives of people. This definition however, is extended to also include social value for animals (insects included), as according to the literature they should be treated as sentient beings (Van Huis, 2019).

The economic layer could also be filled in with metrics, however, as this is again not the aim of this study this was not done. Rather, it was analyzed on ways that value was created for it and also the type of value that was created.

After the TLBMC has been filled in for both the current and the future situation, horizontal and vertical coherence is established. Horizontal coherence focuses on the relationships and actions within each layer, whereas vertical coherence focusses on relationships between the layers (Joyce & Paquin, 2016). Through this step, the research question can be answered as it is able to show how certain environmental and/or social benefits double as economic benefits.

Ethical considerations

To make sure that this research does not violate any ethical conduct, the code of conduct from the University of Groningen is abided.

(https://www.rug.nl/about-ug/policy-and-strategy/research-ethics/?lang=en) .

RESULTS

In this section of the research, the findings are presented. The aim of this research is to discover the societal, environmental and economic impacts and benefits that the insect rearing industry has, both with current barriers and in the future without these barriers. This has been done through the use of the TLBMC, which unlike the original BMC, takes a more holistic approach to business modeling. The bottom sections of each layer are the most prominent, as they constitute what impacts and benefits the business model. Therefore, to be concise but thorough, these sections will make up the core of the results. First, a visualization of the current sustainable business model (CSBM) is created, of which the cost/revenue, environmental impact/benefits and social impacts/benefits sections will be explained. Afterwards, a visualization of the prospective sustainable business model (PSBM) is created. The aim of the PSBM is to showcase the possible sustainable impact and benefits that the insect industry could have if certain barriers (mentioned in the introduction) are overcome. The additions of the PSBM are also explained. Finally, the possibilities of insect rearing outside a western context will be shortly elucidated.

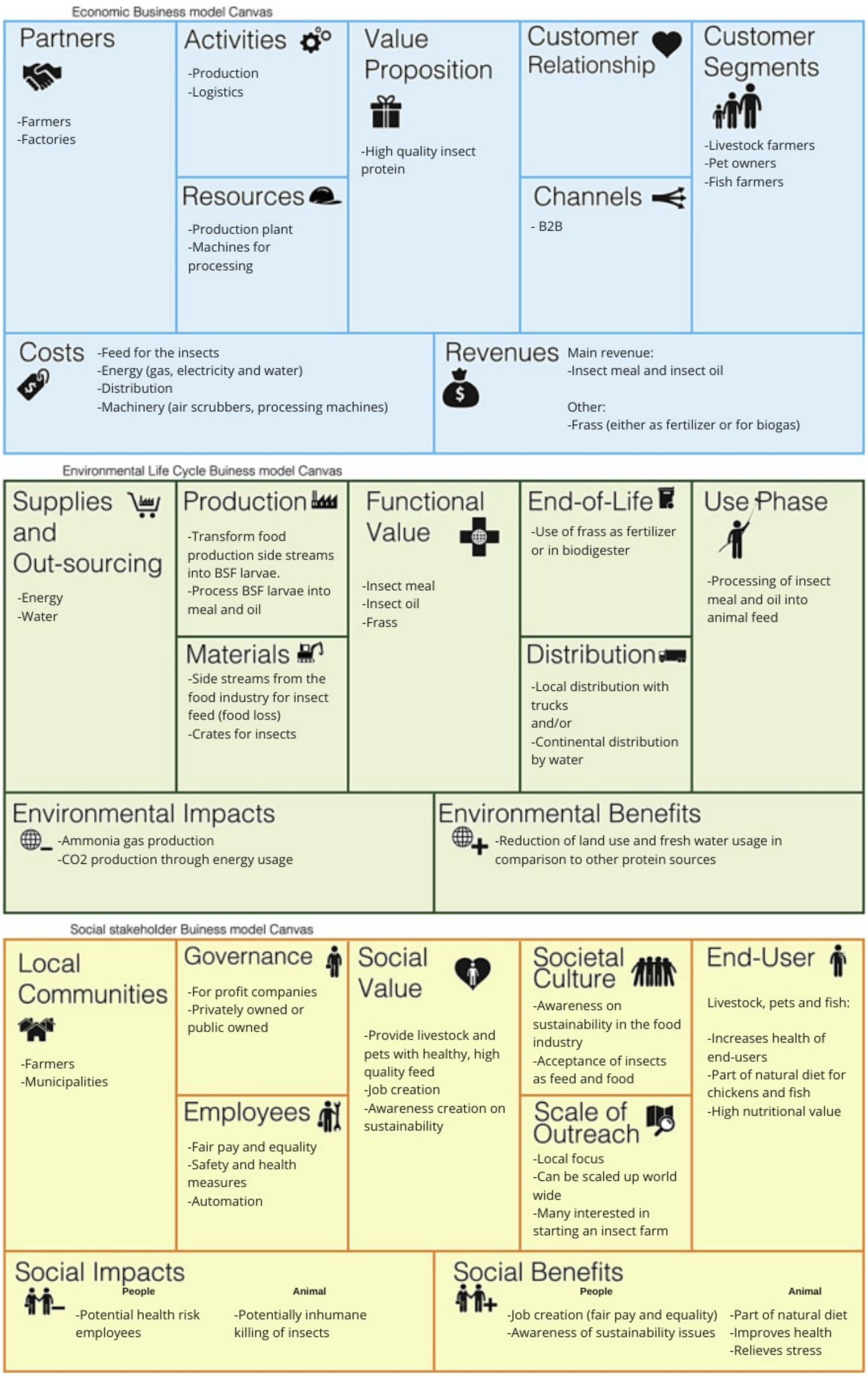

Figure 4.1, Current sustainable business model of BSFL rearing (Joyce & Paquin, 2016).

Current Sustainable Business Model

The CSBM of BSFL rearing in the Netherlands can be seen in figure 4.1. This is the current way that current BSFL rearing companies operate their business and create social, environmental and economic impact and benefits.

Economic layer - Costs

The costs section describes the focal costs incurred to operate the business. As can be seen from figure 4.1, the main costs consist of feed for the insects, energy, distribution and machinery costs. Feed costs are found to be very high in the Netherlands, which is a consequence of the high competition in the side stream market and the services provided by side stream processors.

"A lot of side streams that come out of that industry are already used very much on a very high level in feed, that also means that they have a price, they don't go cheap, and especially they don't go for free". - R7

Another cost was the energy used by the insect farms. Insect farms require a lot of heat for the insects to thrive, especially BSFL need an average temperature of 28°C. However, costs for energy use can be reduced by a technique in which you combine younger small larvae, which produce less heat, with older larger larvae, which produce more heat.

"We would like to mix different ages so that the heat generation of one age group can meet the heat needs of the other age group". - R5

Although it shouldn't be included in the costs section, as it is not a recurring cost, initial costs for the machinery are also incurred. For example, an air scrubber system must be purchased to filter the outgoing air on ammonia and other substances, which is obligatory by the municipalities to reduce their environmental impact.

Economic layer - Revenue

The main revenue from BSFL farming comes from selling the insect meal and oil as feed ingredients for livestock and pets. According to three respondents, because of the high competition in the side stream market and the low costs of other types of protein like soy, there is not a lot of revenue being made at the moment.

"The raw materials are still too expensive, the processes are not optimized either, and there are still too few sales. The market is not yet aligned. So hardly anyone earns anything really". - R6

Another product which can be sold is the frass. Frass is insect manure, which can be sold as a fertilizer. However it can also be used in a bio digester to make biogas, which can consequently be used to heat the insect farm. The latter is a topic of debate as it is unknown if this would be more environmentally friendly.

Environmental layer - Environmental impacts

The biggest environmental impacts of insect rearing, which were mentioned by most respondents, is the production of GHG emissions produced indirectly through energy use of the farm. According to secondary data from Smetana et al (2019), the amount of GHG emissions from rearing BSFL is comparatively lower than the emissions of breeding other livestock (e.g. pigs, cows and chicken), but higher than plant based protein sources (e.g. soy). However, respondents 1 and 7 both mentioned that if the insects are eaten by livestock, that this adds another step in the eventual chain towards human consumption and thus costs extra energy.

"So whenever you add one step, you lose something. So if we feed them directly to human, if you use them as food, then it's really a more sustainable choice". - R7

Another frequently mentioned environmental impact is the production of ammonia gas by the insects. According to the interviews, this is the main reason that insect farms need to buy air scrubbers that filter out the ammonia from the outgoing air. Although this is an environmental impact, by installing these air scrubbers it is mitigated.

Environmental layer - Environmental benefits

The main environmental benefit that BSFL rearing creates is a reduction in land-use. This is first, as the amount of land required to produce a 1 kg of BSFL protein is smaller than that needed for 1 kg of plant based proteins (Smetana et al, 2019). Second, within insect rearing you can make use of vertical farming techniques, which also reduce land use.

"The more people, they want more food and feed, and we have limited land, but if you use insects, with a set amount of land you yield more protein". - R1

What is mentioned in the same LCA, is that a reduction in freshwater use is also one of the environmental benefits (Smetana et al, 2019). A reduction of GHG emissions is also mentioned multiple times by the respondents. Although this is contested by the LCA from Smetana et al (2019) as it is very dependent on what you compare it with and who the consumer is. Therefore it is not added to the CSBM.

Social layer - Social impacts

Regarding the social impacts for people, the respondents often mentioned smelly odors that arise during the rearing to possibly be a problem. According to respondent 4, the smell from a BSFL farm is similar to that of a pig farm. However, as respondent 5 also mentions, an easy remedy to this is to place these BSFL farms outside residential zones to reduce the social impact. The same goes for the transportation around the factory.

"So you have smell and transport movements, that does affect the immediate environment, but if you ensure that you do not have to deal with households in the immediate vicinity, you can reduce that somewhat.". - R5

According to two respondents, insect rearing can also affect the employees of the company. One respondent stated that he had become allergic to mealworms after a while and could no longer work with them directly. Another respondent mentioned automating the rearing process due to shortage of workers in the Netherlands, which would inadvertently mitigate this issue.

“I did it for four years (insect rearing), and then I got allergic”. - R2

When asked about the social impacts for animals (insects included), responses were that there are certain groups of people who think it is inhumane to kill insects while they're alive. The respondents also mentioned that there should be more research about insect welfare.

Social layer - Social benefits

On the people side of social benefits, it was mentioned that within insect companies, fair pay and equality among employees is highly valued. Furthermore, it was also noted that insect companies can play an important role in society by making people aware of sustainability issues surrounding food waste. On the animal side, multiple respondents stated that eating insects can greatly increase animal welfare. Especially for chickens and fish, in which case eating insects is part of their natural diet and has a positive effect on their health.

“A chicken is in principle omnivorous, every bird sometimes pulls a worm out of the ground and at the moment we only feed the chicken a vegetable diet [...] and because of the enormous amounts of vegetable proteins the chickens also get intestinal inflammation more often”. - R3

Prospective Sustainable Business Model

The prospective sustainable business model (PSBM), which can be seen in figure 4.2, shows how BSFL rearing companies can create greater social, environmental and economic benefits, if certain barriers are overcome. According to all respondents, the biggest barrier is policy. Currently, feed policy does not allow non-certified waste streams (e.g. manure, sewage sludge and food waste) to be used as feed for insects. According to both respondents 5 & 7, legislation is going to change in the short term, which is where BSFL rearing companies will be waiting for.

"I mainly think that we should look at regulations, because at the moment many things are not allowed that could make a significant contribution. If we are allowed to process residual flows such as household waste or catering waste, then we can make real impact". - R5

"Legislation is changing. So I think what the insect company [...] are trying to do, is just waiting to be ready at the moment in which the legislation will change and allow to use other streams as well". - R7

Another barrier that was mentioned is acceptance of insects as food for human consumption. Respondent 8 did mention however that people's minds are shifting on the idea of eating insects.

In the following sections, the economic, environmental and social effects of overcoming the aforementioned barriers are explained in relation to the PSBM. Changes to the PSBM are highlighted in yellow to contrast it to the CSBM.

Economic layer

According to the respondents, a big change would incur in the costs for insect feed. This is as non-utilized side streams are very low in value and cannot be used other than in a biodigester or land-fill. This means that lower costs are incurred when buying feed for the insects.

"Because we reduce feed costs tremendously with these neutral or negative worthy side streams, it (environmental and economic value) goes hand in hand". - R5

Two respondents also mentioned how in the future, BSFL rearing companies could function as local waste processors. One respondent even took this a step further by creating a platform in which a municipality and local farmers can cooperate and create an almost closed loop system through the use of small containerized BSFL farms. They also mentioned how through this step, local BSFL rearing companies can help create a more circular economy in the area.

"And then you could go to a municipality and say: 'wouldn't it be interesting for you to collect a lot more organic waste and use it much more widely and efficiently". - R3

Environmental layer

The environmental benefit from using non-utilized side streams and from being able to use insects for human consumption is very large, said almost all experts interviewed. This is as you then create a product out of waste material which cannot be used by livestock. And if you feed it to people instead of feeding it to livestock, you take out a step in the chain towards eventual human consumption, thus saving energy that would otherwise be lost.

“If you really want to create environmental impact you can only use non-utilized side streams that cannot be used by humans or animals”. - R1

It was also mentioned that if local waste is used to feed the insects, that there is less need for transport over long distances, consequently creating a reduced impact on the environment. Although not stated explicitly by the respondents, all of the above will likely result in an overall reduction of CO2 emissions compared to producing other forms of protein.

Social layer

If insect products were eaten by people, then this offers people a sustainable alternative to other sources of protein. According to one respondent, insect protein is also more in line with the composition of our body.

“The product (insect) protein is made out of amino acids. It's composition is much more in line with our human body, than for instance, plant proteins”. - R8

Benefits outside western perspective

Although not incorporated into the PSBM as it is beyond the scope of this research, it was mentioned frequently that opportunities to create social benefits are far greater outside the western world. For example, respondents stated that insect rearing could improve food security in developing countries. Policy in developing countries is usually less stringent, thus BSFL can use waste streams that cannot be eaten by people or livestock and use it to produce high quality protein which people can eat. Furthermore, it was also mentioned that insects have the ability to reduce harmful bacteria and stop certain diseases from spreading. One respondent even mentioned that their company helps set-up insect farms in developing countries to stop marginalized woman from going into to prostitution.

"It also seems to be the case that this may reduce legionella and such things because those larvae have certain antibacterial properties that kill germs, so in theory it is possible". - R4

Besides social benefits, respondents also mentioned that countries which have a climate more native to the insects they breed are more suitable, as you wouldn't have the need to buy an expensive climate system.

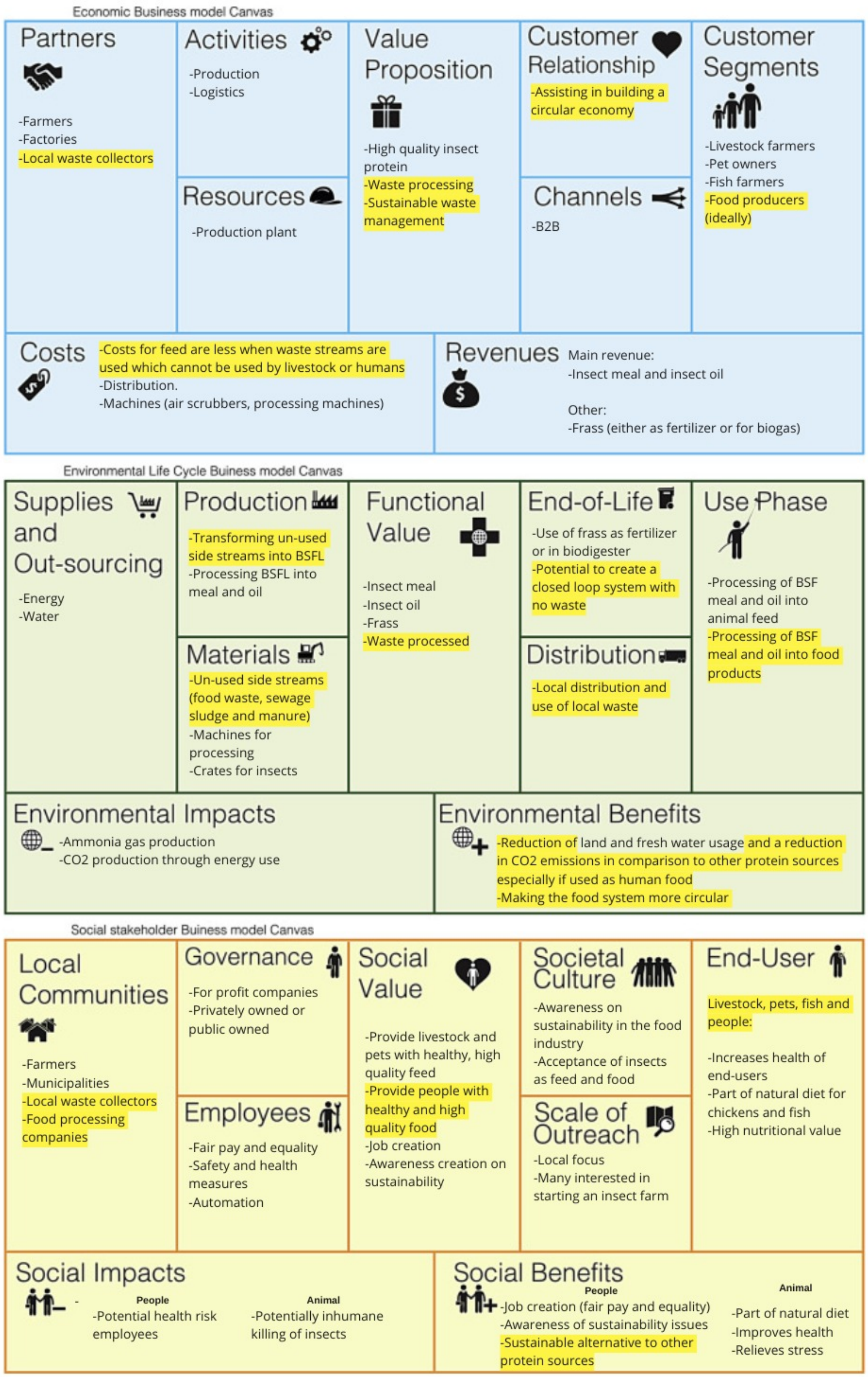

Figure 4.2, Prospective sustainable business model (Joyce & Paquin, 2016).

DISCUSSION

As mentioned in the introduction, the world's food system is under immense pressure. According to both the results and literature, the insect rearing industry can be a vital player towards reducing this pressure. However, at this moment it is being held back by regulatory and food acceptance barriers (Fischer, 2022; Cadinu et al, 2020). By framing a contrast between the current and a potential future situation, this research has given perspective as to what the potential of this industry is and how it attributes value to each pillar of the TBL (Elkington, 1997).

This was done by taking an exploratory qualitative approach in which eight experts in the field of insect rearing were interviewed with regards to the research question: *How can insect rearing companies create environmental and social value alongside economic value, both now and in the future?* With the results obtained and organized in the TLBMC, it is now possible to establish horizontal and vertical coherence.

Horizontal coherence - CSBM

At the economic level, BSFL rearing offers turning food production side streams into high value insect products. These can then be sold to either livestock farmers or the pet food industry. However, at the moment, little revenue is being made due to high competition on the side-stream market and, as noted in the literature, low production efficiency. At the environmental level, besides a reduction in land-use and water usage there seems to be little environmental benefits to it. At the social level, BSFL rearing provides a healthy and high quality protein that can be used as feed. Furthermore, it can create awareness on sustainability issues.

Vertical coherence - CSBM

Under the current situation, a link that can be established between all three layers is that operating the insect farm creates environmental benefits in terms of land- and water use reduction, while also creating awareness on sustainability and turning, albeit, low revenue. Besides this link however, there are no other strong cases to be made.

Horizontal coherence - PSBM

In the PSBM, the situation is quite different to that of the CSBM. First, at the economic level, BSFL rearing offers turning low value unused waste streams into high value insect products, these are sold either as feed to farmers and pet owners, but preferably to food processors who make food out of it. By doing so, it assists in building a circular economy whilst also, in contrast to the CSBM, turning a profit. Environmental benefits are created by using local unused waste streams to create several high value insect products. As a consequence, this reduces land-use, fresh water use and likely realizes a reduction in CO_2 emissions in comparison to using other sources of protein. At the social level, BSFL rearing provides a healthy and high quality protein as feed and as food, which has a positive effect on its consumers' health. Furthermore, it can create awareness on sustainability issues and offers a sustainable alternative to other protein sources.

Vertical coherence - PSBM

The most obvious relationship that can be seen in the PSBM is that of costs, materials and environmental benefits. As was also noted by several respondents, the type of feed used to grow the BSFL, greatly affects the costs, and if low value unused waste streams are being used then this will reduce costs. This is a very welcome sight as, according to the literature, the insect industry is in need of becoming more cost-effective in order to be competitive with other more established protein sources. Improving production efficiency and scaling-up is also needed to improve price competitiveness, however, feed costs are still the main cost for insect rearing companies (Cadinu et al, 2020). Besides reducing costs, using low value food waste also creates environmental benefits as otherwise these unused waste streams would end up in the biodigester or land-fill, whilst if they are used for feed or food it reduces the need for other protein sources that have a larger environmental footprint (Bosch et al, 2019).

Another visible relationship is that between environmental benefits, end-user and social benefits. Using insects as human food not only offers a sustainable and healthy alternative to other protein sources, it also reduces the environmental impact in comparison to other protein sources. Finally, a third relationship which can be found throughout all layers is that BSFL rearing companies can also function as waste processors within society. This is part of the value proposition as it adds sustainable value to the product and to local municipalities, it is also part of the environmental layer as this allows the possibility to create closed loops, and it is part of the social layer as through it municipalities can become more sustainable by processing their own waste in a sustainable manner.

There are undoubtedly more relationships that can be found throughout the layers. However, these three are the most prominent ones in relation to the research question and aim as they create environmental and/or social value alongside economic value.

Implications, Future Research and Recommendations

As noted in the introduction, the field of insect rearing is still quite nascent, with the majority of research going into the environmental impacts of insect rearing and few studies into its financial feasibility. While there has been some research into the overall challenges of insect rearing (Cadinu et al, 2020), as well as research that combines social, environmental and economic aspects of insects as food (Lange & Nakamura, 2021), none take an industry expert perspective nor create a contrast between the current situation and a potential future situation. By doing so, this research takes a transdisciplinary approach, which is much needed within the scientific community to create transferable knowledge (Lang et al., 2012). This gives both researchers and others a practical perspective of what the insect industry is doing now, but more notably, what the insect industry can do when legislation and social acceptance allows it to.

It became clear in the interviews that insect companies rearing BSFL are not expecting to yield a high return on investments within the CSBM, in fact they are waiting for legislation to change in order to break a profit. Thus, there is a need for institutional change, which can very well be created by entrepreneurs themselves. For example, the research by Alvarez, Young, & Woolley (2015) shares a very similar situation, in which a fisherman successfully engages in institutional entrepreneurship and creates wide institutional change for king crab fisheries on multiple aspects like quality control and international fishing agreements. Currently, a large insect company named Protix is engaging in institutional change and created a lobbyist group

(IPIFF) which strives to promote and support the entire insect sector within the EU (Protix, 2021). As was the case for the king crab entrepreneur, there is a need for strong arguments to change legislation, this research helps deliver strong arguments in a practical and understandable manner (Alvarez et al, 2015). This is as in contrast to previous research, this research shows not only the types of value created for each pillar of the TBL, but also how they can affect or even enhance each other, which makes for a stronger case (Schaltegger et al, 2012). To solidify the case made for BSFL rearing even more, however, a quantitative study on how an insect company creates economic, environmental and social value is needed.

The research has several implications towards entrepreneurs as well. First, the created business models could function as a blueprint for entrepreneurs seeking to start a business in BSFL rearing. Although both are very general and focussed within a Dutch context, entrepreneurs can adjust them to their situation and preferences. An interesting future research avenue in this perspective would be to study how different approaches to BSFL rearing create different sustainable impacts. This study focussed on the centralized approach to BSFL rearing, in which all insects are made in a one large factory. However, another approach is decentralized production, in which multiple smaller containerized factories can be set up at different locations to produce BSFL. Second, the environmental, social and financial benefits named in the PSBM could be used by entrepreneurs to convince investors and municipalities to fund and authorize their business.

Finally, in line with the research by Lange & Nakamura (2021), social benefits of insect rearing are larger in developing countries, as it can dramatically improve food security. This research expands on this by discovering that economic opportunities for starting an insect farm in developing countries are also very large. This has to do with a usually favorable climate, less stringent policy and easy operations of the insect farm. A more in depth research into the opportunities of insect farming in developing countries would be very interesting and could become beneficial in promoting insect business in these regions

Limitations

The main limitation of this research is that both the CSBM and the PSBM are very general in the sense that they are not built on an actual case but on insights of experts in the field of insect rearing. This means that certain parts of what is mentioned in both business models might not be applicable for every BSFL business in the Netherlands. Even though the aim of this research was not to create a business model that exactly reflects on how these businesses operate, it can be seen as less legitimate. Another limitation is that some sections of the TLBMC could not be filled in properly due to difficulty to assess intangible properties or because respondents just did not have expertise on some subjects. For example, societal culture is hard to measure and the results were mainly based on assumptions made by the respondents. This also goes for some sections of the environmental layer, in which some respondents mentioned benefits which were contested by the LCA of Smetana et al (2019).

Conclusion

As the amount of people on this planet keeps growing, so does the need for sustainable solutions to cope with it. The insect industry provides such a solution, but is obstructed in its path of sustainable impact maximization by multiple barriers. Overcoming these barriers will require a lot of research and political convincing. The findings of this research contribute to this in two main ways. First, by showing that far larger environmental and economic benefits could be attained simultaneously when feed policy changes towards allowing the use of non-certified waste streams, legislators might be more incentivised to change feed laws.

Second, by creating practical and transferable knowledge on how the insect industry creates value for each pillar of the TBL both now and in the future, researchers and entrepreneurs alike get a better perspective of how the industry operates and what its potential is. This can play a major role in scaling an industry that has huge potential benefits for our plant.

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Appendix A - Interview guide

Questions for interview

Before the questions: explain the field and aim of the research.

Introduction question

1. Please tell me who you are, what your current position or job is and what your responsibilities are?
2. Please tell me in your perspective what the business model of insect rearing entails?
3. Is insect rearing at the moment a viable business model?
    a. Does it in its current state attribute to both economic and sustainable welfare in your perspective?

Environmental

4. Can you take me on a tour through the production process of insect rearing, in particular of the Black soldier fly, and what impacts on the environment every aspect of it has?
    a. What materials and supplies (also energy, water, etc) are needed during the process?
    b. How is the end-product used after it leaves the factory?
    c. What are the environmental benefits and impacts of insect rearing in general?
5. Which parts of the aforementioned answers does not only create environmental, but also economical value? In other words, which parts of the production process that create environmental value also create economic value alongside it?
6. How can insect rearing companies create **more** environmental value? In other words, what are the next steps forwards?
    a. What is stopping companies from creating this additional value?

Societal

7. How are or can insect rearing companies affect the community?
    a. How does insect rearing affect people's lives (ranging from people in the area to employees)?
    b. How could insect rearing affect animal welfare (both animals and insects included)?
    c. How can insect rearing companies establish relationships with other organizations or even with communities?
8. How are insect rearing companies organized from the inside (i.e. type of governance structure, working culture, diversity, etc).
9. How do or could insect companies combine social value creation with economic value creation?

10. How can insect rearing companies create **more** societal value? In other words, what are the next steps forwards?
    a. What is stopping companies from creating this additional value?

End

11. Is there anything that in your perspective is missing in this interview or information that could be interesting to this research?

Thank you for your participation!

Appendix B - Consent form

Form of consent: Creating the triple bottom line: A case of insect rearing.

Please tick the appropriate boxes	**Yes**	**No**	
Description and aim of the study This research aims at investigating how the triple bottom line can be achieved in insect rearing. To do this, a tool called the triple layers business model canvas is used, with this interview data the tool will be filled in. Therefore the goal of this interview is to gain information on how an insect rearing company can create environmental and social value.			
● I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐	
● I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions or withdraw from the study until **26.04.2022**, without having to give a reason.	☐	☐	
● I understand that taking part in the study involves that the interview will be audio or video recorded, transcribed and analysed by a student of the RUG (namely: Jop Bijvoet), only he and the supervisors have access to the data provided during the interviews. The recordings will be transcribed. The use of the recordings will be limited to academic purposes, and they will be destroyed after the submission of the project.	☐	☐	
● I give my permission to be quoted verbatium in the final report	☐	☐	
● *I request my name to be anonymized in the transcript and the final report*	☐	☐	
● I understand that personal information collected about me that can identify me, such as e.g. my name or where I live, will not be shared beyond the study team. ● The interviewee will receive the complete report near the end of January. ● If the interviewee requests it, his or her name will be anonymized in the transcript and the final report.			

I have read and understood the explanations given to me. By signing this form, I agree to the terms listed above.			
Signatures **The participant**			
______________________ ______________________ ________ Name of participant Signature Date			

The researcher

___________________ ______________________ ______________________

Signature Date

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